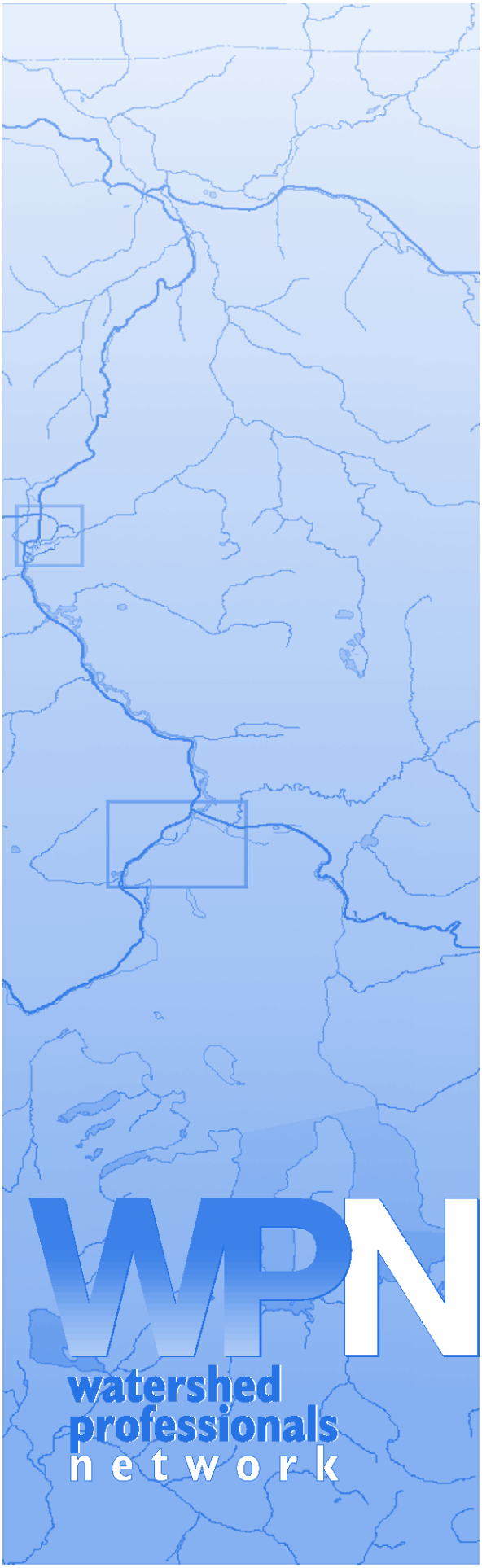


APPENDIX A

WRIA 30

LEVEL I WATERSHED ASSESSMENT

Prepared for:

Klickitat County Planning Unit

Prepared by:

Watershed Professionals Network
and
Aspect Consulting, Inc.

January, 2005

Appendix A

WRIA 30

LEVEL I WATERSHED ASSESSMENT

January 10, 2005

Prepared for: Klickitat County Planning Department
228 West Main Street, MS-CH-17
Goldendale, WA 98620
(509) 773-2481

Prepared by: Watershed Professionals Network
15208 Goodrich Dr. NW
Gig Harbor WA 90329
(253) 858-5444

and

ASPECT Consulting, Inc.
179 Madrone Lane North
Bainbridge Island, WA 98110
206-780-9370

Funding: Washington Department of Ecology Grant No. G0000104

APPENDIX A

Table of Contents

Chapter 1: Introduction

1.1 Purpose ***1-1***
1.2 Legislative Authority ***1-1***
1.3 WRIA 30 Planning unit ***1-2***
1.4 Klickitat Watershed Assessment Study Area ***1-2***
1.5 Document Organization ***1-5***

Chapter 2: Hydrologic Framework

2.1 Topography ***2-1***
2.2 Soils ***2-8***
2.3 Geologic Setting ***2-11***
2.4 Precipitation ***2-20***
2.4.1 Average Precipitation *2-20*
2.4.2 Year-to-Year Variability *2-25*
2.4.3 Snow pack *2-28*
2.5 Land Cover / Land Use **2-31**

Chapter 3: Fish Habitat Quality

3.1 Background ***3-4***
3.2 Methods ***3-5***
3.3 Natural Fish Passage Barriers ***3-8***
3.4 Subbasin Hatchery Operations ***3-9***
3.4.1 Goldendale Hatchery *3-9*
3.4.2 Klickitat Hatchery *3-10*
3.4.3 Fish Stocking From Other Hatcheries *3-10*
3.5 Stock Status and Population Trends ***3-11***
3.5.1 Chinook Salmon (Onchorynchus tshawytscha) *3-14*
3.5.2 Coho (Onchorynchus kisutch) *3-18*
3.5.3 Steelhead (Onchorynchus mykiss) *3-19*
3.5.4 Bull Trout (Salvelinus confluentus) *3-21*
3.5.5 Cutthroat Trout (Oncorhynchus clarki) *3-23*
3.5.6 Resident Rainbow Trout (Oncorhynchus mykiss) *3-23*
3.5.7 Brook Trout (Salvelinus fontinalis) *3-23*
3.5.8 Pacific Lamprey (Lampetra tridentatus) *3-24*
3.5.9 Other Fish Species *3-24*
3.6 Summary of Habitat Conditions ***3-24***
3.6.1 Impassable Culverts *3-25*
3.6.2 Ecosystem Diagnosis and Treatment (EDT) Analysis *3-25*
3.6.3 Subbasin Summaries *3-25*

Chapter 4: Water Quality

4.1 Water Quality Overview ***4-3***
4.2 Water Quality Criteria and Impaired Water ***4-3***
4.3 Pollution Sources ***4-7***
4.4 Methods ***4-9***
4.4.1 Surface Water *4-9*
4.4.2 Groundwater *4-14*
4.5 Surface Water Quality ***4-14***
4.5.1 Middle Klickitat Subbasin *4-14*
4.5.2 Lower Klickitat Subbasin *4-15*
4.5.3 Little Klickitat *4-20*
4.5.4 Swale Creek *4-28*
4.6 Groundwater Quality ***4-29***
4.6.1 Data Sources *4-29*
4.6.2 Data Summary *4-30*
4.6.3 Other Water Quality Issues *4-34*
4.6.4 Conclusion *4-34*
4.7 Data Gaps and Recommendations ***4-34***

Chapter 5: Water Quantity

5.1 Surface Water ***1***
5.1.1 Stream flow Estimates *1*
5.1.2 Trend Analysis *15*
5.1.3 Peak Flows *26*
5.2 Groundwater ***26***
5.2.1 Groundwater Recharge and Discharge *28*
5.2.2 Groundwater Occurrence and Flow Directions *34*
5.2.3 Groundwater Conditions and Hydraulic Continuity by Subbasin *40*

Chapter 6: Water Rights and Water Use

6.1 Water Rights ***6-1***
6.1.1 Water Rights Analysis Methods *6-2*
6.1.2 Results of Water Rights Analysis *6-3*
6.2 Estimated Water Use ***6-20***
6.2.1 Estimated Irrigation Water Use *6-21*
6.2.2 Residential Water Use *6-25*
6.2.3 Non-Residential Water Use *6-31*
6.2.4 Estimated Water Use by Subbasin *6-32*

Chapter 7: Land Use Effects

7.1 Outfall From Road Drainage ***7-1***
7.2 Increased Impervious Area and Compaction ***7-3***
7.3 Decreased Floodplain Storage ***7-4***
7.4 Decreased Wetland Function ***7-5***

7.5 Altered Channel Capacity ***7-7***
7.6 Altered Channel Complexity ***7-8***
7.6.1 Channel Confinement by Structures *7-9*
7.6.2 Modification of Stream Adjacent Vegetation *7-10*
7.6.3 Clearing Channels of Rocks and/or Wood *7-11*
7.6.4 Sediment Inputs *7-12*
7.6.5 Cumulative Effects of Land Uses on Channel Incision *7-12*
7.7 Vegetation Removal Effects on Hydrology ***7-12***
7.8 Summary ***7-14***

Chapter 8: Data Gaps and Recommendations

8.1 High Priority Data Gaps ***8-1***
8.2 Lower Priority Data Gaps (Recommended For Future Monitoring) ***8-5***
8.3 Other Gaps ***8-6***

Chapter 9: References

Chapter 10 Glossary

List of Tables

Chapter 1: Introduction

Table 1-1. Subbasin areas. _____ *1-5*

Chapter 2: Hydrologic Framework

Table 2-1. Subbasin areas, elevations, and slopes. _____ *2-5*
Table 2-2. Descriptions of hydrologic soil group properties. _____ *2-9*
Table 2-3. Summary of percent subbasin area by Hydrologic Soil Group. _____ *2-9*
Table 2-4. Percent of subbasin area by geologic type in each subbasin. . _____ *2-20*
Table 2-5. Climatic data stations in the vicinity of WRIA 30. _____ *2-22*
Table 2-6. Recent Pacific Decadal Oscillation (PDO) cycles in the Pacific Northwest. .*2-27*
Table 2-7. Natural Resource Conservation Service SNOTEL and snow course** stations in the vicinity of WRIA 30.* _____ *2-28*
Table 2-8. Equations predicting snow pack (S; inches SWE) as a function of elevation.2-29
Table 2-9. Descriptions of current land cover/land use / land cover types found in WRIA 30. _____ *2-34*
Table 2-10. Summary of current land cover/land use / land cover types found in WRIA 30. _____ *2-35*

Chapter 3: Fish Habitat Quality

Table 3-1. Summary of applicable Fisheries Reports. _____ *3-7*
Table 3-2: Klickitat River subbasin Salmon, Steelhead, Trout and Bull Trout - Stock Profiles. _____ *3-12*
Table 3-3: Native species known or suspected to be present in the Klickitat watershed. _____ *3-24*

Chapter 4: Water Quality

Table 4-1. Waters within WRIA 30 designated for char aquatic life, core salmon/trout aquatic life, and extraordinary primary contact recreation under WAC 173-201A. _____ *4-4*
Table 4-2. 1997 Washington State Water Quality Criteria _____ *4-4*
Table 4-3. 2003 Washington State bacteria criteria for freshwater. _____ *4-5*
Table 4- 4. 2003 Washington State Water Quality Criteria _____ *4-6*
Table 4-5. 303(d) Listed Water Segments in WRIA 30 (1996 and 1998 listings).. ____ *4-8*
Table 4- 6. Municipal and Industrial NPDES and State Permit Holders in WRIA 30, excluding those that discharge to the Columbia River. _____ *4-9*
Table 4- 7. Summary of WDOE's Monitoring Data for the Klickitat River near Pitt. The criteria used for this table is the 1997 criteria. _____ *4-17*
Table 4-8. Comparison of WDOE's Monitoring Data for the Klickitat River near Pitt.4-18
Table 4-9. Summary of WDOE's Monitoring Data for the Klickitat River near Lyle. _ *4-20*
Table 4-10. Summary of WDOE's Monitoring Data for the Little Klickitat River near Wahkiacus. _____ *4-23*

Table 4-11. Comparison of WDOE's Monitoring Data for the Little Klickitat River near Wahkiacus. _____ *4-24*
Table 4-12. Number of August Days the Maximum Daily Temperature Met or Exceeded 15oC. in the Little Klickitat, its Tributaries, and Swale Creek. _____ *4-26*
Table 4-13. Identification and Description of Major Water Quality Data. _____ *4-36*

Chapter 5: Water Quantity

Table 5-1. USGS stream gages in WRIA 30. _____ *5-3*
Table 5-2. Subbasin characteristics considered when selecting representative stream gages. _____ *5-5*
Table 5-3. Summary of trend analysis results. _____ *5-16*
Table 5-4. Regression results for equations predicting stream flow based on precipitation and residual trend analysis results. _____ *5-20*
Table 5-5. Estimated peak discharge at USGS stream gages within WRIA 30 by recurrence interval. _____ *5-27*
Table 5-6. Estimated Annual Recharge Volumes by Subbasin _____ *5-32*

Chapter 6: Water Rights and Water Use

Table 6-1. Waterbody Segments on 1998 303(d) List Based on Instream Flows. _____ *6-1*
Table 6-2. Recorded Water Rights, Claims, and Applications by Primary Beneficial Use for Each Subbasin. _____ *6-5*
Table 6-3. Allocated Annual Water Rights (Certificates + Permits) in WRIA 30 by Primary Beneficial Use. _____ *6-6*
Table 6-4. Cumulative Recorded Water Rights and Claims by Source, Middle Klickitat. _____ *6-12*
Table 6-5. Cumulative Recorded Water Rights and Claims by Source, Little Klickitat Subbasin. _____ *6-15*
Table 6-6. Cumulative Recorded Water Rights and Claims by Source, Swale Creek. _____ *6-16*
Table 6-7. Cumulative Recorded Water Rights and Claims by Source, Lower Klickitat Subbasin. _____ *6-18*
Table 6-8. Cumulative Recorded Water Rights and Claims by Source, Columbia Tributaries _____ *6-20*
Table 6-9. Comparison of Irrigated Acre Estimates _____ *6-22*
Table 6-10. Estimated Irrigation Water Use by Subbasin _____ *6-25*
Table 6-11. Estimated Public Water System Water Use. _____ *6-27*
Table 6-12. 2000 Population Data by Subbasin _____ *6-30*
Table 6-13. Estimated Self-Supplied Residential Annual Water Use _____ *6-30*
Table 6- 14. Estimate of Maximum Self-Supplied Residential Annual Water Use. _____ *6-31*
Table 6-15. Estimated Total Water Use for WRIA 30 by Subbasin _____ *6-33*

Chapter 7: Land Use Effects

Table 7- 1. Road density by subbasin. _____ *4*
Table 7- 2. Percent subbasin area within the 100- and 500-year floodplains. _____ *5*

List of Figures

Chapter 1: Introduction

Figure 1-1. Water Resources Inventory Area (WRIA) 30 showing subbasins used in this assessment. 1-4

Chapter 2: Hydrologic Framework

Figure 2-1. Shaded-relief map of WRIA 30. 2-2
Figure 2-2. Cumulative subbasin area by elevation. 2-4
Figure 2-3. Cumulative subbasin area by slope class. 2-4
Figure 2-4. Washington Department of Natural Resources precipitation zones in the vicinity of WRIA 30. 2-6
Figure 2-5. Proportion of subbasin area within the five precipitation zones defined by the Washington Department of natural Resources. 2-7
Figure 2-6. Hydrologic soil groups found in WRIA 30. 2-10
Figure 2-7. Surficial Geology and Structure 2-14
Figure 2- 8. Geologic Cross Section A-A' 2-16
Figure 2- 9. Geologic Cross Section B-B' 2-17
Figure 2- 10. Geologic Cross Section C-C' 2-18
Figure 2- 11. Geologic Cross Section D-D' 2-19
Figure 2-12. Climatic data stations in the vicinity of WRIA 30. 2-23
Figure 2-13. Mean annual precipitation (inches) for the period 1961-1990. 2-24
Figure 2-14. Mean monthly precipitation distribution. 2-25
Figure 2-15. Annual precipitation at the Goldendale / Goldendale 2E climate station, and cumulative standardized departure from normal of annual precipitation. 2-26
Figure 2-16. Estimated mean first-of-the-month snow pack within WRIA 30. 2-30
Figure 2-17. Snow pack (in inches of snow-water equivalent) at two climate stations in the vicinity of WRIA 30. 2-30
Figure 2-18. Current land cover and land use in WRIA 30. Descriptions of land use categories are given in Table 2-9. 2-33
Figure 2-19. Summary by major land cover/land use categories for the subbasins within WRIA 30. 2-36

Chapter 3: Fish Habitat Quality

Figure 3-1. Timing of key life history phases of anadromous fish species in the Klickitat River Watershed. 3-13
Figure 3-2. Distribution of spring chinook in the Klickitat River Subbasin. 3-15
Figure 3-3: Distribution of fall chinook in the Klickitat River Subbasin. 3-17
Figure 3-4: Distribution of coho in the Klickitat River Subbasin. 3-19
Figure 3-5: Distribution of steelhead in the Klickitat River Subbasin. 3-22

Chapter 4: Water Quality

Figure 4- 1. Surface Water Quality Monitoring Stations in WRIA 30. 4-12

Chapter 5: Water Quantity

Figure 5-1. USGS stream gages in WRIA 30. Data Sources: USGS (2002a). _____ *5-2*
Figure 5-2. Timelines of the 12 USGS stream gages located within WRIA 30 that have mean daily flow data. _____ *5-4*
Figure 5-3. Mean Annual Flow Time Series at the Klickitat River gage near Glenwood _____ *5-6*
Figure 5-4. Monthly median and low flows at the Klickitat River gage near Glenwood _____ *5-7*
Figure 5-5. Mean monthly stream flows, expressed as unit-area runoff at two gages in the Middle Klickitat subbasin. _____ *5-8*
Figure 5-6. Comparison of mean monthly stream flows at the Klickitat River gage near Pitt for the water years 1997 through 2000 and long-term time periods. _ *5-9*
Figure 5-7. Estimated median and low flows by month for the Middle Klickitat subbasin.5-9
Figure 5-8. Mean monthly stream flows, expressed as unit-area runoff at three gages in the Little Klickitat subbasin for the time period from August 1964 through September 1970. _____ *5-11*
Figure 5- 9. Mean annual flow time series for the stream gage on the Little Klickitat River near Wahkiacus. _____ *5-11*
Figure 5-10. Estimated median and low flows by month for the Little Klickitat subbasin. _____ *5-12*
Figure 5-11. Mean annual flow time series at the Klickitat River gage near Pitt . ___ *5-13*
Figure 5- 12. Median and low flows by month at the Klickitat River gage near Pitt. _ *5-13*
Figure 5-13. Estimated median and low flows by month for stream flow inputs in the Lower Klickitat subbasin excluding inputs from upstream subbasins. __ *5-14*
Figure 5-14. Frequency of annual low flows by month at the Little Klickitat River gage near Wahkiacus and the Klickitat River gage near Pitt. _____ *5-17*
Figure 5-15. Annual low flows at the Klickitat River gage near Pitt. _____ *5-17*
Figure 5-16. Annual low flows at the Little Klickitat River gage near Wahkiacus. __ *5-18*
Figure 5-17. Relationship between mean annual discharge at the Little Klickitat River gage near Wahkiacus and annual precipitation at the Goldendale/Goldendale 2E station. _____ *5-20*
Figure 5-18. Temporal distribution of residual variation in relationship between mean annual discharge at the Little Klickitat River gage near Wahkiacus and annual precipitation at the Goldendale/Goldendale 2E station. _____ *5-21*
Figure 5-19. Relationship between annual low flow at the Little Klickitat River gage near Wahkiacus and the precipitation index at the Goldendale/Goldendale 2E station. _____ *5-21*
Figure 5-20. Temporal distribution of residual variation in relationship between annual low flow discharge at the Little Klickitat River near Wahkiacus gage and precipitation index at the Goldendale/Goldendale 2E station. _____ *5-22*
Figure 5-21. Relationship between mean annual discharge at the Klickitat River gage near Pitt and annual precipitation at the Goldendale/Goldendale 2E station. _____ *5-23*
Figure 5-22. Temporal distribution of residual variation in relationship between mean annual discharge at the Klickitat River gage near Pitt and annual precipitation at the Goldendale/Goldendale 2E station. _____ *5-23*

Figure 5-23. Relationship between annual low flow discharge at the Klickitat River gage near Pitt, and precipitation index at the Goldendale/Goldendale 2E station. 5-24
Figure 5-24. Temporal distribution of residual variation in relationship between annual low flow discharge at the Klickitat River gage near Pitt and precipitation index at the Goldendale/Goldendale 2E station. 5-24
Figure 5-25. Relationship between annual low flow discharge at the Klickitat River gage near Pitt, and maximum snow pack at the Lost Horse SNOTEL site. 5-25
Figure 5-26. Estimated Annual Groundwater Recharge Rates.. 5-30
Figure 5- 27. Groundwater Elevations and Inferred Flow Directions in the Grande Ronde Basalt. 5-35
Figure 5-28. Groundwater Elevations and Inferred Flow Directions in the Wanapum Basalt. 5-38

Chapter 6: Water Rights and Water Use

Figure 6-1. Distribution of Water Right Certificates and Permits. 6-8
Figure 6-2. Distribution of Water Claims. 6-9
Figure 6-3. Distribution of Water Right Applications. 6-10
Figure 6-4. Recorded Annual Water Rights by Use in Middle Klickitat Subbasin. 6-11
Figure 6-5. Recorded Annual Water Rights by Use in Little Klickitat Subbasin. 6-13
Figure 6-6. Recorded Annual Water Rights by Use in Swale Creek Subbasin. 6-14
Figure 6-7. Recorded Annual Water Rights by Use in Lower Klickitat Subbasin. 6-17
Figure 6-8. Recorded Annual Water Rights by Use in Columbia Tributaries Subbasin 6-19
Figure 6-9. Irrigated Acres in Klickitat County, 1920-1997 6-23

Chapter 7: Land Use Effects

Figure 7- 1. Generalized diagram of the primary interactions between land uses found in WRIA 30 and changes in peak, annual, and low stream flows. 7-2

APPENDIX A

Chapter 1: Introduction

Table of Contents

1.1 Purpose ***1-1***
1.2 Legislative Authority ***1-1***
1.3 WRIA 30 Planning unit ***1-2***
1.4 Klickitat Watershed Assessment Study Area ***1-3***
1.5 Document Organization ***1-5***

List of Figures

Figure 1-1. Water Resources Inventory Area (WRIA) 30 showing subbasins used in this assessment. *1-4*

Chapter 1: Introduction

1.1 PURPOSE

A Level I Watershed Assessment was conducted in Water Resource Inventory Area (WRIA) 30 to support the development of a watershed plan. The assessment documents the known information regarding water availability, water rights, water use, water quality, and fish habitat. The Level I analysis also documents data gaps and makes recommendations for further study to support the basin planning process. The methods used in the assessment general followed the guidelines of the Washington Department of Ecology's *Guide to Watershed Planning and Management* as amended. Information gathered in this Level I assessment will be used during the development of the watershed plan. This document summarizes the results of the Level 1 Assessment. Work completed for this assessment was funded through Washington Department of Ecology grant number G0000104

1.2 LEGISLATIVE AUTHORITY

In 1998 Chapter 90.82 of the Revised Code of Washington was amended with the passage of ESHB 2514. This law is also known as the Watershed Planning Act. The Watershed Planning Act was established to address the diminishing water availability and quality, and the loss of critical habitat for fish and wildlife in the State of Washington. The Watershed Planning Act provides a framework for local citizens, tribes, and state and local agencies to work together to develop watershed management plans for entire watersheds. Plans are intended to satisfy water supply needs. Optionally, plans can also include actions intended to protect and improve water quality, protect and enhance fish and wildlife habitat, and/or can contain recommendations for instream flows.

As part of the planning process, a Watershed Assessment needs to be completed for each Water Resource Inventory Area (WRIA) to evaluate water supply and use. Guidance for completing these assessments were developed by Washington Department of Ecology (Economic and Engineering Services, 1999) and amended in 2001 (Economic and Engineering Services, 2001). The Level 1 Watershed Assessment provides an assessment based on currently available information. Information evaluated in the watershed assessment includes any existing information relative to current stream flow, groundwater quantities, aquifer connectivity, existing water rights, existing water use, estimates of future water needs, estimates of water available for future appropriations, current water quality conditions, fish presence and distribution, and quality of fish habitat.

Recommendations are made regarding data gaps and information needed to improve the understanding of water supply needs, instream flows, and water quality. These recommendations focus on information that is likely to affect the interpretation of data or

provide information necessary to support basin planning efforts. As needed, a Level II assessment may be completed to fill those data gaps.

1.3 WRIA 30 PLANNING UNIT

The primary purpose of the WRIA 30 Planning Unit is to develop the watershed plan for WRIA 30, including the watershed assessment described in this document. The WRIA 30 Planning Unit is composed of representatives of the following interests[1]:

- Washington Department of Ecology
- Klickitat County
- City of Goldendale
- Klickitat PUD No. 1
- Central Klickitat Conservation District
- Klickitat County Health Department
- Yakama Nation
- Klickitat Citizens Review Committee
- Large Industry
- Small Business
- Irrigators in the Eastern area of the WRIA
- Irrigators in the Western area of the WRIA
- Livestock Growers
- Timber interests in the Eastern area of the WRIA
- Timber interests in the Western area of the WRIA
- Education
- Environmental
- Port of Klickitat (ex-officio)
- Klickitat County Water conservancy Board
- USDA Forest Service (ex-officio), and
- Citizens at large

[1] As of the drafting of this document, the Klickitat County Health Department and Large Industry did not yet have representatives appointed to the Planning Unit.

1.4 KLICKITAT WATERSHED ASSESSMENT STUDY AREA

The study area includes the Klickitat watershed (WRIA 30) located in Klickitat (lower portions of basin) and Yakima (upper portions of basin) Counties, Washington. The communities of Goldendale, Lyle, Dallesport, Murdock, Klickitat, Centerville, and Glenwood are located within WRIA 30. The study area is surrounded by Wind-White Salmon (WRIA 29) watershed to the west of the lower portion of the basin, Cowlitz (WRIA 26) west of the upper basin, Rock Glade (WRIA 31) to the east to the lower portion of the basin, Lower Yakima (WRIA 37) east of the upper basin, and Middle Yakima (WRIA 38) to the north. The Columbia River lies along the southern edge of the watershed.

Mount Adams is located in the northwest portion of the watershed. Much of the stream flow in the upper portions of the watershed originates on the mountain. Hence, flows in the upper watershed and the mainstem are affected by glacial and snow melt. The Little Klickitat River drains from the Simcoe Mountains located on the northeast side of the watershed and the Swale Creek drains primarily from the hills to the east and south of the subbasin.

For the purposes of this assessment, the WRIA has been sub-divided into seven sub-basins (Figure 1-1, Table 1-1). Subbasin boundaries were delineated to maximize the use of true watersheds. Most of the subbasins incorporate one or more major tributaries as well as some of the smaller side tributaries that drain to the Klickitat River, however, the subbasin designated as "Columbia Tributaries" encompasses several very small tributaries, all of which drain directly to the Columbia River. The Upper Subbasin and the eastern half of the Middle Klickitat Subbasin are dominated by Yakama Nation closed lands and will not be included in the planning efforts.

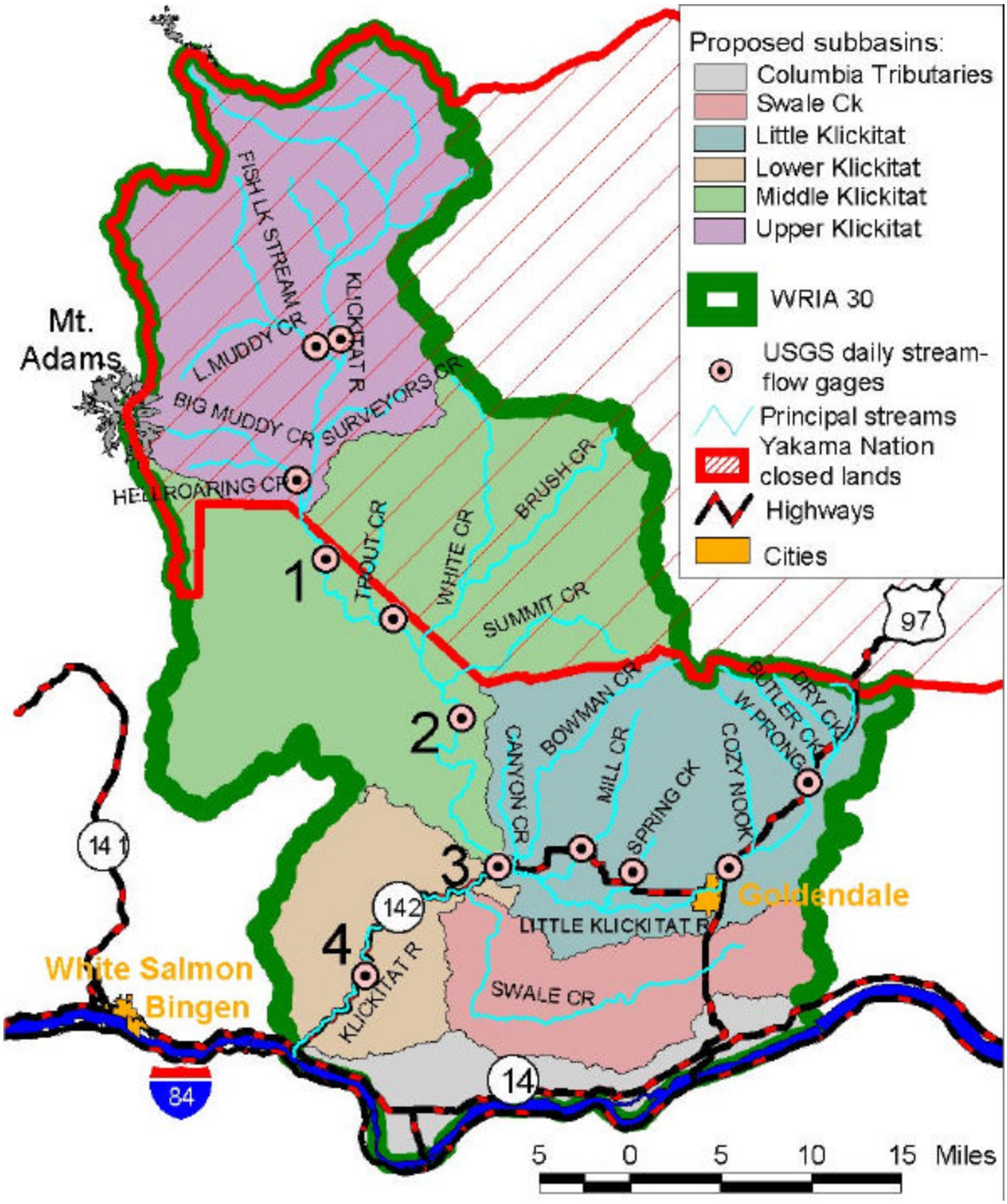


Figure 1-1. Water Resources Inventory Area (WRIA) 30 showing subbasins used in this assessment.

1.5 DOCUMENT ORGANIZATION

Information in this document is organized as follows:

Chapter 1 is this introduction.

Chapter 2 of this document provides an overview of the basin geology, soils, precipitation, and land use.

Chapter 3 summarizes the available fish habitat information.

Chapter 4 summarizes water quality data.

Chapter 5 provides information on water quantity. This chapter includes discussions on stream flow, groundwater inputs, and instream flows.

Chapter 6 includes information on water rights and water use.

Current and future land use effects on basin flows are discussed in Chapter 7.

Data gaps and recommendations are discussed in Chapter 8.

All references cited are included in Chapter 9.

A glossary of technical terms used in this document is provided in Chapter 10.

Additional detailed information related to the various chapters is provided in the appendices.

APPENDIX A

Chapter 2: Hydrologic Framework

Table of Contents

2.1 Topography ***2-1***

2.2 Soils ***2-8***

2.3 Geologic Setting ***2-11***

2.4 Precipitation ***2-19***

2.4.1 Average Precipitation 2-19
2.4.2 Year-to-Year Variability 2-24
2.4.3 Snow pack 2-27

2.5 Land Cover / Land Use ***2-30***

List of Tables

Table 2-1. Subbasin areas, elevations, and slopes. 2-5
Table 2-2. Descriptions of hydrologic soil group properties. 2-9
Table 2-3. Summary of percent subbasin area by Hydrologic Soil Group. 2-9
Table 2-4. Percent of subbasin area by geologic type in each subbasin. 2-19
Table 2-5. Climatic data stations in the vicinity of WRIA 30. 2-21
Table 2-6. Recent Pacific Decadal Oscillation (PDO) cycles in the Pacific Northwest. 2-26
Table 2-7. Natural Resource Conservation Service SNOTEL and snow course** stations in the vicinity of WRIA 30. 2-27*
Table 2-8. Equations predicting snow pack (S; inches SWE) as a function of elevation. 2-28
Table 2-9. Descriptions of current land cover/land use / land cover types found in WRIA 30. 2-33
Table 2-10. Summary of current land cover/land use / land cover types found in WRIA 30. 2-34

List of Figures

Figure 2-1. Shaded-relief map of WRIA 30. 2-2
Figure 2-2. Cumulative subbasin area by elevation. 2-4
Figure 2-3. Cumulative subbasin area by slope class. 2-4
Figure 2-4. Washington Department of Natural Resources precipitation zones in the vicinity of WRIA 30. 2-6
Figure 2-5. Proportion of subbasin area within the five precipitation zones defined by the Washington Department of natural Resources. 2-7
Figure 2-6. Hydrologic soil groups found in WRIA 30. 2-10
Figure 2-7. Surficial Geology and Structure 2-13
Figure 2- 8. Geologic Cross Section A-A' 2-15
Figure 2- 9. Geologic Cross Section B-B' 2-16
Figure 2- 10. Geologic Cross Section C-C' 2-17
Figure 2- 11. Geologic Cross Section D-D' 2-18
Figure 2-12. Climatic data stations in the vicinity of WRIA 30. 2-22
Figure 2-13. Mean annual precipitation (inches) for the period 1961-1990. 2-23
Figure 2-14. Mean monthly precipitation distribution. 2-24
Figure 2-15. Annual precipitation at the Goldendale / Goldendale 2E climate station, and cumulative standardized departure from normal of annual precipitation. 2-25
Figure 2-16. Estimated mean first-of-the-month snow pack within WRIA 30. 2-29
Figure 2-17. Snow pack (in inches of snow-water equivalent) at two climate stations in the vicinity of WRIA 30. 2-29
Figure 2-18. Current land cover and land use in WRIA 30. Descriptions of land use categories are given in Table 2-9. 2-32
Figure 2-19. Summary by major land cover/land use categories for the subbasins within WRIA 30. 2-35

Chapter 2: Hydrologic Framework

Water Resources Inventory Area (WRIA) 30 was broken into six subbasins for the purposes of this assessment (Figure 2-1; Table 2-1). This subbasin approach allows for better resolution in the assessment by dividing the overall WRIA into smaller, more manageable sub areas. The rationale for subbasin delineation was to first delineate the major tributaries (i.e., Swale Creek and the Little Klickitat River) into subbasins. Next, the mainstem Klickitat River was divided into three areas based on political and geographical boundaries. The Upper Klickitat subbasin represents the portion of the entire basin that is completely within the Yakama Nation closed lands. The boundary between the Middle and Lower Klickitat roughly coincides with the confluence of the two major tributaries. Finally, the Columbia Tributaries subbasin was delineated to include all the small drainages in the WRIA that are tributary to the Columbia River rather than the Klickitat River.

Several characteristics of the watershed affect local hydrologic conditions. The most significant of these factors are topography, soils, geology, precipitation, and land use. Information regarding these basin characteristics is provided in this section.

2.1 TOPOGRAPHY

One of the most basic parameters affecting watershed hydrology is basin topography. The elevation range found within a watershed, or subbasin, determines to a large extent the hydrologic regime (i.e., rain-, rain-on-snow, or snowmelt-dominated runoff patterns) of the area, which in turn determines the possible effects land use may have on stream flow. Similarly, basin relief determines the potential energy available to move water through the system.

The topography of WRIA 30 varies in response to the underlying geology of the area. The Upper Klickitat subbasin and the northern portions of the Middle Klickitat subbasin lie within the Southern Washington Cascades physiographic province (Franklin and Dyrness, 1988). The geology is dominated by relatively recent basalts, andesite flows, and pyroclastic

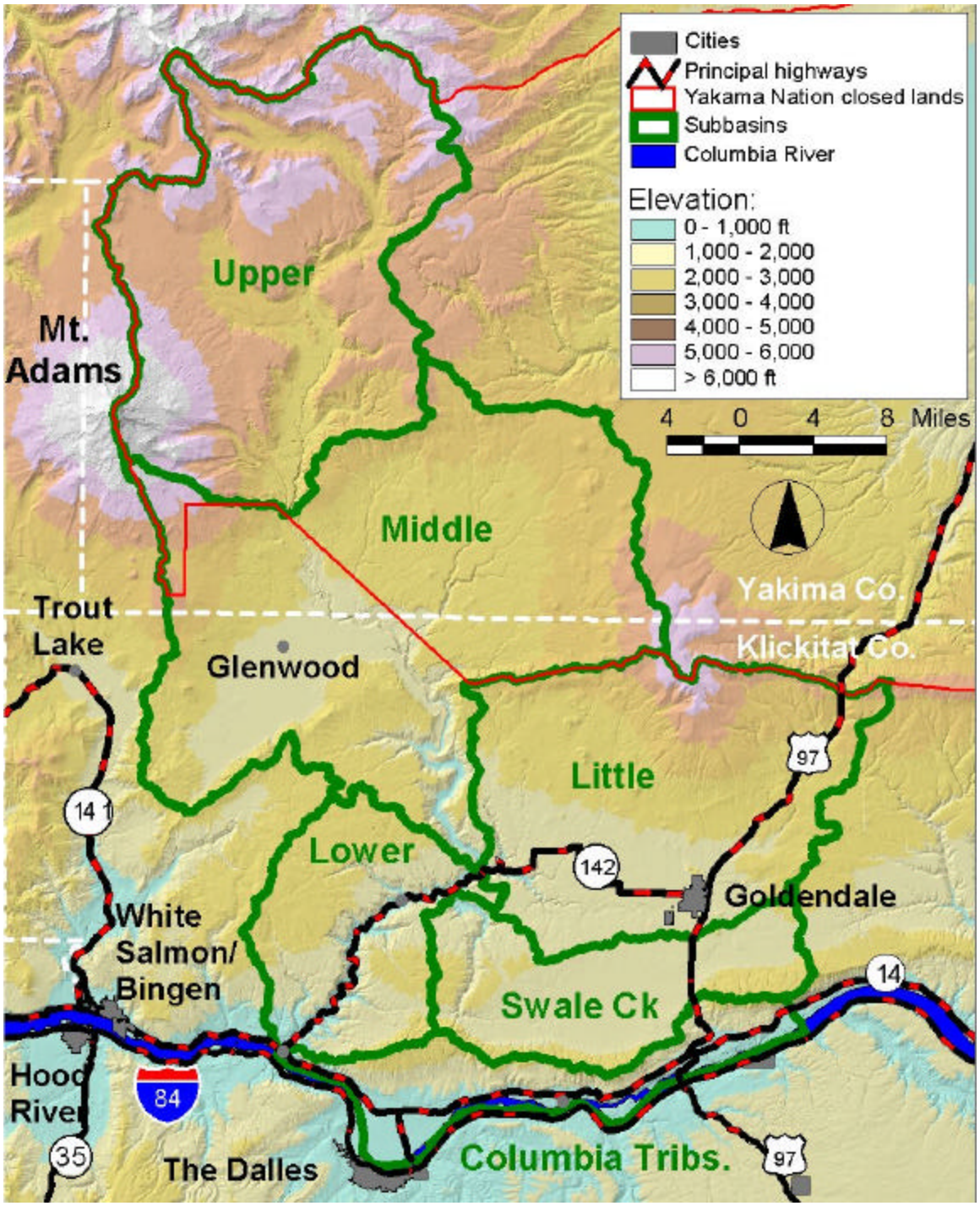


Figure 2-1. Shaded-relief map of WRIA 30. Data sources: BLM (2002), ODAS (1998), WDOE (2000). USGS (2001), WDOT (2002, 2001, 2000, 1998, 1995)

rocks[1] (Raines and Johnson, 1996), and contains many areas of high topographic relief (Figure 2-1), particularly in the vicinity of Mt. Adams. The remainder of WRIA 30 falls within the Columbia Basin physiographic province, and contains large areas of Miocene basalt flows. The topography within much of this remaining area consists of low rolling hills with the exception of areas where water features have dissected the underlying basalt (e.g., mainstem of the Klickitat River, mouths of most tributaries, and along the Columbia River), and in the vicinity of the Simcoe Mountains.

Median subbasin elevations generally decrease moving downstream through the basin, however, slopes are steeper both in the Upper and Lower Klickitat subbasins. The ground with lower relief is largely located in the Middle Klickitat, Little Klickitat, and Swale Creek subbasins (Figures 2-1, 2-2, 2-3, Table 2-1).

The Washington Department of Natural Resources (WDNR) has defined five precipitation zones within the state based on climate, elevation, latitude, and vegetation (WDNR, 1991) (Figure 2-4). These precipitation zones define areas that are most likely to experience rain-on-snow related peak stream flows. Rain-on-snow is the common term used to describe wintertime conditions when relatively warm wind and rain combine to produce rapid snowmelt. Of the five precipitation zones defined by the WDNR, rain-on-now events are unlikely to occur in both the highest (highland zone) and lowest (lowland zone) elevation zones either due to the unlikelihood of warm wintertime conditions that produce substantial snowmelt or the lack of significant snow accumulation. Of the three remaining precipitation zones, the greatest likelihood of rain-on-snow peak flow events occurs within the rain-on-snow zone.

The Upper Klickitat subbasin is the highest elevation subbasin within WRIA 30 (Figure 2-2). It ranges from approximately 2,000 feet at the outlet of the subbasin to 12,276 feet at the summit of Mt. Adams (Table 2-1). The Upper Klickitat subbasin is also the steepest subbasin, with a median subbasin slope of 16%. Less than 1% of the total subbasin area has slopes steeper than 100% (Figure 2-3). Approximately half of the subbasin falls within the highland zone, 40% within the snow-dominated zone, and only 10% within the rain-on-snow zone (Figure 2-5). Consequently, the hydrograph within the subbasin is likely snowmelt-dominated, with the highest flows in the late spring months.

[1] Basalts and Andesite are two of the most common types of solidified lava. Pyroclastic rock refers to fragmented rock material formed by a volcanic explosion or ejection from a volcanic vent.

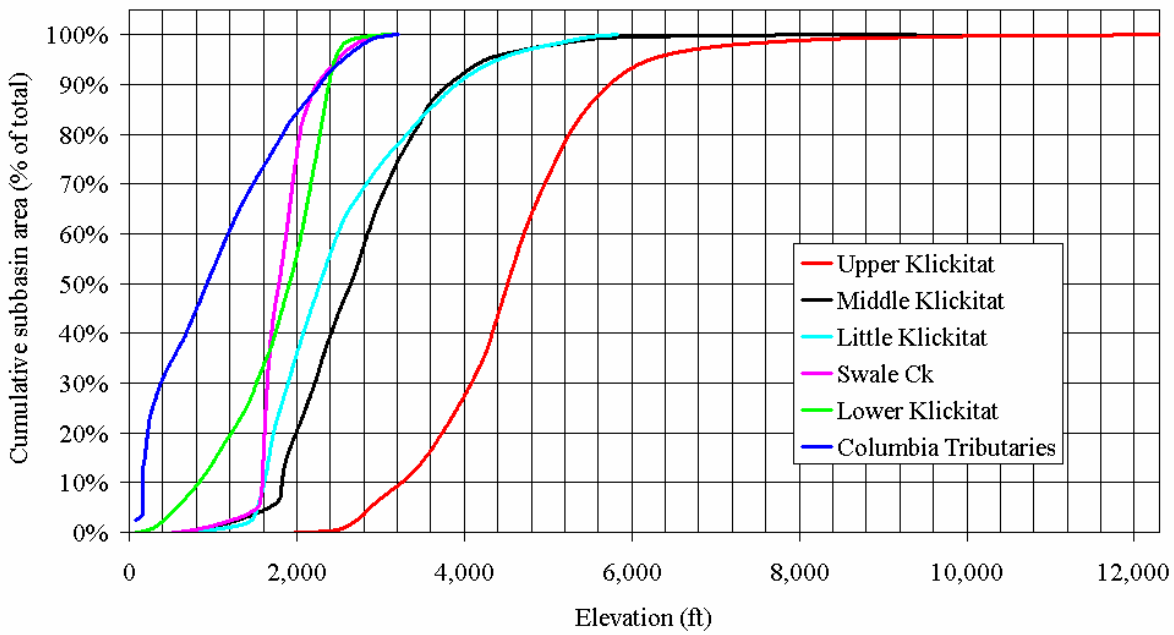


Figure 2-2. Cumulative subbasin area by elevation. Data Source: USGS (2001).

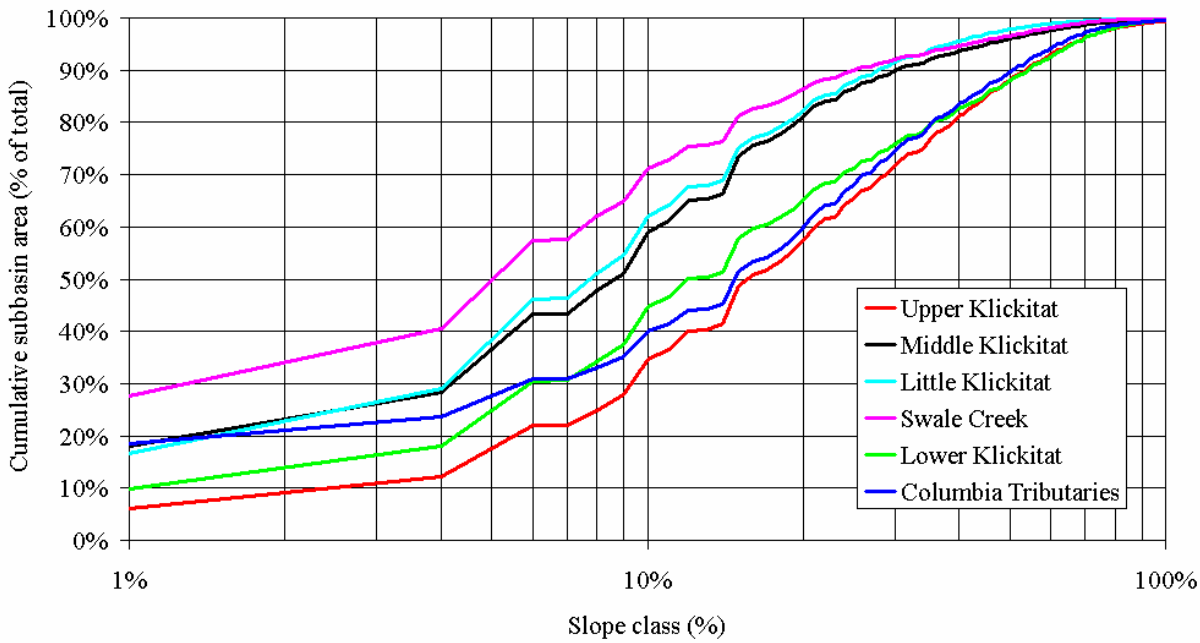


Figure 2-3. Cumulative subbasin area by slope class. Data Source: USGS (2001)

Table 2-1. Subbasin areas, elevations, and slopes. Data Source: USGS (2001).

Subbasin	Drainage area (mi^2)	Elevation (ft)			Median Slope (%)
		Median	Min.	Max.	
Upper Klickitat	350	4,518	1,969	12,276	16%
Middle Klickitat	467	2,644	558	9,397	9%
Little Klickitat	280	2,275	558	5,824	8%
Swale Ck	126	1,785	509	3,219	5%
Lower Klickitat	128	1,913	75	3,166	12%
Columbia Tributaries	91	929	75	3,215	15%
Entire WRIA 30	**1,442**				

The Middle and Little Klickitat subbasins are similar with respect to basin elevation and slope (Table 2-1, Figures 2-2, 2-3). Approximately half of the Middle Klickitat subbasin and 1/3 of the Little Klickitat subbasin falls within the rain-on-snow precipitation zone (Figure 2-5). Consequently, all streams with the exception of the mainstem Klickitat River have a rain-on-snow dominated hydrograph with the highest flows occurring in the winter months during relatively warm winter storms.

Swale Creek is the "flattest" subbasin within WRIA 30 (Table 2-1, Figures 2-2, 2-3). Within the subbasin, the primary area of topographic relief occurs in Swale Creek Canyon near the confluence with the Klickitat River (Figure 2-1). Swale Creek is located entirely within the rain-dominated precipitation zone (Figure 2-5), consequently, the hydrograph within the Swale subbasin likely reflects both rain-on-snow and rainfall events. The highest flows likely occur in the winter months during relatively warm winter storms and in response to local thunderstorms with accompanying high-intensity rainfall.

The Columbia Tributaries subbasin is lower in elevation than the Lower Klickitat subbasin (Table 2-1, Figure 2-2); however, the two subbasins are similar with respect to subbasin slopes (Figure 2-3). The primary areas of topographic relief in both subbasins are a result of down cutting into the Columbia Plateau by the Klickitat and Columbia Rivers.

Approximately 1/3 of the Lower Klickitat subbasin is located within the rain-on-snow zone. The remainder is in the rain-dominated precipitation zone (Figure 2-5). Consequently, the hydrograph within the subbasin is likely affected by both a rain-on-snow and rainfall runoff. The highest flows likely occur in the winter months during relatively warm winter storms and in response to local thunderstorms with accompanying high-intensity rainfall.

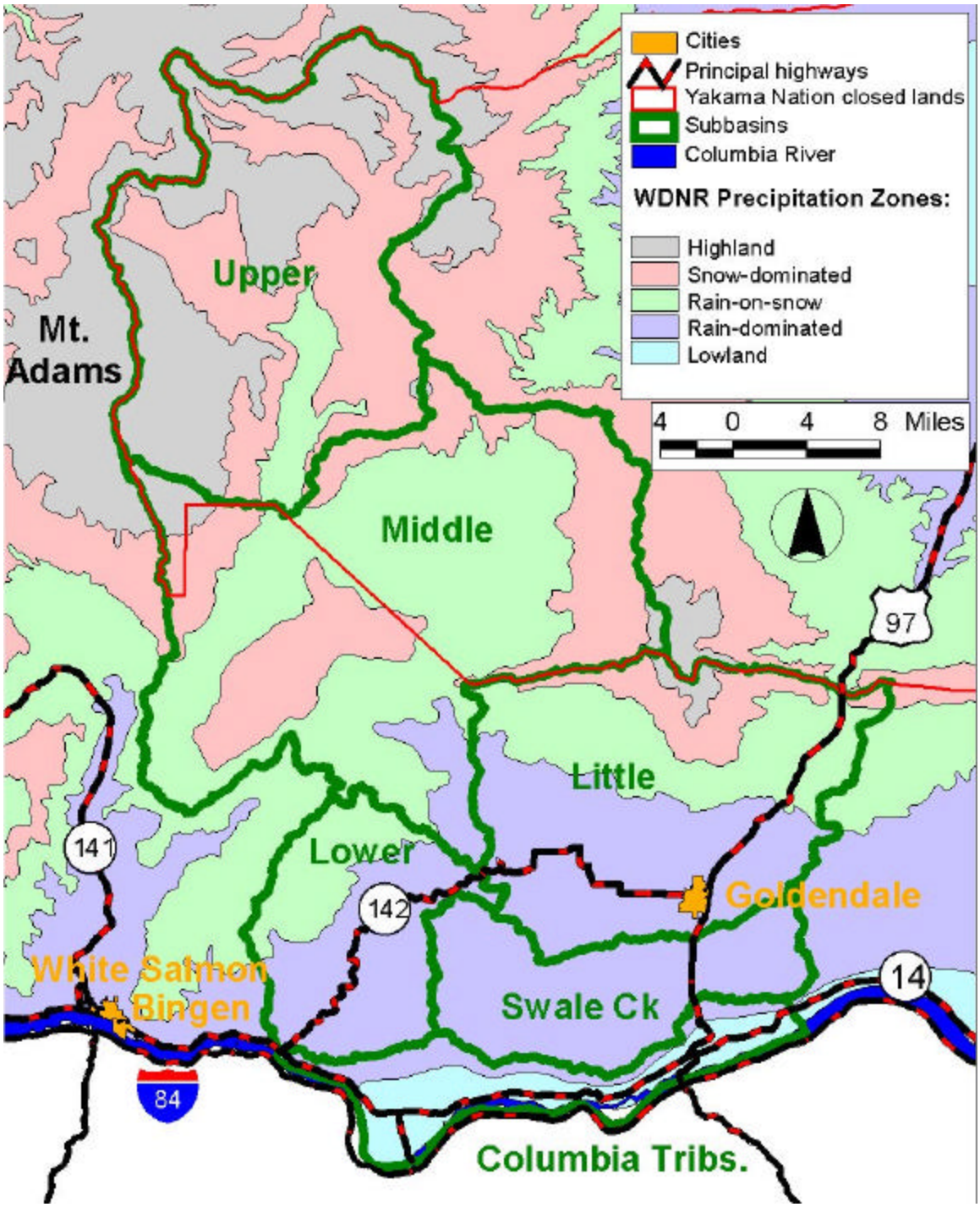
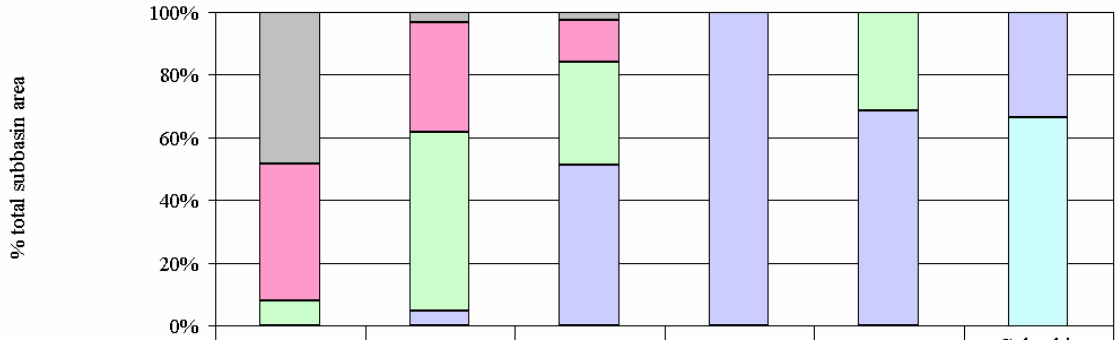


Figure 2-4. Washington Department of Natural Resources precipitation zones in the vicinity of WRIA 30. Data sources: BLM (2002), WDOE (2000). WDNR (1991), WDOT (2002, 2000, 1998)



	Upper Klickitat	Middle Klickitat	Little Klickitat	Swale Ck	Lower Klickitat	Columbia Tributaries
Highland	48%	3%	3%			
Snow-dominated	44%	35%	13%			
Rain-on-snow	8%	57%	33%		31%	
Rain-dominated		5%	51%	100%	69%	34%
Lowland						66%

Figure 2-5. Proportion of subbasin area within the five precipitation zones defined by the Washington Department of natural Resources. Data source: WDNR (1991).

Approximately 2/3 of the Columbia Tributaries subbasin is located within the Lowland precipitation zone and the remainder is in the rain-dominated zone (Figure 2-5). Consequently, streams within the Columbia Tributaries subbasin are unlikely to be significantly influenced by rain-on-snow events. The hydrograph for these tributaries is likely dominated by rainfall, with the highest flows occurring in response to high-intensity rainfall events.

In summary, the variations in the elevation ranges of the subbasins found within WRIA 30 result in variable expected runoff patterns among the subbasins. Streams within the Upper Klickitat subbasin and the Klickitat River mainstem itself, are likely to have a snowmelt-dominated hydrograph, with the highest flows occurring in the late spring months. In the mid-elevation ranges, streams are likely to have rain-on-snow dominated hydrographs, with the highest flows occurring in the winter months during relatively warm winter storms. In the lowest elevation areas streams are unlikely to be significantly influenced by rain-on-snow events, and are likely to have a rainfall driven hydrograph, with the highest flows occurring in response to high-intensity rainfall events.

The gentle relief of a large portion of the WRIA will limit the potential energy available to move water through the system, resulting in relatively low stream velocities and erosion

potential, and will allow for precipitation to percolate to aquifers[2]. Conversely, areas of steeper relief, found primarily in the Upper Klickitat subbasin, and within steep canyon areas, have greater erosion potential, and a greater propensity for moving water out of the system. The data needed to describe the topography of the subbasins (i.e., digital elevation model data) is readily available and of adequate resolution to be used if any level II modeling of basin hydrology is required.

2.2 SOILS

The properties of soils found within a watershed influence the movement of water through and within the soil layers. Digital information on soils for WRIA 30 is available from four separate sources. The USDA Natural Resources Conservation Service (Formerly Soil Conservation Service) has published data for the northern portion of the Upper Klickitat subbasin (NRCS, 2000), and has draft data available for a portion of Klickitat County (NRCS, 2001a) and for the Yakama Indian Reservation (NRCS, 2002). These draft coverages are currently incomplete and are subject to revision, but were made available for this analysis by the NRCS Spokane office (C. Scripter, NRCS, personal comm., 7/19/2002). The remainder of WRIA 30 is covered by soils data available from the WDNR (2002).

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) (NRCS, 1986). The four HSG classifications are given in Table 2-2. Hydrologic soil group information was available for two of the NRCS GIS coverages (NRCS, 2000; NRCS, 2001a), and was interpreted for the remaining areas based on soil series type and published HSG ratings (NRCS, 1986) where possible. Approximately 8% of the WRIA does not currently have HSG ratings.

The majority of WRIA 30 soils have a HSG rating of “B”, indicating that moderate rates of infiltration and water transmission (Figure 2-6, Table 2-3). Infiltration and transmission rates are highest in the Middle Klickitat subbasin, where close to 90% of the soils are in HSG groups A and B, and lowest in the Swale Creek and the Columbia Tributaries subbasins.

Information on HSG characteristics would be necessary if any level II modeling of basin hydrology is required. For the most part, the data needed to describe the HSGs within the subbasins is readily available and of adequate resolution to be used if any level II modeling of basin hydrology is required. The data gaps that currently exist will be filled following completion of the digital soil surveys now in progress.

[2] Note that the information provided in this section is intended as a framework for understanding hydrologic processes at the WRIA scale. Site-specific characteristics such as vegetative cover, soil, soil conditions, and local hydraulics will have a greater effect on reach-level conditions than overall subbasin topography.

Table 2-2. 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).

Table 2-3. Summary of percent subbasin area by Hydrologic Soil Group. Values given as "0%" indicate less than 0.5% of the subbasin area is in this type. Data reported as falling into two HSG groups (e.g. "A/D") indicate soil complexes whose component soils fall into more than one HSG category.

Subbasin	**A**	**A/D**	**B**	**B/D**	**C**	**C/D**	**D**	**Glaciers**	**Water**	**Urban**	**Unavailable**
Upper Klickitat	1%	1%	69%	5%	2%	0%	1%	3%	0%		19%
Middle Klickitat	2%	0%	86%	0%	2%	0%	6%	0%	0%		4%
Little Klickitat	0%		75%		11%		10%		0%		4%
Swale Ck	0%		42%		43%		11%		0%		4%
Lower Klickitat	0%		70%		22%		6%		1%		1%
Columbia Tributaries	8%		35%		4%		31%		0%	0%	22%
Entire WRIA 30	**1%**	**0%**	**71%**	**1%**	**9%**	**0%**	**8%**	**1%**	**0%**	**0%**	**8%**

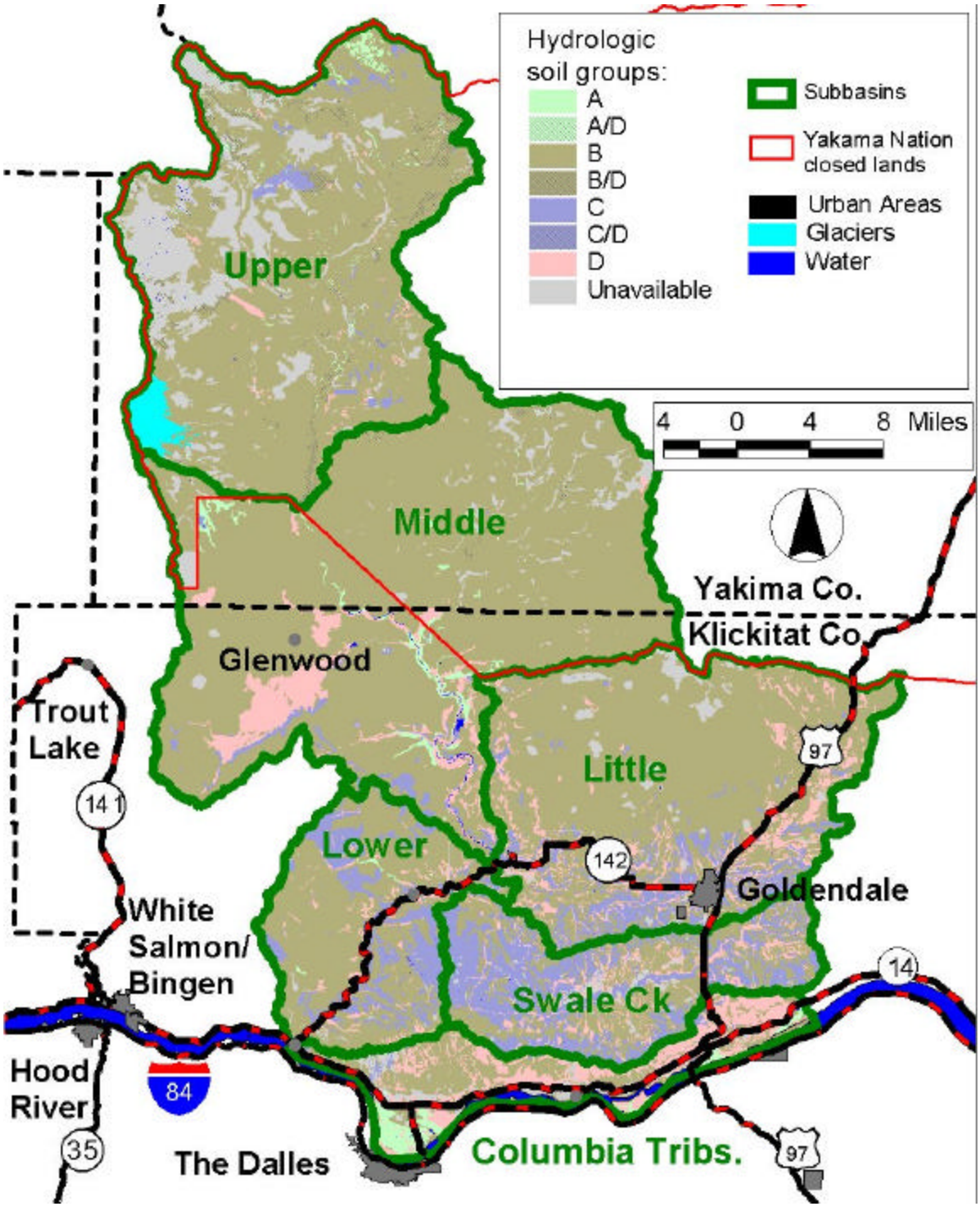


Figure 2-6. Hydrologic soil groups found in WRIA 30. Data Sources: NRCS (2002, 2001a, 2000), WDNR (2002).

2.3 GEOLOGIC SETTING

The underlying geology of a watershed, or subbasin, influences the movement and storage of groundwater in the area. The principal information regarding geology of WRIA 30 was obtained from Newcomb (1969), Cline (1976), Brown (1979), and Drost and Whiteman (1986), as well as information from specific projects within the watershed. The vast majority of available geologic information pertains to the southern portion of the watershed within Klickitat County. There is little geologic information available within the northern watershed, particularly the Upper Klickitat Subbasin.

WRIA 30 has a generalized geologic history including: (1) widespread extrusion of numerous Miocene-age lava flows (Columbia River Basalt Group; CRB) from vents east of the watershed with a combined thickness ranging from zero to several thousand feet; (2) uplift of the Cascade Range immediately to the west, with resulting upwarp and erosion of the lava flows; (3) localized extrusion of lavas and ash from Mount Adams and several smaller volcanic and cinder cones; and (4) glaciation on the higher peaks, resulting in erosion of these peaks and deposition in down slope. The erosion resistant nature of the volcanic strata has resulted in the creation of deep, steep-walled canyons with limited floodplain development over most of the watershed.

The watershed is largely underlain by bedrock of the CRB and younger volcanics with interbedded terrestrial sediments (silt, sand, and gravel) deposited during time periods between the individual lava flows. Figure 2-7 is a surficial geologic map of the watershed, from Drost and Whiteman (1986). Figures 2-8, 2-9, 2-10, and 2-11 provide four generalized geologic cross sections across the southern portion of watershed (cross section alignments are depicted on Figure 2-7). Older volcanic rocks underlie the CRB; however, these older rocks only occur near the surface in the northernmost margin of the Upper Klickitat Subbasin (Figure 2-7) and have limited relevance to water resources of the watershed as a whole.

The CRB underlies the southern and eastern portions of WRIA 30, and represents the largest source for groundwater supply within the watershed. The CRB flows were extruded during Miocene time from vents and northwest-trending fissures in the southeast corner of the state, east of WRIA 30. The flows were extremely fluid, and some of them reached the Pacific Ocean via the ancestral Columbia River drainage. The CRB includes (from oldest to youngest) the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. The Saddle Mountains Basalt is only present east of WRIA 30 and is not discussed further here.

The Grande Ronde Basalt forms the lower, basement geologic unit beneath all but the northernmost portions of WRIA 30. The interpreted subsurface extent of the Grande Ronde within WRIA 30 is depicted on Figure 5-27 in Section 5.2. The thickness of the Grande Ronde increases from zero feet in the northern and western margin of WRIA 30 to at least several thousand feet thick in the southeastern margin of the watershed. Within the southern portions of the watershed, surface exposure of the Grande Ronde is limited to deeper sections of the Klickitat River canyon, along the Columbia River valley, and in exposed portions of major east-west trending anticlinal features. Outcrops of the Grande Ronde Basalt are

exposed more extensively in the northern watershed (Figure 2-7, Table 2-4). Interbeds of sedimentary material are rare and generally only a few feet thick within the Grande Ronde.

The Wanapum Basalt is not as regionally extensive as the Grande Ronde, but is present beneath most of the southeastern watershed except where it has been eroded away within the Klickitat River canyon (see Figure 5-28 in Section 5.2). The Wanapum is well exposed at the surface across much of the southern watershed (Figure 2-7), and reaches a maximum thickness of greater than 1,000 feet beneath the eastern portion of the watershed. The Wanapum is comprised of multiple individual basalt flows and interbedded sedimentary units of variable thickness and composition.

Volcanic bedrock younger than the Miocene-age CRB dominates much of the northern portion of the watershed. These younger (Quaternary) volcanics include flows from Mount Adams and other Cascade Mountains along the northern and western portions of the watershed, and the Simcoe Volcanics that form the Simcoe Mountains north and northwest of Goldendale. In contrast to the Wanapum and Grande Ronde Basalts, which have a distant volcanic source, the source of the Simcoe Volcanics is local, creating a highly-variable unit that ranges from solid basalt flows to pyroclastic deposits (ash, cinders, and scoria) and mud flows. The Simcoe Volcanics form the cinder cones evident in the Goldendale area.

Sediments between, within, and overlying the basalt flows of the CRB occur as a result of deposition by drainage systems during the time periods between the individual basalt flows. The sediments are not considered part of the CRB, rather they are assigned to the Ellensburg Formation, which is a sedimentary deposit ranging in composition from silt to gravel and is easily eroded. This unit is generally extensive beneath the southern portion of the watershed, but varies considerably in thickness (may be absent) and yield potential for groundwater supply. The sedimentary interbed separating the Grande Ronde from the overlying Wanapum is commonly referred to as the Vantage member of the Ellensburg Formation.

Two major groups of geologic structures occur within WRIA 30. The first is a series of east-west trending anticlinal folds running most of the length of the southern watershed – part of the Yakima Fold Belt Subprovince of the Columbia Basin. These include, from north to south, the Toppenish, Horse Heavens, Bingen, and Columbia Hills anticlines (Figure 2-7). These form topographically prominent ridges across the watershed. A series of smaller east-west folds occur throughout the watershed. Superimposed upon these major east-west structures are a series of northwest-southeast trending folds and faults. Major north-south faults include the Warwick Fault near the town of Warwick and the Goldendale Fault northeast of Goldendale.

In many areas of the watershed, the volcanic bedrock is overlain by unconsolidated sedimentary deposits comprised of gravels, sands, and silts of glacial or fluvial origin (collectively referred to as alluvium). Where the surficial alluvium is extensive, such as in the Swale Creek valley south of Goldendale and in the Camas Prairie area surrounding Glenwood, it can provide a groundwater source for domestic supplies.

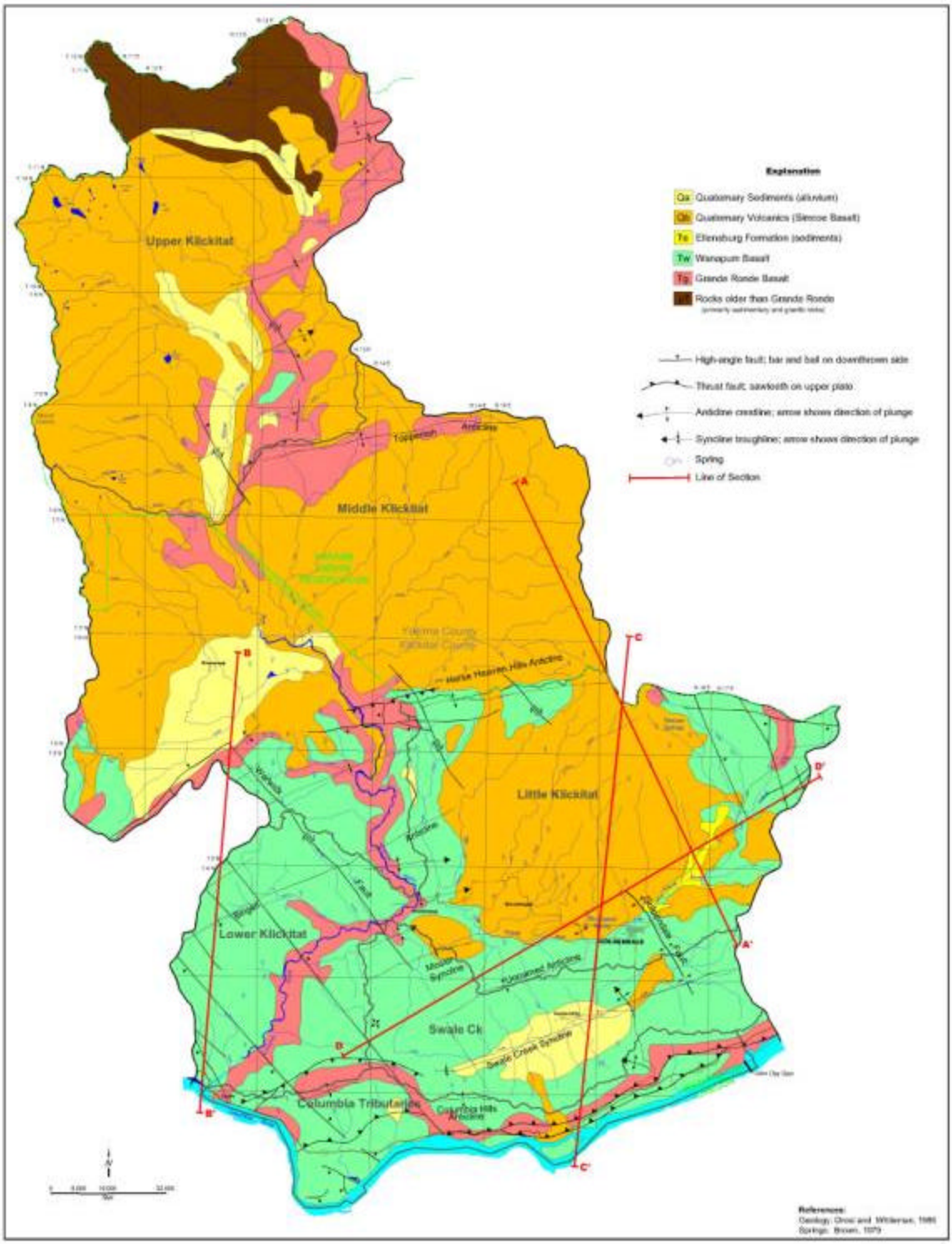


Figure 2-7. Surficial Geology and Structure

Intentionally blank

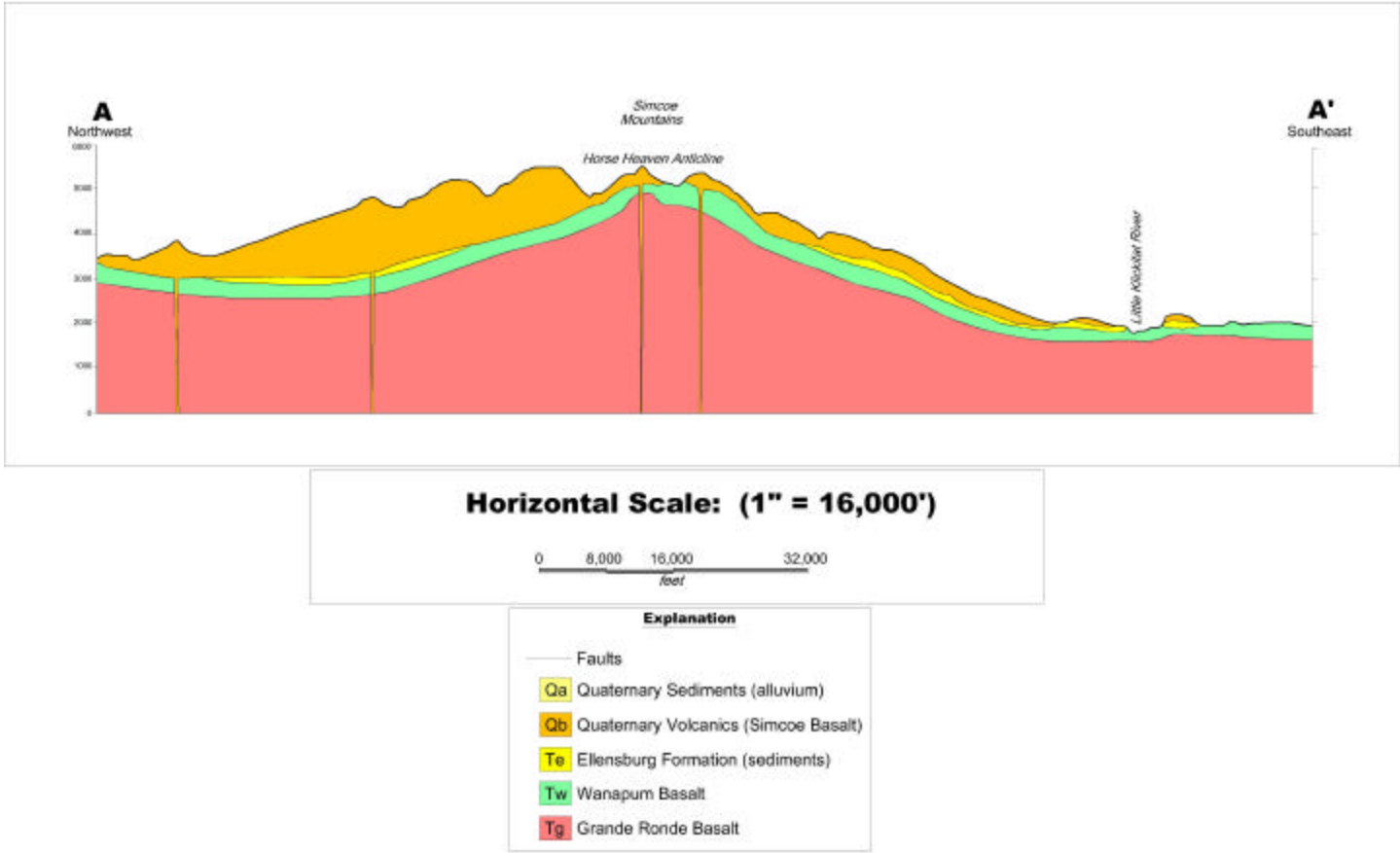


Figure 2-8. Geologic Cross Section A-A'

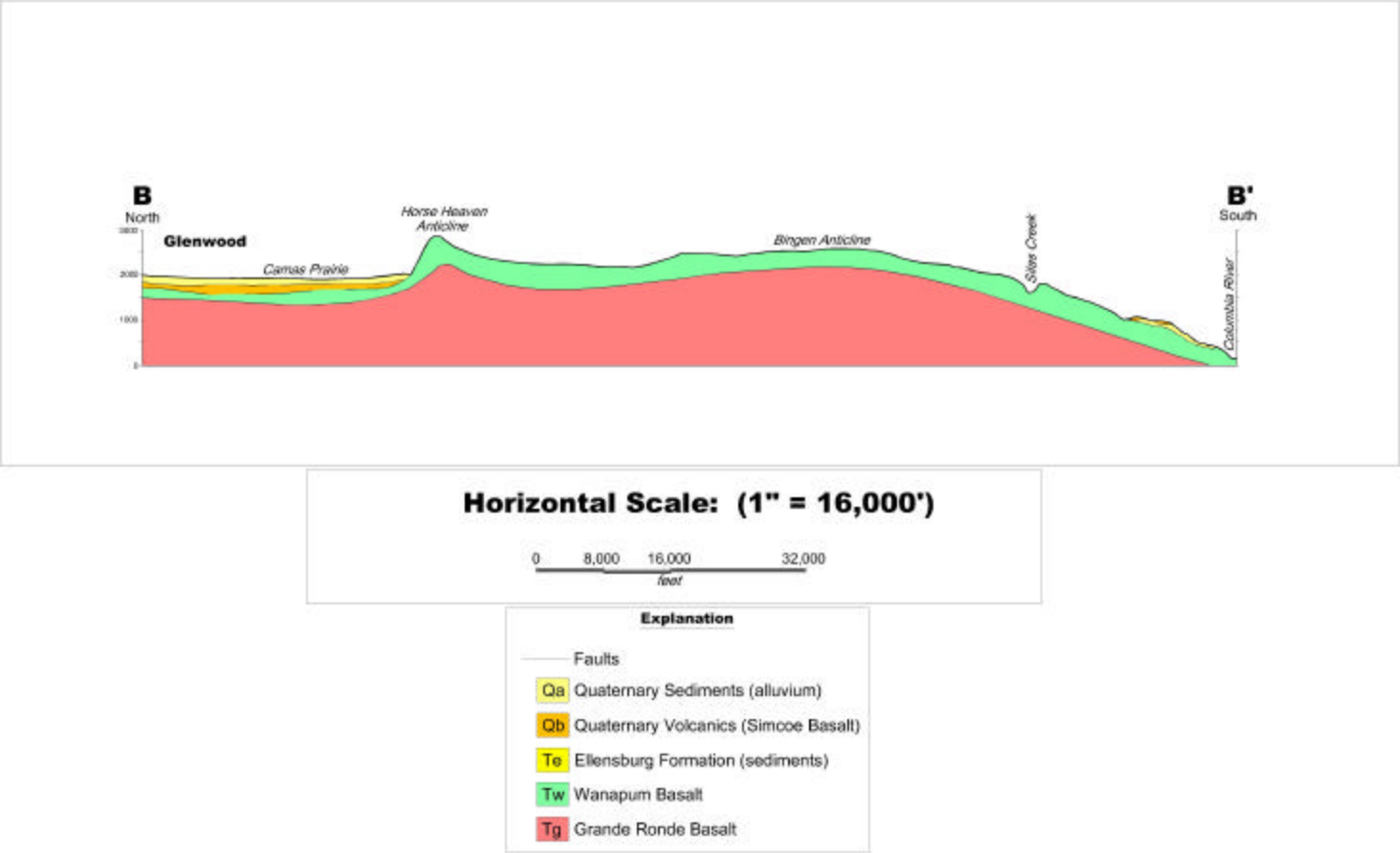


Figure 2- 9. Geologic Cross Section B-B'

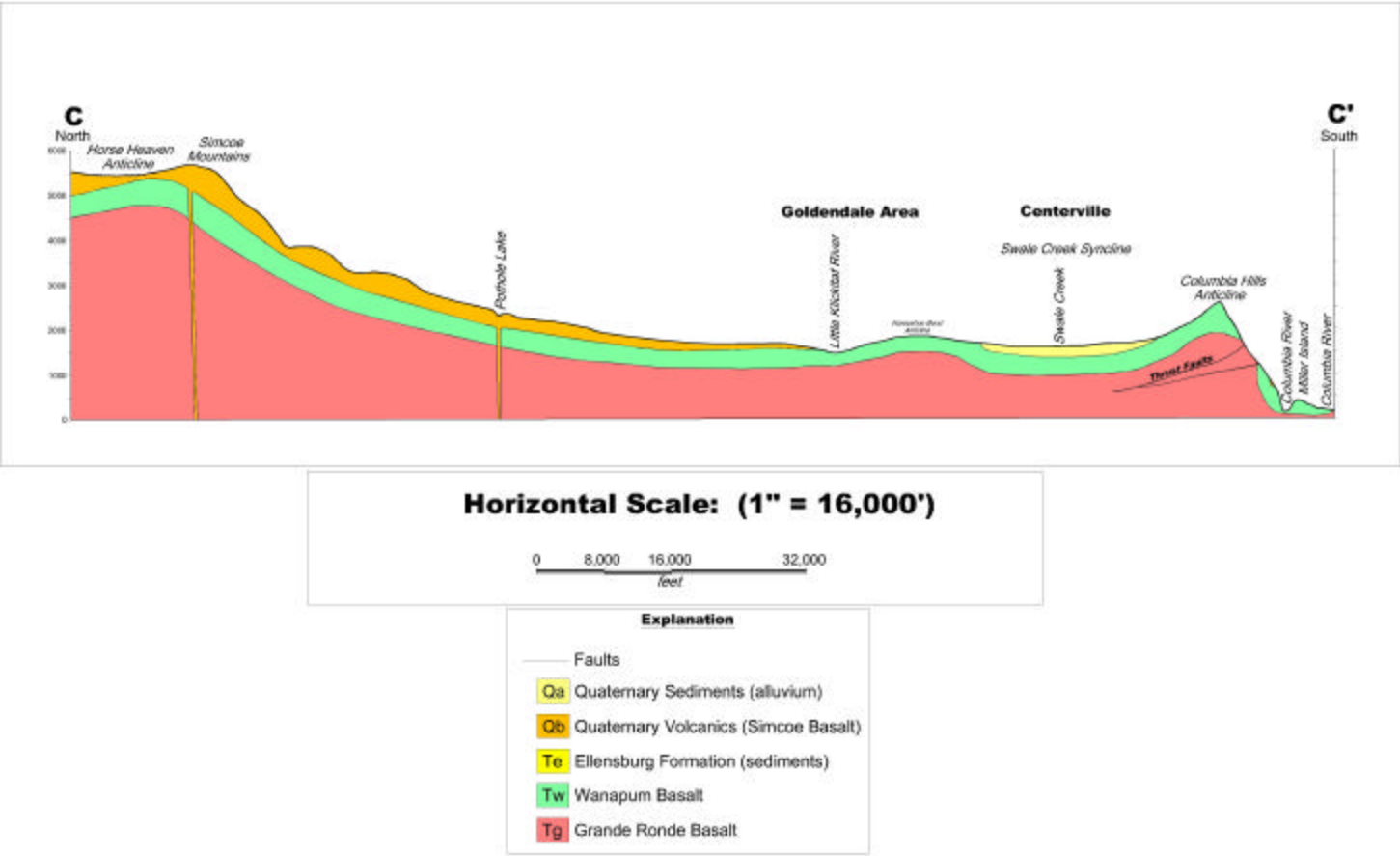


Figure 2- 10. Geologic Cross Section C-C'

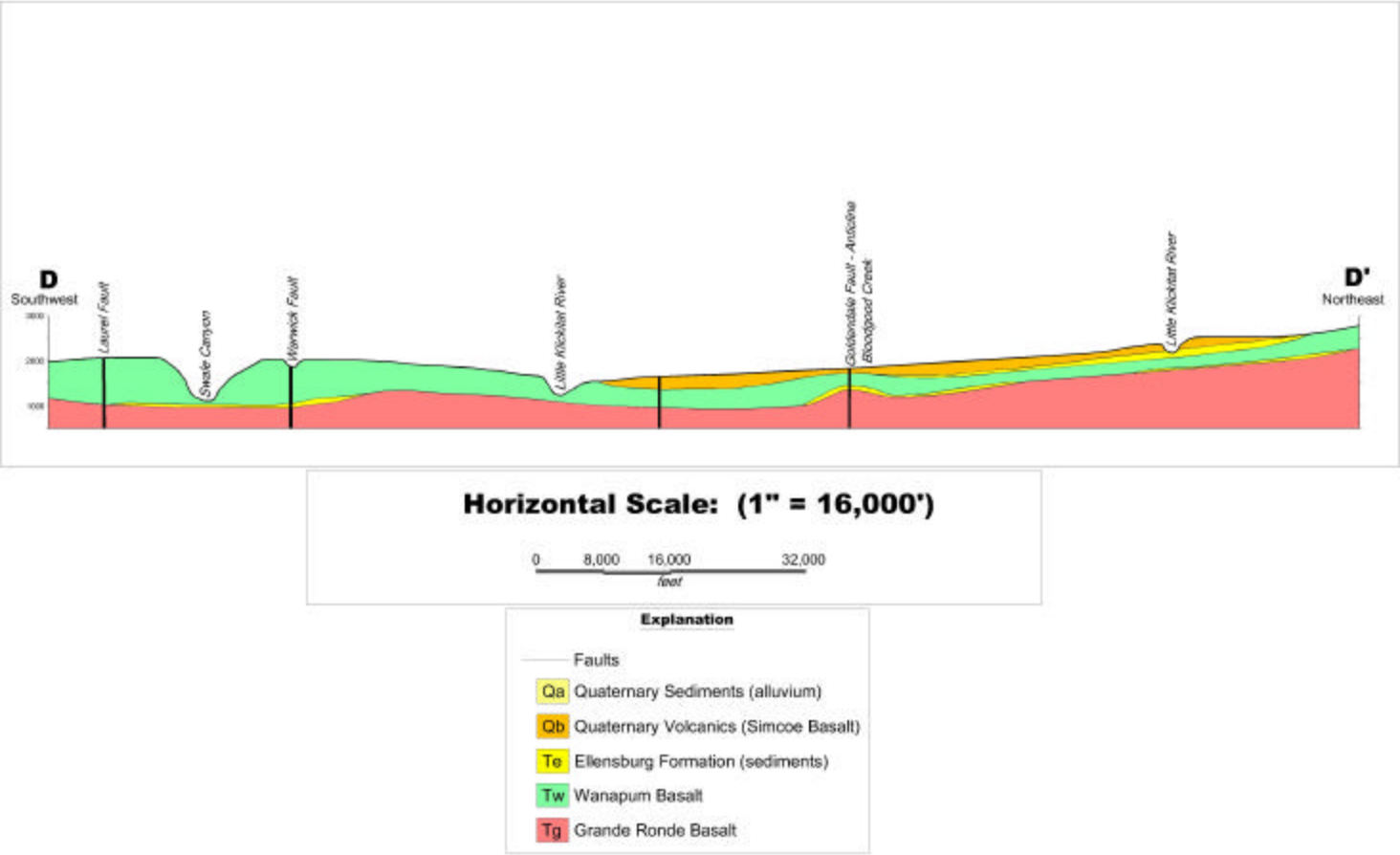


Figure 2- 11. Geologic Cross Section D-D'

2.4 PRECIPITATION

Precipitation is the primary determinant of runoff in a watershed. The purpose of this section of the assessment is to characterize the spatial and temporal variation in precipitation in WRIA 30. Precipitation data are available from twenty-two National Climatic Data Center (NCDC) cooperative weather stations and two NRCS SNOTEL stations located within or near WRIA 30 (Figure 2-12, Table 2-5). Not all climate stations are currently active and several may contain longer records than those listed in Table 2-5.

2.4.1 Average Precipitation

The Oregon Climate Service (1998) has published digital maps of mean annual and monthly precipitation for the State of Washington, based on available precipitation records for the period 1961-1990. The Oregon Climate Service maps were produced using techniques developed by Daly and others (1994), 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 Oregon Climate Service incorporate precipitation data from the local stations shown in Figure 2-12. 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.

Mean annual precipitation within WRIA 30 generally increases with elevation and from east to west (Figure 2-13). Mean annual precipitation is as little as 9 inches per year in the eastern end of the Columbia Tributaries subbasin and as much as 105 inches per year on Mount Adams in the Upper Klickitat subbasin. Overall, mean annual precipitation is:

67” in the Upper Klickitat,
51” in the Middle Klickitat,
26” in the Little Klickitat,
23” in Swale Ck,
26” in the Lower Klickitat,
20” in the Columbia Tributaries, and
45” for the Entire WRIA 30.

Mean monthly precipitation for each subbasin was also estimated using data available from the Oregon Climate Service (1998). Mean monthly precipitation patterns are similar to mean annual precipitation. The lowest monthly values are found in the Columbia Tributaries subbasin and the highest in the Upper Klickitat subbasin (Figure 2-14). Mean monthly precipitation values are highest in the months of December and January and lowest in July and August.

Table 2-4. Percent of subbasin area by geologic type in each subbasin. Values given as "0%" indicate less than 0.5% of the subbasin area is in this type.

	Upper Klickitat	Middle Klickitat	Little Klickitat	Swale Ck	Lower Klickitat	Columbia Tributaries	Entire WRIA 30
SEDIMENTS AND SEDIMENTARY ROCKS							
QUATERNARY SEDIMENTS							
Qa - Alluvium	8%	1%	1%	7%	2%	1%	3%
Qoa - Older alluvium					0%	0%	0%
Qd - Holocene dune sand						1%	0%
Qls - Landslide debris	1%	1%	1%	0%	3%	3%	1%
Ql - Loess				3%			0%
Qfs - Flood sand and silt					0%		0%
Qfg - Flood gravel					0%	3%	0%
Qad - Undifferentiated drift	4%	2%					1%
PLEISTOCENE-PLIOCENE SEDIMENTS							
QPc - Continental sediments			1%	14%			1%
MIOCENE SEDIMENTARY ROCKS							
Mc - Continental sedimentary rocks		0%	1%	1%	4%	2%	1%
VOLCANIC ROCKS AND DEPOSITS							
QUATERNARY VOLCANIC ROCKS AND DEPOSITS							
Qva - Andesite flows	22%	7%					8%
Qvb - Basalt flows	9%	20%	0%	1%		1%	9%
Qvc - Volcaniclastic deposits, undivided	0%						0%
PLEISTOCENE-PLIOCENE VOLCANIC ROCKS							
QPva - Andesite flows	0%						0%
QPvb - Basalt flows	23%	47%	61%	3%	2%		33%
PLIOCENE VOLCANIC ROCKS							
Pvr - Rhyolite	0%		1%				0%
Pvt - Tuff	0%						0%
MIOCENE VOLCANIC ROCKS							
Mvs - Middle to upper Miocene Saddle Mountains Basalt		0%			3%	0%	0%
Mvw - Middle Miocene Wanapum Basalt	1%	12%	33%	68%	74%	62%	27%
Mvg - Middle Miocene Grande Ronde Basalt	17%	10%	1%	3%	12%	16%	10%
MIOCENE-OLIGOCENE VOLCANIC ROCKS							
MOv - Volcanic rocks	3%						1%
MOva - Andesite flows	11%						3%
MOvc - Volcaniclastic rocks	0%						0%
INTRUSIVE ROCKS AND LAVA DOMES							
PLEISTOCENE-PLIOCENE INTRUSIVE ROCKS							
QPian - Intrusive andesite	0%						0%
PLIOCENE INTRUSIVE ROCKS							
Pida - Intrusive dacite			0%				0%
OTHER							
Glacier - glacier	1%	0%					0%
Open Water - open water	0%		0%			11%	1%

Table 2-5. Climatic data stations in the vicinity of WRIA 30. Refer to Figure 2-13 for station locations. Data Sources: Brunengo (1997), EarthInfo (1996), NCDC 2002), NRCS (2001b).

Map #	Sta. #	Station Name	Elev. (ft)	Precipitation data availability:					
				Hourly:		Daily:		Monthly:	
				From	To	From	To	From	To
1	53019	Lost Horse SNOTEL	5,000	n/a	n/a	10/1/1990	**Present**	10/1990	**Present**
2	53035	Potato Hill SNOTEL	4,500	n/a	n/a	10/1/1981	**Present**	10/1981	**Present**
3	350753	Big Eddy	131	n/a	n/a	7/2/1948	3/31/1957	9/1916	3/1957
4	354003	Hood River Exp Stn.	500	8/14/1948	1/31/1968	1/1/1928	**Present**	1/1910	**Present**
5	354008	Hood River Tucker Br	383	1/1/1968	**Present**	n/a	n/a	n/a	n/a
6	354293	John Day Dam	190	11/13/1957	11/30/1958	11/14/1957	1/31/1958	12/1957	1/1958
7	358407	The Dalles	102	n/a	n/a	7/1/1948	**Present**	1/1910	**Present**
8	358410	The Dalles 2	279	n/a	n/a	8/1/1967	1/31/1975	8/1967	1/1975
9	359068	Wasco	1,264	n/a	n/a	7/1/1948	**Present**	1/1910	**Present**
10	450217	Appleton	2,336	n/a	n/a	6/12/1959	**Present**	6/1959	**Present**
11	451257	Centerville 2 SW	1,650	7/5/1948	6/30/1956	4/2/1950	9/30/1951	7/1948	6/1956
12	451968	Dallesport AP	240	8/1/1948	9/30/1951	7/1/1948	**Present**	7/1948	**Present**
13	451972	Dallesport 9 N	1,923	n/a	n/a	6/1/1948	12/31/1980	6/1948	12/1980
14	453183	Glenwood	1,896	7/1/1948	**Present**	4/1/1950	9/30/1951	9/1942	9/1951
15	453184	Glenwood 2	1,850	n/a	n/a	9/1/1979	**Present**	9/1979	**Present**
16	453222	Goldendale	1,657	n/a	n/a	1/1/1931	**Present**	9/1910	**Present**
17	453226	Goldendale 2E	1,700	n/a	n/a	5/1/1972	2/28/1995	5/1972	2/1995
18	454035	John Day Dam	190	11/1/1958	8/31/1972	11/18/1958	8/31/1972	11/1958	8/1972
19	455659	Mount Adams RS	1,960	1/1/1971	**Present**	6/1/1948	**Present**	9/1924	**Present**
20	457340	Satus Pass	3,104	6/1/1956	11/30/1967	6/14/1956	11/30/1967	6/1956	11/1967
21	457342	Satus Pass 2 SSW	2,610	11/1/1967	**Present**	1/1/1968	**Present**	1/1968	**Present**
22	458688	Underwood 4 W	1,260	8/1/1948	1/31/1962	4/1/1950	9/30/1951	2/1949	9/1951
23	459183	White Salmon 4 NNE	2,011	n/a	n/a	6/1/1948	11/30/1952	1/1919	11/1952
24	459185	White Salmon 8 NNE	2,060	n/a	n/a	8/1/1953	4/30/1959	8/1953	4/1959

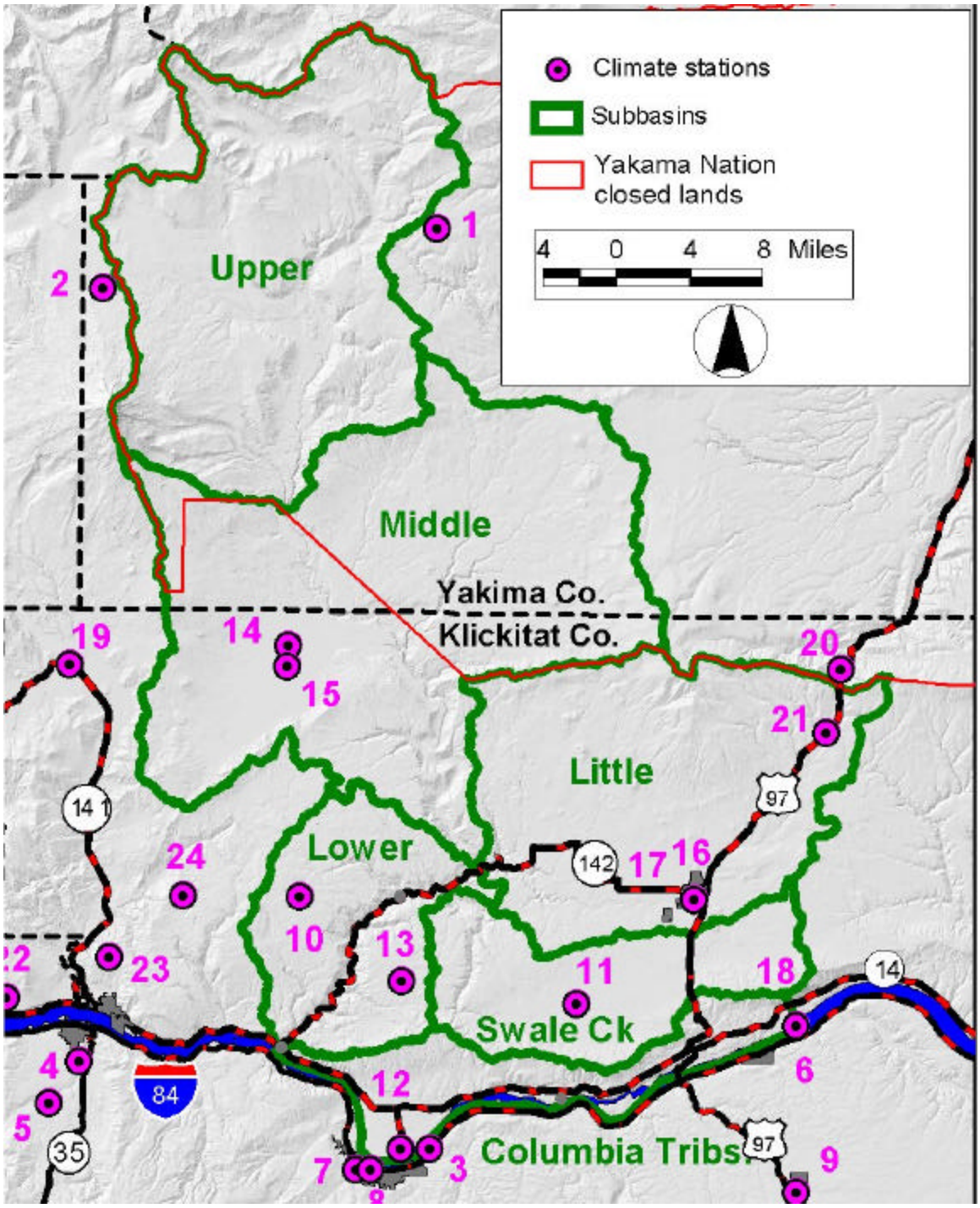


Figure 2-12. Climatic data stations in the vicinity of WRIA 30. Refer to Table 2-5 for data availability. Data Sources: EarthInfo (1996), NRCS (2001b).

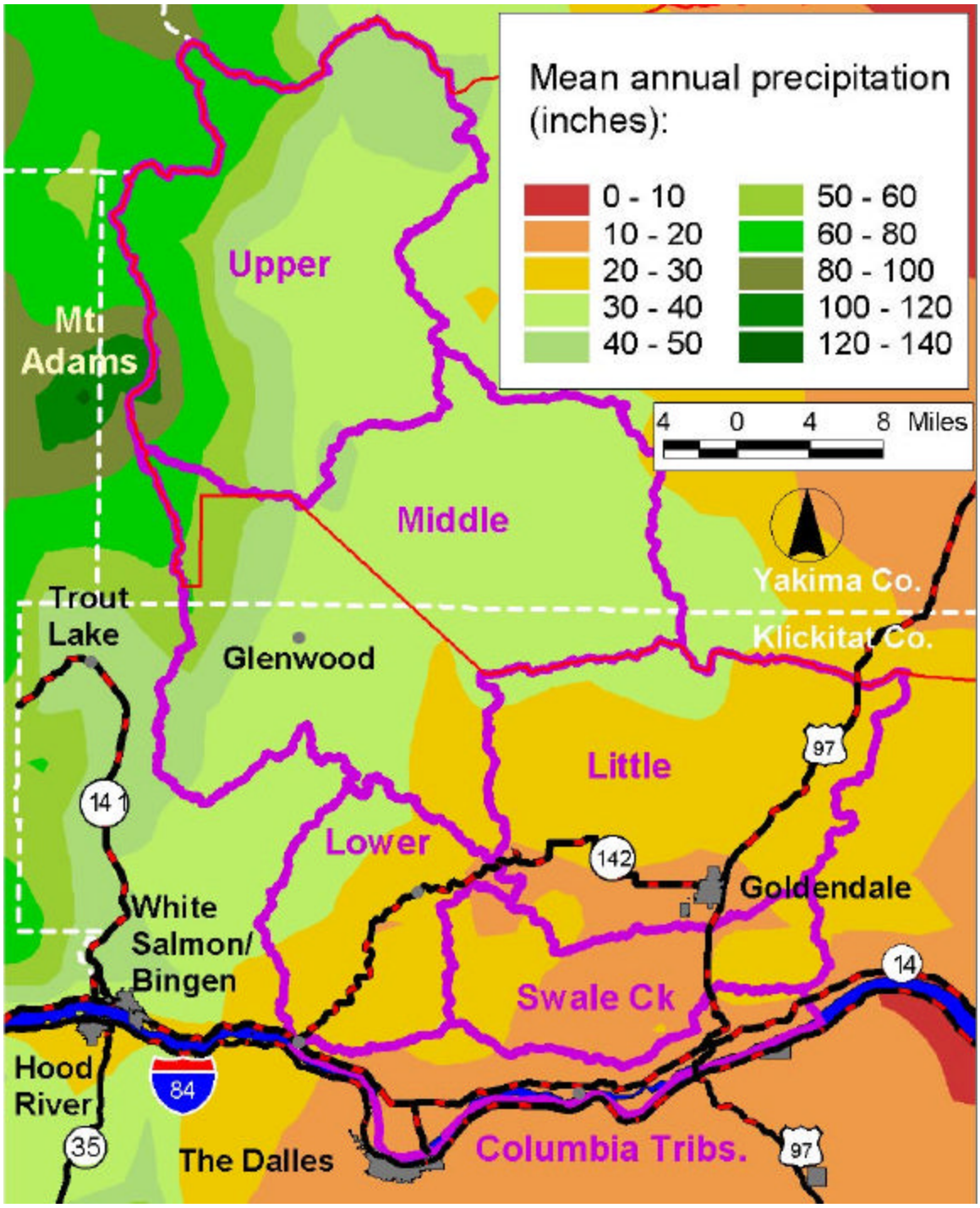


Figure 2-13. Mean annual precipitation (inches) for the period 1961-1990. Data Source: Oregon Climate Service (1998).

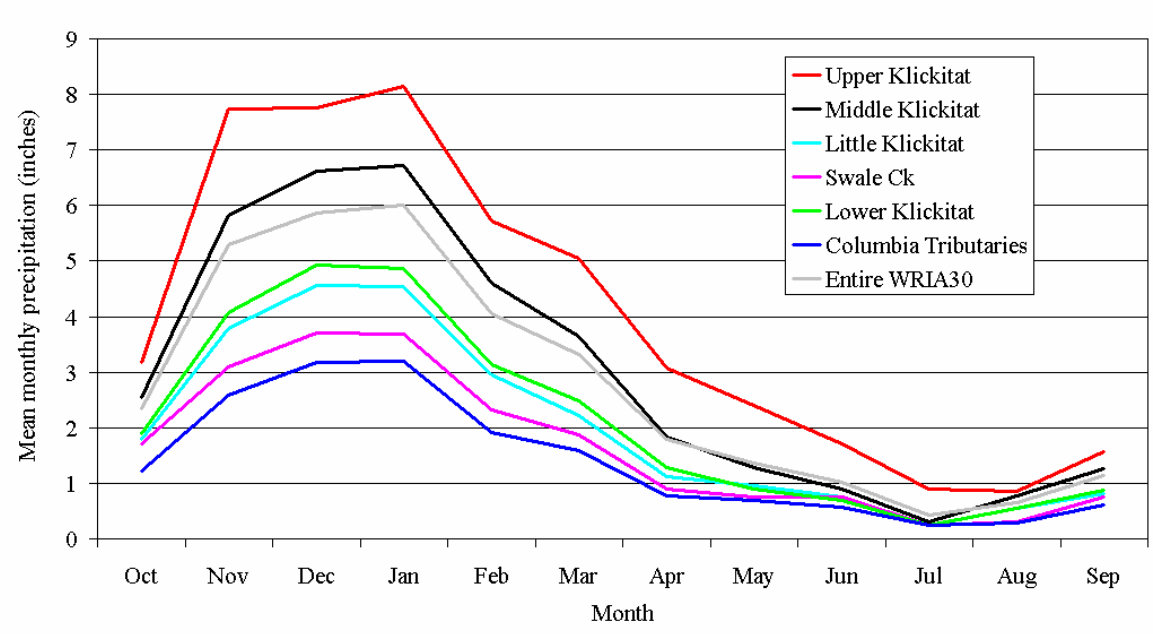


Figure 2-14. Mean monthly precipitation distribution. Data Source: Oregon Climate Service (1998).

2.4.2 Year-to-Year Variability

Year-to-year variability in precipitation was assessed using long-term precipitation records from the Goldendale and Goldendale 2E climate stations (Table 2-5). The Goldendale stations were selected because they have the longest data record from within WRIA 30. For the purposes of this assessment the two records were combined into a single record[3]. Total monthly precipitation values were used to calculate annual precipitation by water year[4]. Monthly values were used if there were three or less days missing in a single month. Over the period of record 17 months had greater than three missing daily values. Values for these months were estimated using regression equations developed with the adjacent The Dalles/The Dalles 2 and Dallesport AP climate stations. Values for these regression equations are given below and the annual precipitation record for the Goldendale / Goldendale 2E climate station is shown in Figure 2-15.

$$\mathbf{P_{GD} = 1.0431\ P_{TD} + 0.1923\ ;\ r^2 = 0.87,\ n = 788}$$

$$\mathbf{P_{GD} = 1.0613\ P_{DP} + 0.1928\ ;\ r^2 = 0.91,\ n = 625}$$

[3] The Goldendale station is missing data from the period May 1972 to February 1995; the period of record for the Goldendale 2E station. The close proximity of the two stations allows the data to be combined.
[4] Water year is defined as October 1 through September 30. The water year number comes from the calendar year for January 1 to September 30. E.g., Water Year 1990 would begin on 10/1/1989, and continue through 9/30/1990. This definition of water year is recognized by most water resource agencies.

Where: P_{GD} = Monthly precipitation at the Goldendale/Goldendale 2E climate stations,

P_{TD} = Monthly precipitation at The Dalles/The Dalles 2 climate stations, and

P_{DP} = Monthly precipitation at the Dallesport AP climate station

The term "r^2" is a statistical measure of how well a regression line approximates real data points; an r^2 of 1.0 indicates a perfect fit. The term "n" refers to the number of data points used in developing the equation.

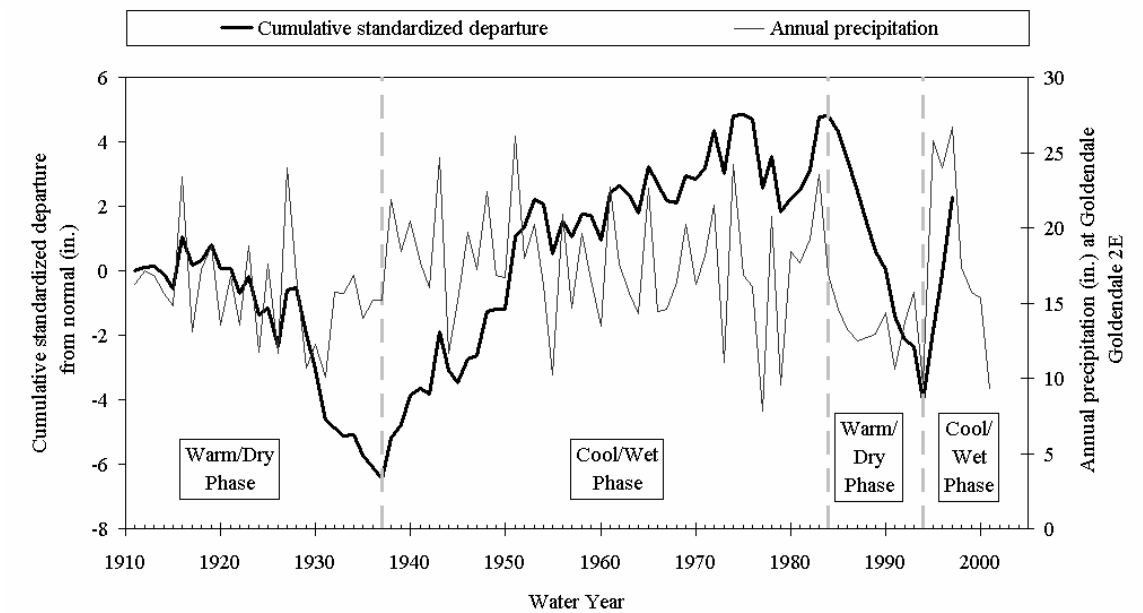


Figure 2-15. Annual precipitation at the Goldendale / Goldendale 2E climate station, and cumulative standardized departure from normal of annual precipitation. Local Pacific Decadal Oscillation (PDO) cycles are shown as vertical dashed lines.

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, Mote et al, 1999) suggest that five distinct PDO cycles have occurred since the late 1800s (Table 2-6).

Table 2-6. Recent Pacific Decadal Oscillation (PDO) cycles in the Pacific Northwest (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)

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).

Statistical techniques were applied to the annual precipitation records for the Goldendale/Goldendale 2E climate station to understand whether local trends follow the documented PDO cycles. Data was processed in the following manner:

1. The mean and standard deviation was calculated for the annual precipitation at each 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 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.

Precipitation patterns from the Goldendale/Goldendale 2E climate station (Figure 2-15) generally follow the documented regional trends (Table 2-6). The warm/dry phase that is regionally reported to have lasted until 1946 appears to have ended sometime around 1937, and the following cool/wet phase appears to have lasted from 1937 to 1984. A short-warm/dry phase appears to have occurred from approximately 1984 to 1994, and we currently appear to be in a cool/wet phase, however, the data are not conclusive regarding the most recent period of time.

The information on precipitation presented in this section was used in the stream flow assessment (Section 5.1) and the groundwater assessment (Section 5.2). In addition, this information would be necessary if any level II modeling of basin hydrology is required. It should be kept in mind that the results presented in this section represent average conditions for annual and monthly conditions within the subbasins of WRIA 30. Additional analysis, beyond the scope of this level I assessment, would be required to address the variability in these annual and/or monthly estimates. Although the number of climate stations within WRIA 30 are few, and the station data records are in many cases of short duration and/or discontinuous, the available data was sufficient for completing the level I assessment.

2.4.3 Snow pack

Data on snow pack[5] are available from several stations maintained by the Natural Resources Conservation Service (NRCS, 2002) in the vicinity of WRIA 30 (Table 2-7). Of the nine stations in the area, only one, the Satus Pass snow course, is located within WRIA 30. The Lost Horse station is located approximately one mile east of the Upper Klickitat subbasin.

Table 2-7. Natural Resource Conservation Service SNOTEL* and snow course stations in the vicinity of WRIA 30. Data source: NRCS (2002).**

Station	County, State	Latitude	Longitude	Elev. (ft)	POR	Type
High Prairie	Hood River, OR	45° 20’	121° 32’	6,100	1984-2002	Snow course
Mill Creek Meadow	Hood River, OR	45° 27’	121° 31’	4,400	1985-2002	Snow course
Parkdale (Disc)	Hood River, OR	45° 28’	121° 40’	1,770	1961-1974	Snow course
Upper Valley (Disc)	Hood River, OR	45° 27’	121° 39’	2,530	1961-1974	Snow course
Knebal Springs (Disc)	Wasco, OR	45° 29’	121° 25’	3,850	1959-1975	Snow course
Satus Pass	Klickitat, WA	45° 59’	120° 41’	4,030	1957-2002	Snow course
Ahtanum R.S.	Yakima, WA	46° 31’	121° 01’	3,100	1941-2002	Snow course
Green Lake Pillow	Yakima, WA	46° 33’	121° 10’	6,000	1941-2001	SNOTEL
Lost Horse Snotel	Yakima, WA	46° 21’	121° 07’	5,000	1991-2001	SNOTEL

Notes: * SNOTEL (for SNOwpack TELemetry) stations are automated stations that collect daily snowpack and related climatic data.
** Measurements of snow depth and water equivalent are measured manually on or near the first of each month along snow courses during the snow cover season (Jan. – June).

Mean first-of-the-month snow water equivalent (SWE) snowpack from each of the stations was used to develop regression equations predicting mean first-of-the-month snow pack as a function of elevation (Table 2-8). Equations were combined with digital elevation model data (USGS, 2001) to produce maps of estimated mean first-of-the-

[5] Snow pack is a measure of the depth of snow on the ground. Snow pack is typically expressed in terms of inches of snow water equivalent, or SWE. Snow-water equivalent refers to the depth of water that would be produced by melting the snow that is present.

month snow pack within WRIA 30 (Figure 2-16). In average years, a shallow snow pack is typically present on January 1st in the majority of the Upper, Middle, and Little Klickitat subbasins (Figure 2-16) and in approximately half of the Lower and Swale Creek subbasins. Snow is largely absent in the Columbia Tributaries subbasin on January 1st. Snow pack typically increases in depth throughout the winter and spring in the Upper Klickitat subbasin and in the higher elevation areas of the Middle and Little Klickitat subbasins (Figure 2-16). Snow pack is typically at its maximum by April 1st.

Variability in snow pack is illustrated for the two stations located within or near WRIA 30 (Figure 2-17). Snow pack is typically present at the Lost Horse station from October through early June, with the deepest snow pack typically occurring on or around April 1st. Maximum snow pack is approximately 20 inches SWE on average, but has varied from as little as 11 inches to as much as 37 inches. First-of-the-month snow pack measurements are available at the Satus Pass station for the months of February through May (Figure 2-17). Maximum snow pack at Satus Pass is, on average, approximately 8 inches SWE, and typically occurs around March 1st. Maximum snow pack at Satus Pass ranges from zero in some years to as much as 20 inches SWE.

Table 2-8. Equations predicting snow pack (S; inches SWE) as a function of elevation (El; feet).

Period	Equation	r^2	Number of stations
Jan 1st	S = 0.0031El - 5.2352	0.76	7
Feb 1st	S = 0.005El - 9.328	0.74	8
Mar 1st	S = 0.0068El - 14.815	0.74	9
Apr 1st	S = 0.0094El - 26.09	0.74	8
May 1st	S = 0.0098El - 37.27	0.99	3
Jun 1st	S = 0.0051El - 25.2	n/a	2

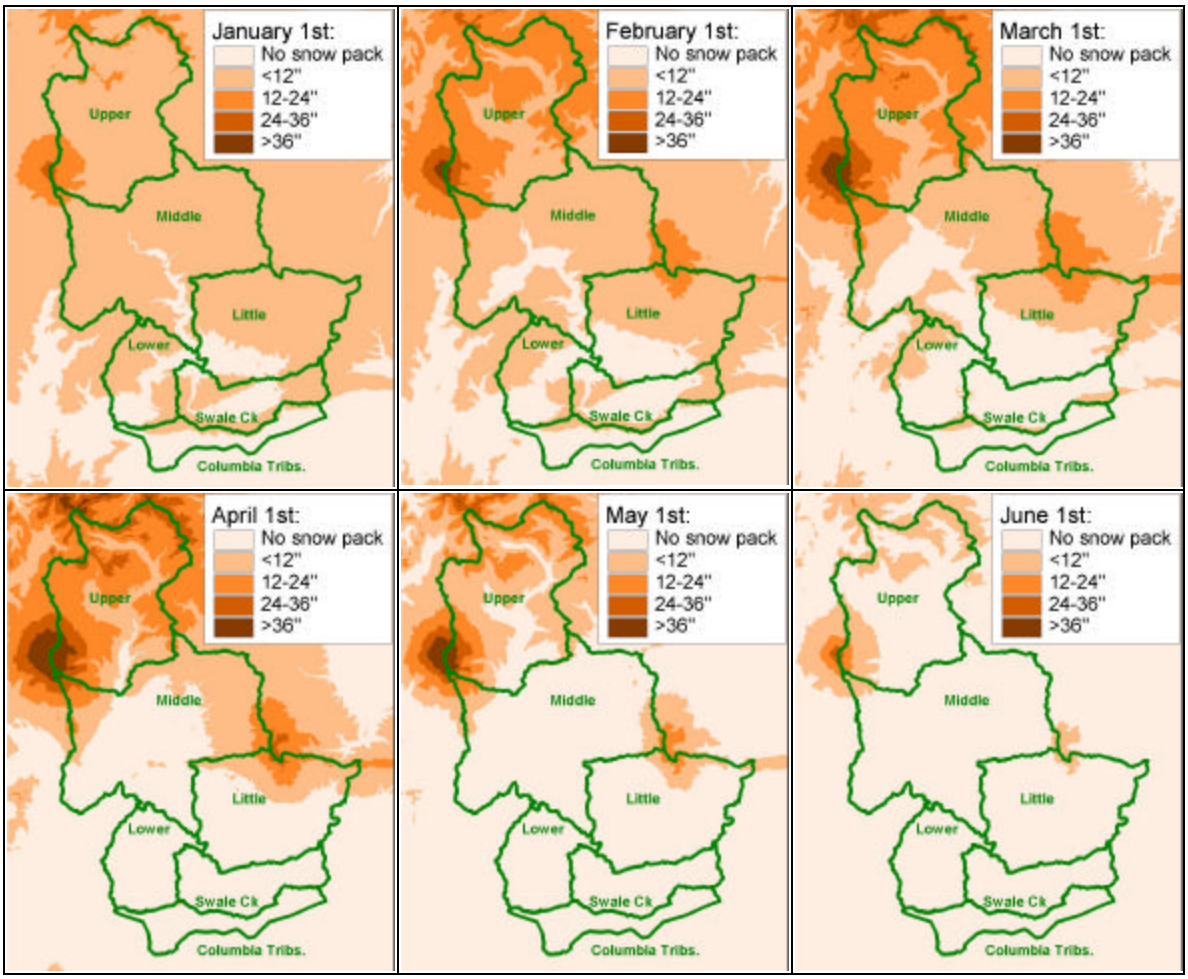


Figure 2-16. Estimated mean first-of-the-month snow pack within WRIA 30. Data sources: NRCS (2002); USGS (2001).

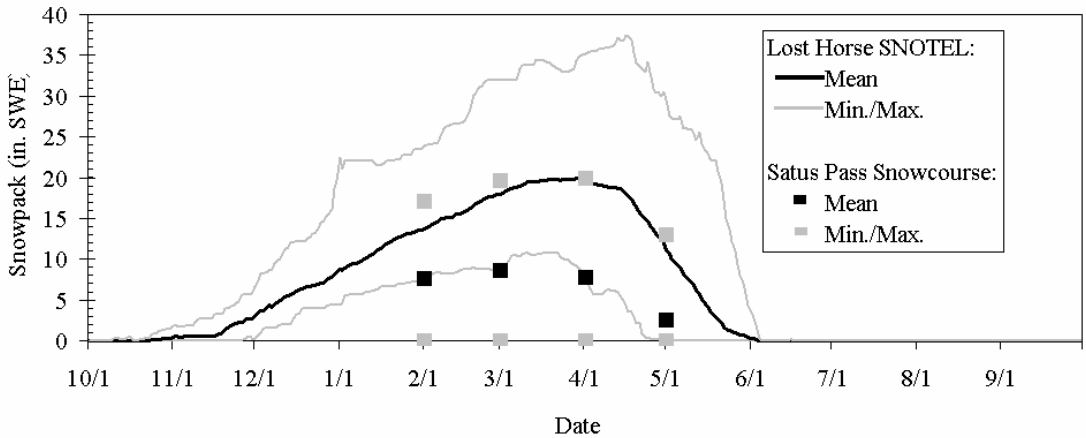


Figure 2-17. Snow pack (in inches of snow-water equivalent) at two climate stations in the vicinity of WRIA 30.

2.5 LAND COVER / LAND USE

Land use and land cover within a watershed may directly affect water availability through changes in watershed parameters affecting runoff (e.g., impermeable area associated with certain land uses, changes in vegetation patterns), as well as indirectly through the variable water demand associated with different water uses. The purpose of this section of the assessment is to characterize current land use within the subbasins found in WRIA 30.

Current land use and land cover within WRIA 30 was estimated using existing GIS coverages available from the USGS (1999). The USGS data are part of the National Land Cover Dataset that was compiled from Landsat satellite imagery captured in the early 1990s. The data has a spatial resolution of 30 meters and is supplemented by other data where available.

The primary land cover / land use category within the Upper, Middle, Little, and Lower Klickitat subbasins is "forested uplands" (Figures 2-18 and 2-19; Table 2-9). The Swale Creek and Columbia Tributaries subbasins have only a minor proportion (12% and 7% respectively) that is forested. Evergreen forests make up the majority of the forested classification in all subbasins. Only minor amounts in the "Deciduous" and "Mixed" forest types are present (Table 2-10).

The classification "Shrubland" make up a large proportion of the Swale Creek (47% of subbasin area) and Columbia Tributaries (50%) subbasins (Figures 2-18 and 2-19; Tables 2-9 and 2-10). A significant proportion of both the Little Klickitat (20%) and Lower Klickitat (11%) subbasins are also in the Shrubland classification, while only minor amounts are found in both the Upper Klickitat (3%) and Middle Klickitat (1%) subbasins (Table 2-10).

"Herbaceous Planted/Cultivated" areas are found in all subbasins with the exception of the Upper Klickitat (Figures 2-18 and 2-19; Tables 2-9 and 2-10). Swale Creek subbasin has the greatest portion of herbaceous planted/cultivated areas (33% of the total subbasin area) (Table 2-10). The Little Klickitat subbasin has 11% of its area is in the Herbaceous Planted/Cultivated classification. The remaining subbasins have less than 4% of total subbasin area in this classification.

"Herbaceous Uplands" are found in all subbasins and range from 27% of total subbasin area in the Columbia Tributaries to 1% of the subbasin in the Middle Klickitat subbasin. Areas identified as "Barren" are also found in all subbasins. The Barren classification consists primarily of lands with the "Transitional" designation. These areas are primarily recent (as of the time that the imagery was acquired) clearcut areas that have not reforested and rock outcrop areas. The classification "Water" includes both open water areas and perennial ice and snow. Significant areas of ice and snow exist in the Upper Klickitat subbasin (1% of subbasin area), and 11% of the Columbia Tributaries is in the

open water designation (the Columbia River). "Developed" lands comprise 2% or less of the subbasin area in the Little Klickitat and Columbia Tributaries subbasins and are found primarily in the vicinity of the cities of Goldendale and Dallesport.

Information on land use is provided in this level I assessment primarily for the purposes of characterizing the subbasins, and to assess the utility of existing information should any level II modeling of basin hydrology be recommended. Some error is present in the estimated land uses/covers due to the age of the source imagery and inherent errors associated with processing Landsat data. A new National Land Cover, using year 2000 imagery, is expected to be released by the USGS later this year.

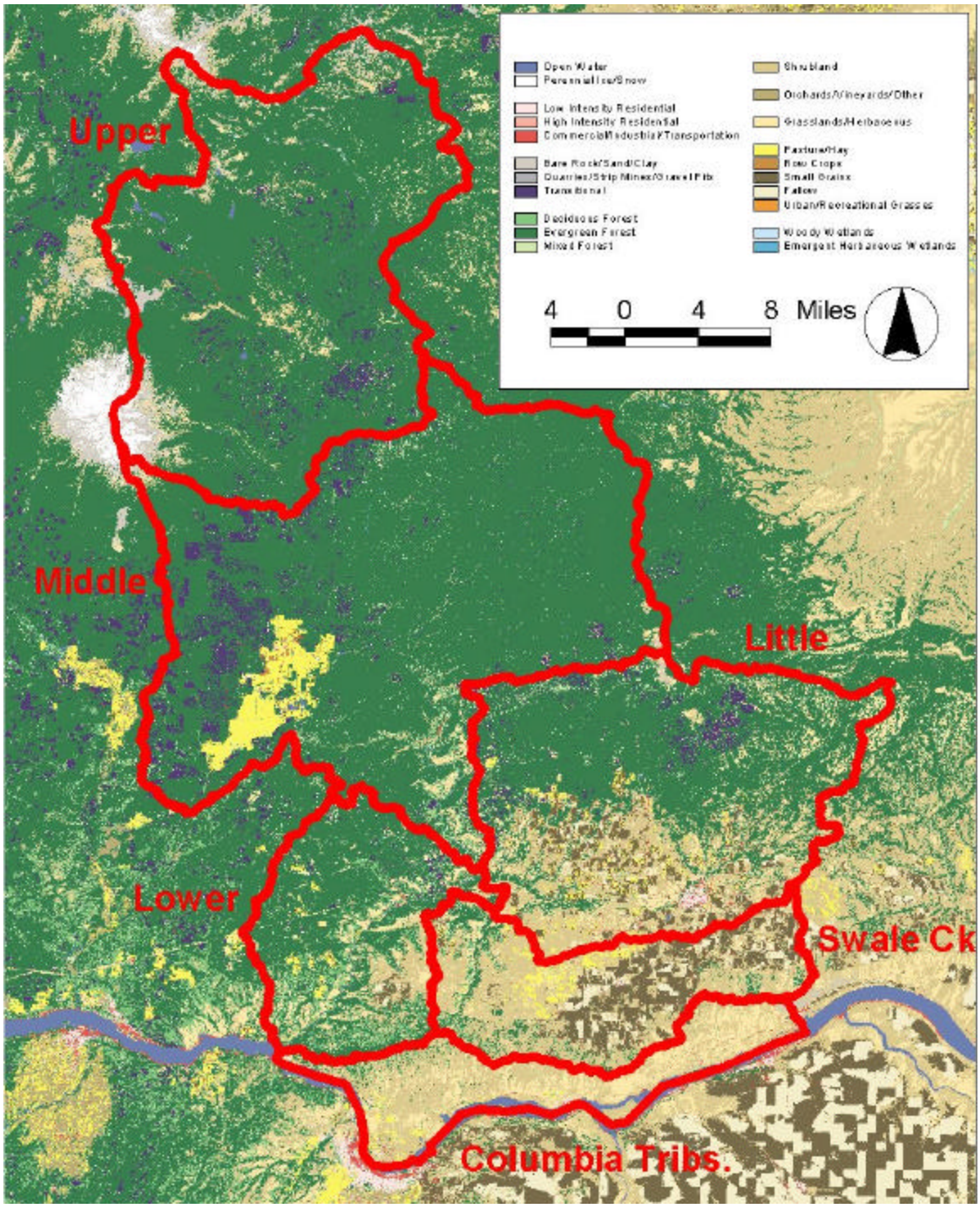


Figure 2-18. Current land cover and land use in WRIA 30. Descriptions of land use categories are given in Table 2-9. Data Source: USGS (1999).

Table 2-9. Descriptions of current land cover/land use / land cover types found in WRIA 30. (Descriptions taken from the NLCD Land Cover Classification System Land Cover Class Definitions (USGS, 1991))

Water: **Open Water** - areas of open water. **Perennial Ice/Snow** - All areas characterized by year-long cover of ice and/or snow.
Developed: **Low Intensity Residential** - Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas. **High Intensity Residential** - Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover. **Commercial/Industrial/Transportation** - Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Barren: **Bare Rock/Sand/Clay** - Perennially barren areas of bedrock, desert, pavement, scarps, talus, slides, volcanic material, glacial debris, and other accumulations of earthen material. **Quarries/Strip Mines/Gravel Pits** - Areas of extractive mining activities with significant surface expression. **Transitional** - Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Forested Upland: **Deciduous Forest** - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change. **Evergreen Forest** - Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage. **Mixed Forest** - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Shrubland: **Shrubland** - Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.
Non-natural Woody: **Orchards/Vineyards/Other** - Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.
Herbaceous Upland: **Grasslands/Herbaceous** - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.
Planted/Cultivated: **Pasture/Hay** - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops. **Row Crops** - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton. **Small Grains** - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice **Fallow** - Areas used for the production of crops that are temporarily barren or with sparse vegetative cover as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage. **Urban/Recreational Grasses** - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.
Wetlands: **Woody Wetlands** - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water. **Emergent Herbaceous Wetlands** - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

Table 2-10. Summary of current land cover/land use / land cover types found in WRIA 30. Values are percent subbasin area. Values given as "0%" indicate less than 0.5% of the subbasin area is in this type.

	Upper Klickitat	Middle Klickitat	Little Klickitat	Swale Creek	Lower Klickitat	Columbia Tributaries
Water						
Open Water	0%	0%	0%	0%	0%	11%
Perennial Ice/Snow	1%	0%				
Developed						
Low Intensity Residential		0%	1%	0%	0%	1%
High Intensity Residential			0%		0%	0%
Commercial/Industrial/Transportation	0%	0%	1%	0%	0%	1%
Barren						
Bare Rock/Sand/Clay	4%	0%	0%	0%	0%	0%
Quarries/Strip Mines/Gravel Pits		0%	0%		0%	
Transitional	5%	8%	4%	0%	2%	0%
Vegetated; Natural Forested Upland						
Deciduous Forest	0%	1%	1%	2%	10%	2%
Evergreen Forest	83%	82%	53%	8%	61%	4%
Mixed Forest	0%	2%	3%	1%	4%	0%
Shrubland						
Shrubland	3%	1%	20%	47%	11%	50%
Non-natural Woody						
Orchards/Vineyards/Other		0%			0%	0%
Herbaceous Upland						
Grasslands/Herbaceous	3%	1%	7%	8%	9%	27%
Herbaceous Planted/Cultivated						
Pasture/Hay		4%	2%	4%	1%	2%
Row Crops		0%	0%		0%	
Small Grains		0%	7%	23%	1%	0%
Fallow		0%	2%	6%	0%	0%
Urban/Recreational Grasses			0%			0%
Wetlands						
Woody Wetlands	0%	0%	0%	0%	0%	0%
Emergent Herbaceous Wetlands	0%	0%	0%	0%	0%	0%

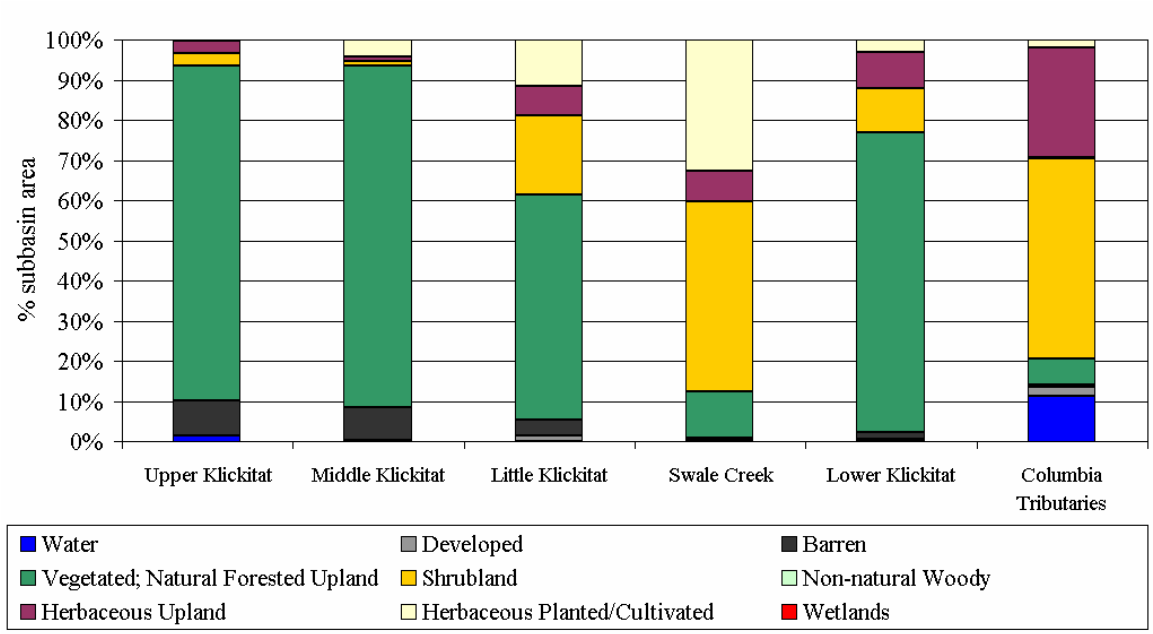


Figure 2-19. Summary by major land cover/land use categories for the subbasins within WRIA 30.

APPENDIX A

Chapter 3: Fish Habitat Quality

Table of Contents

3.1 Background ***3-1***

3.2 Methods ***3-2***

3.3 Natural Fish Passage Barriers ***3-4***

3.4 Subbasin Hatchery Operations ***3-6***
3.4.1 Goldendale Hatchery *3-6*
3.4.2 Klickitat Hatchery *3-7*
3.4.3 Fish Stocking From Other Hatcheries *3-7*

3.5 Stock Status and Population Trends ***3-7***
3.5.1 Chinook Salmon (Onchorynchus tshawytscha) *3-10*
3.5.2 Coho (Onchorynchus kisutch) *3-13*
3.5.3 Steelhead (Onchorynchus mykiss) *3-15*
3.5.4 Bull Trout (Salvelinus confluentus) *3-17*
3.5.5 Cutthroat Trout (Oncorhynchus clarki) *3-17*
3.5.6 Resident Rainbow Trout (Oncorhynchus mykiss) *3-18*
3.5.7 Brook Trout (Salvelinus fontinalis) *3-18*
3.5.8 Pacific Lamprey (Lampetra tridentatus) *3-18*
3.5.9 Other Fish Species *3-18*

3.6 Summary of Habitat Conditions ***3-19***
3.6.1 Impassable Culverts *3-19*
3.6.2 Ecosystem Diagnosis and Treatment (EDT) Analysis *3-20*
3.6.3 Subbasin Summaries *3-20*

List of Tables

Table 3-1. Summary of applicable Fisheries Reports. *3-3*
Table 3-2: Klickitat River subbasin Salmon, Steelhead, Trout and Bull Trout - Stock Profiles. *3-8*
Table 3-3: Native species known or suspected to be present in the Klickitat watershed. *3-19*

List of Figures

Figure 3-1. Timing of key life history phases of anadromous fish species in the Klickitat River Watershed. _____3-9
Figure 3-2. Distribution of spring chinook in the Klickitat River Subbasin._____3-11
Figure 3-3: Distribution of fall chinook in the Klickitat River Subbasin. _____3-12
Figure 3-4: Distribution of coho in the Klickitat River Subbasin. _____3-14
Figure 3-5: Distribution of steelhead in the Klickitat River Subbasin. _____3-16

Chapter 3: Fish Habitat Quality

This section summarizes available information on the fish populations, stock status, and habitat conditions in the Klickitat River subbasin (WRIA 30). Salmon and trout have been the focus of most studies of fish populations and habitat conditions in the Klickitat River subbasin. This document summarizes information in reports developed by a variety of sources including Washington Department of Fish and Wildlife, Klickitat County, Bonneville Power Administration (BPA) and the Yakima Nation (Tribal Government).

The goals of this document are to provide:

1) An overview of fish populations in WRIA 30,
2) A comprehensive review of WRIA 30 habitat studies which have been published,
3) A discussion of natural events, and pollution from natural sources that occur independent of human activities,
4) An examination of the characteristic fish use of each of the streams where data is available, and,
5) An examination of the potential impacts to characteristic fish use, caused by changes in watershed hydrology.

The Klickitat River subbasin contains stocks of spring chinook, fall up river bright (URB) chinook, fall (tule) chinook, coho, winter and summer steelhead, resident rainbow, bull trout, cutthroat trout and brook trout, as well as other native and introduced fish species.

3.1 BACKGROUND

The geology of the watershed is dominated by extensive erosion resistant basalt flows which have formed deep (700 to 1500 feet) steep-walled canyons. These canyons constrain floodplain development along most of the mainstem Klickitat (WSCC 1999). Local variations in erosion resistance of the underlying geology have resulted in the formation of cascades and waterfalls along the mainstem and in many tributaries. These falls are among the main factors limiting the anadromous fish distribution in the watershed (WSCC 1999).

Channel gradients in the Mainstem Klickitat River range from 0.4 to 0.8 percent downstream of the Klickitat hatchery (RM 42.4), between 1 and 2 percent above the hatchery to just beyond Diamond Fork (RM 78), and to 0.5 percent or less to McCormick Meadows (RM 85). Above McCormick Meadow channel gradient increases to 8 percent or greater to the headwaters. Lyle Falls (RM 2.2) and Castile Falls (RM 64 to 64.5) are two notable falls that restrict fish distribution.

Tributaries to the Mainstem include Swale Creek (RM 17.2), Little Klickitat River (RM 19.8), Outlet Creek (RM 39.7), Big Muddy Creek (RM 53.8), West Fork Klickitat River (RM 63.1) and Diamond Fork (RM 76.8). Downstream of Castile Falls, the tributaries tend to have limited low gradient reaches (100 feet to several miles), followed by a falls or a moderate to high gradient (greater than 4%) reach (WSCC 1999).

This geomorphology creates a pattern where most of the Klickitat mainstem is a canyon with steep walls and a narrow valley floor. In these canyon reaches the riparian areas are more or less intact since the steep hill slopes limit access. The stream reaches in the plateau areas are lower gradient and are able to develop meander patterns. These areas tend to have more agricultural and urban land use, which can affect habitat quality (WSCC 1999).

Big Muddy Creek, a tributary to the West Fork Klickitat River, originates at the Rusk and Klickitat glaciers on the east flank of Mount Adams and Little Muddy Creek originates at the Wilson glacier (http://vulcan.wr.usgs.gov /Volcanoes/Adams/Maps/map_adams.html). There are occasional glacial outburst floods that feed torrents of water and volcanic debris into Big Muddy Creek (Sharp et al. 2000). Little Muddy Creek also carries a large volume of fine sediments due to the weathering of volcanic rocks and glacial action (Sharp et al. 2000). During the warmest months, a sediment plume from these tributaries colors the Klickitat River from the West Fork to the Columbia River 63 miles downstream. The source of these sediments is the input of glacial meltwater during the warmer months.

3.2 METHODS

This report is based on existing information contained in published reports (Table 3-1). The fish distribution maps were obtained from Sharp et al. 2000. Natural fish passage barriers were identified through the review of literature listed below. Habitat condition data was also obtained from review of literature.

One of the primary sources of fish distribution and habitat condition information was the Washington State Conservation Commission Salmonid Habitat Limiting Factors, final Report; WRIA 30; Klickitat Watershed. This report is a compilation of the information supplemented with local expertise or professional judgment of biologists who participated in producing the report. The report appears to be comprehensive regarding watershed conditions in the WRIA. However, the report provides little data and few citations to published information. Hence, it is difficult to determine the quality of the information reported in the document.

These comments also extend to the Draft Klickitat Subbasin Summary (Sharp et al. 2000). The only cited data that specifically addresses habitat conditions, fish distribution, and land use effects are the limiting factors analysis discussed above, the Boise Cascade Watershed Analysis (Raines et al 1999; used for only a short section), a 1949 survey of fish resources in the Columbia River and its tributaries (Bryant 1949), a BPA stock assessment report (Howell et al 1985), and a 1976 reconnaissance survey of water resources in the upper watershed (Cline 1976). Hence, the majority of the information

presented in the report is either unsubstantiated or based on unpublished data that was not provided.

This report relied on these publications because they represent the only sources of information regarding fish and fish habitat. We suspect that other data exists to support at least some of the information presented in these documents; however it is not published and was not made available for this effort.

Given the lack of published data regarding fish resources and habitat conditions within the WRIA, the reader should recognize that at least some portion of the information presented in the available documents is likely based on professional judgment. Studies designed to document current fish distribution, habitat quality, and land use interactions with aquatic habitat are highly recommended to fill this information gap.

Table 3-1. Summary of applicable Fisheries Reports.

Author, Year	Title	Content Review
Agencies and Indian Tribes of the Columbia Basin Fish & Wildlife Authority. 1990.	Integrated System Plan for Salmon and Steelhead Production in the Columbia River Basin	Very general information – no specific details.
Appleby, A. and T. Anderson. 1994.	Effects of Acclimation on the Survival of Spring Chinook Salmon. BPA project No. 89-30, Contract No. DE-B179-89BP00467.	Very specific research report. Not applicable to describing subbasin conditions.
BPA. 1990.	Environmental Assessment: Yakima-Klickitat Project. Office of Power Sales, Bonneville Power Administration.	Refers to Lind 1988 for chinook information.
Brock, S. and A. Stohr. 2002.	Little Klickitat River Watershed Temperature total Maximum Daily Load. WA State Dept. Ecology. Publ. 02-03-031.	Contains information on stream temperature and riparian shade in the Little Klickitat River.
Caldwell, B. and S. Hirschey. 1990.	Little Klickitat River Basin Fish Habitat analysis using the Instream Flow Incremental Methodology	Contains limited information on habitat quality. Also contains an assessment of the effects of flow on the quantity of fish habitat.
Clayton, D.E. 1999.	Lower Little Klickitat River Draft Watershed Management Plan, Central Klickitat Conservation District	Little Klickitat from Goldendale to confluence with Klickitat River
Crawford, Bruce 1979.	Origin and History of the Trout Brood Stocks of the Washington Department of Game. Found at: http://www.watrailblazers.org/science/crawford_rainbow_history.html	Information on history of Goldendale Hatchery
Fast, D.E., J. Hubble, T. Scribner, M. V. Johnson, W. B. Sharp. 1989.	Yakima/ Klickitat Natural Production and Enhancement Program. BPA Project no. 1988-120, Grant. DE-A179-1988BP93203. 125 electronic pages.	Overview of 1988 spawner surveys and electroshocking effort.
Inter-Fluve. 2002.	Swale Creek Channel Assessment Project. Submitted to the Yakama Nation Fisheries Program. Toppenish, WA.	Contains habitat data regarding the canyon reach of Swale Creek.

Author, Year	Title	Content Review
Raines, M. et al. 1999.	Upper Little Klickitat Watershed Analysis. Boise Cascade Corporation	Detailed analysis covering the Upper Little Klickitat River
Sampson, M. and D. Fast. 2000.	Yakama Nation 'Monitoring and Evaluation" Project number 95-063-25 The Confederated Tribes and Bands of the Yakama Nations "Yakima/Klickitat Fisheries Project" Final Report 2000, BPA Report DOE/BP-00650-1, 265 electronic pages.	General review of projects, culvert passage inventory info. And EDT information.
Sampson, M. R. 2002.	Yakama Nation, 2002, Management, Data & Habitat Project No. 1988-120-25 Final Report 4/1/01-3/31/02 The Confederated Tribes and Bands of the Yakama Nations BPA Report DOE/BP-0004822-2-1, 65 electronic pages.	No specific data – project reviews.
Sharp et. al. 2000.	DRAFT Klickitat Subbasin Summary, NWPPC 83 pgs.	Overview – primary source of information.
Thiesfield, S.L., Ronald H. Peak, Brian S. McNamara, Isadore Honanie. 2001.	Fiscal Year 2001 Annual Report. Bull Trout Population Assessment in the White Salmon and Klickitat Rivers, Columbia River Gorge, Washington. Report to Bonneville Power Administration, Contract no. 00004474, Project No. 199902400, 77 electronic pages (BPA Report/BP-00004474-1)	Bull trout only found in West Fork, Trappers, Clearwater & Little Muddy. Natural falls influence distribution.
WDF, WDW (SASSI). 1993.	1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). WDF, WDW & Western Washington Treaty Indian Tribes.	Stock Status Information
WDFW. 1998.	Washington State Salmonid Stock Inventory, Bull Trout/ Dolly Varden	Stock Status Information
WDFW. 2000.	2000 Washington State Salmonid Stock Inventory, Coastal Cutthroat Trout	Stock Status Information
Washington State Conservation Commission (WSCC). 1991.	Central and Eastern Klickitat Conservation Districts Watershed Inventory Project, Final Report. Prepared for the Washington State Conservation Commission, Grant Contract # 89-34-02.	No specific fish information – mostly focused on WQ
Washington State Conservation Commission (WSCC). 1999.	Salmonid Habitat Limiting Factors, final Report. WRIA 30; Klickitat Watershed	Anadromous fish only, primary source for this report.

3.3 NATURAL FISH PASSAGE BARRIERS

One of the major limitations on anadromous fish production is the presence of a number of natural migration barriers in the watershed. The Klickitat River flows through a deep, steep walled canyon with impassable or marginally passable falls and cascades where the river flows over more resistant bedrock. In addition, access to many of the tributaries is restricted because there are impassably high gradients close to the tributary mouths (WSCC 1999). The following provides brief descriptions of the most significant natural fish passage barriers and impediments.

Lyle Falls (RM 2.2)

This is a series of five falls from 4 to 12 feet high which historically was considered impassable during low water conditions in the summer and early falls, preventing fall chinook and coho from utilizing the watershed (WSCC 1999). In 1952, Washington Department of Fisheries removed rock and constructed two fishways at the falls, which improved fish passage. Currently Lyle Falls is not a barrier to any salmon or steelhead stocks, but passage at the falls is considered difficult (WSCC 1999).

Castile Falls (RM 64.0)

This is a series of 11 falls with an elevation change of 80 feet over one-half mile. These falls are considered the historic upper limit of anadromous fish usage on the Mainstem (WSCC 1999). There have been efforts by Washington Department of Fisheries to improve fish passage with marginal success. Currently, BPA funding is available to complete the design and construction of the Castile Falls Fishway at RM 64 (estimated completion date 2003). The focus of this project is to reconstruct two tunnel fishways, a single above-ground fishway, install a new Alaskan steep pass fishway, and construct a walkway to adhere to new safety requirements.

Little Klickitat River Falls (RM 6.1)

This is a falls which the Washington Department of Fish and Wildlife considers the Little Klickitat River falls at river mile 6.1 to be passable by steelhead, at least under some conditions. The height of the falls has been variably reported as 15 to 16 feet. In March of 2001, Yakama Nation biologists measured the height of the falls height at 14.7 feet relative to the stream surface.

The frequency with which the falls is passable is unknown. Surveys of steelhead redds conducted by the Yakama Nation in 1996 and 1997 indicate that some passage occurs at least in some years. In the reaches upstream of Goldendale, the Yakama Nation reported seeing 20 redds in 1996 and 9 redds in 1997 (Raines et al 1999). Additional redds may have been observed in other sections of the Little Klickitat River but data regarding these observations was not available. When questioned, local long time residents indicated they have never seen steelhead above the falls, suggesting that the presence of steelhead is not common.

The occurrence of major flood events may occasionally improve passage at the falls. Major flow events occurred during the steelhead migration period in for both the 1996 and 1997 year classes. The record of mainstem flows indicates that the February 1996 event (potentially passage and the influencing the number of redds observed in 1996) was greater than a 90 year event and the November 1996 event (potentially influencing passage and the resulting number of redds observed in 1997) was roughly a 10-year event. No flow data was available for the Little Klickitat River for these years and flow patterns in the Little Klickitat may not reflect those observed in the mainstem Klickitat River due to substantial differences in water sources (see Section 5.0). Hence, the actual

frequency that steelhead pass these falls and/or the magnitude of flow required to permit passage are unknown.

West Fork Klickitat River Falls (RM 0.3 & 4.6)

Thiesfeld et al. (2001) found a previously undescribed 15 to 20 foot falls 0.3 miles upstream of the confluence with the main Klickitat. He felt the falls was likely a passage barrier. There is also a 12-foot falls at RM 4.6, which is considered a barrier to all fish species (WSCC 1999).

3.4 SUBBASIN HATCHERY OPERATIONS

Hatchery operations have had a significant influence on the anadromous fish species composition and significant numbers of rainbow trout are stocked in the Klickitat system. There are two hatcheries in the subbasin. The Goldendale Hatchery is dedicated solely to the production of resident rainbow trout. The Klickitat hatchery is dedicated to the production of anadromous fish stocks. Escapement for chinook and coho has been managed to provide for hatchery requirements without considering natural production (WSCC 1999). Thus, hatchery production has resulted in some hybridization of the native spring chinook stock (WSCC 1999). Following are brief descriptions of the history and operations of the hatcheries.

3.4.1 Goldendale Hatchery

The Goldendale Hatchery was built in 1938 at a large spring with a water temperature of 50° F (Crawford 1979). It produced its first generation of fish in 1939, which consisted of Owhi Lake eastern brook trout and Meader rainbow trout (Crawford 1979).

The rainbow trout broodstock spawning program at the Goldendale Hatchery has a goal of producing 6.4 million eggs. In addition to supplying the hatchery's needs, these eggs are shipped throughout the state and represent nearly half of the rainbow trout production of the entire state. These are distributed to hatcheries throughout the mid Columbia basin and western Washington to provide both legal size and fingerling rainbow trout for lakes, reservoirs, and streams. The majority of the early eggs are used for fingerling plants while the later eggs are used for stocking legal size fish. Typical annual production at Goldendale Hatchery is 2,263 rainbow broodstock plants (at 7.4 pounds per fish) and 157,000 rainbow legal plants (at 3 fish per pound). Additionally 57,750 fry (1,675 pounds) are produced annually (Ault 2002), including:

- 23,750 Rainbow trout,
- 3,000 Tiger Trout (cross between the female brown trout and the male brook trout - *Salmo trutta x salvelinus fontinalis*)),
- 5,000 Cutthroat Trout,
- 19,000 Eastern Brook Trout, and
- 7,000 Brown Trout.

3.4.2 Klickitat Hatchery

The Klickitat Hatchery is located on Klickitat River at RM 42.4 on the mainstem Klickitat near the town of Glenwood, Washington. The Klickitat Hatchery was authorized and constructed for hydropower mitigation under the Mitchell Act of 1936. It began operation as part of the Columbia River Fisheries Development Program in 1952 (Sharp et al. 2000). The hatchery currently produces adult fall chinook, Type-N coho, and spring chinook to contribute to NE Pacific and Columbia River Basin commercial and sport fisheries.

Hatchery spring chinook broodstock are currently collected through a volunteer trap fed by hatchery spring water (Sharp et al. 2000). The spring chinook program calls for release of 600,000 smolts (7 fish/lb) at the hatchery. An additional 150,000 to 200,000 fry are generally available for outplanting in upper basin above Castile Falls (Sharp et al. 2000). Spring chinook smolts are released mid-March to correspond with the period of high spill over Bonneville Dam and Spring Creek National Fish hatchery releases (Sharp et al. 2000).

3.4.3 Fish Stocking From Other Hatcheries

In order to provide a terminal fishery for Tribal and other fishers, 4,000,000 eyed eggs of fall URB chinook stock from Priest & Lyons Ferry hatcheries are delivered for final rearing (Sharp et al. 2000). These are released at the hatchery. There are also 3.85 million coho smolts released into the Klickitat River (1.35 released at the hatchery and 2.5 million directly into river at various locations downstream of the hatchery). Additionally, 120,000 Skamania steelhead smolts are annually released directly into the lower river downstream of the hatchery (Sharp et al. 2000)

3.5 STOCK STATUS AND POPULATION TRENDS

Currently, there are three stocks of chinook (spring, tule, upriver bright), one coho, and two steelhead stocks (summer, winter) in the Klickitat watershed (Table 3-1). Bull trout have also been found in the basin.

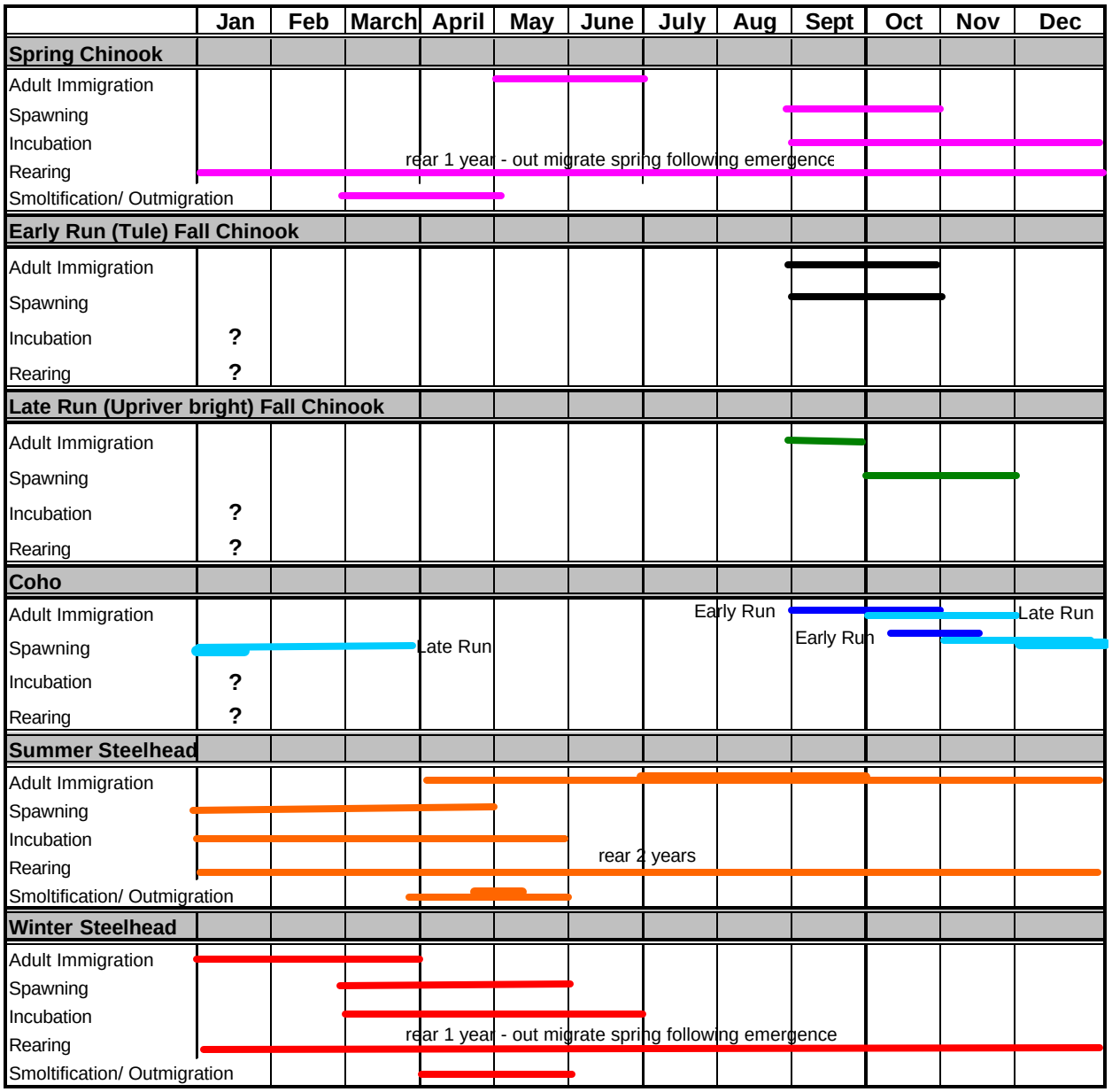
Summer steelhead are known to be native to the Klickitat watershed. Winter steelhead were not observed in the basin before the early 1980s, but are presumed to have been present historically. Tule fall chinook and coho were introduced starting in the 1940s and early 1950s (WSCC 1999). Upriver bright fall chinook are also considered to be an introduced stock (Myers et al 2003). They were first found in the basin in 1989 (WSCC 1999).

The timing of the different life history phases for the anadromous species varies considerably by species and stock (Figure 3-1). Adult and juvenile salmonids of one species/stock or another are present in the watershed year round.

Table 3-2: Klickitat River subbasin Salmon, Steelhead, Trout and Bull Trout - Stock Profiles (SASSI 1992).

Stock	Major Subbasin(s)	SASSI Stock Status	Stock Origin	ESA Status
Spring Chinook	Lower, Middle Portions of Upper, Little & Swale Creek[2]	Depressed	Native - Mixed	
Fall (Tule) Chinook	Lower, Middle	Depressed	Mixed	
Fall Upriver Bright (URB) Chinook	Lower, Middle	Depressed	Non-native	
Summer Chinook	Lower, Middle	?	?	
Coho	Lower, Middle Portions of Upper& Little[2]	Depressed[1]	Mixed	
Winter Steelhead	Lower, Middle, Upper, Little & Swale Creek[2]	Unknown	Native	Threatened
Summer Steelhead	Lower, Middle, Upper, Little & Swale Creek[2]	Unknown	Native	Threatened
Bull Trout	Upper	Unknown	Native	Threatened
Coastal Cutthroat	Lower	Unknown	Native	

[1] Note coho were introduced to the watershed starting in the 1940s and early 1950s and are not a native. Stock depressed indicates that current numbers are lower than previous years.
[2]Distribution is limited to the lower 14 miles of Swale Creek. Distribution of chinook and coho in the Little Klickitat is limited to the lower 6.1 miles of the stream. Passage of steelhead upstream of river mile 6.1 in the Little Klickitat is uncertain, see text.



? – indicates no data is available.

Figure 3-1. Timing of key life history phases of anadromous fish species in the Klickitat River Watershed (from WSCC 1999). Wider line indicates peak of migration.

3.5.1 Chinook Salmon (*Onchorynchus tshawytscha*)

Following are descriptions of the history, life history and status of each chinook salmon stock.

3.5.1.1 Spring Chinook

Bryant (1949) referred to large runs of spring chinook prior to 1920 and a significant Native American fishery at Lyle Falls (RM 2.2). There are reports of spring chinook spawning in the West Fork of the Klickitat River (RM 63.1) as well as the mainstem (Bryant 1949).

Hatchery production of spring chinook began in 1950 with the release of 11,900 yearlings of unknown origin (WSCC 1999). Currently, the stock is considered to be of mixed origin and is sustained by both hatchery and natural production. Genetic analysis conducted between 1989 and 1994 indicated that hatchery and naturally spawning Klickitat spring chinook were genetically indistinguishable (Sharp 2000).

Spring chinook are primarily found in the mainstem of the Klickitat River, downstream of Castile Falls (Figure 3-2). Adult spring chinook pass through Bonneville Dam from mid-April to mid-May, migration past Lyle Falls peaks in May and June (WSCC 1999). Adults hold in the mainstem until mid to late August. Spawning peaks in late August and early September and will continue until late October (WSCC 1999).

The main spawning area is between Castile Falls (RM 64) downriver to Big Muddy confluence (RM 53.8) and near Parott's Bridge (RM 49). Spring chinook spawning has been observed in the mainstem as far upstream as RM 84, although only limited spawning occurs above Castile Falls (RM 64) due to difficult access (WSCC 1999). Tributary spawning has not been observed (Sharp 2000).

Based on juvenile development patterns observed in the hatchery, fry are believed to emerge in late November through early December and rear in the streams for a year. Smoltification and out migration are believed to occur from late March through April (WSCC 1999). Juvenile spring chinook have been observed rearing in all of the spawning areas and in the mouths of larger tributaries (WSCC 1999). Tributaries where rearing chinook have been observed include the Little Klickitat River below the falls, Summit Creek, White Creek and Trout Creek (WSCC 1999). In addition, recent Yakama Nation observations have noted rearing chinook in the lower reach of Swale Creek (Sharp, personal communication).

From 1977 to 1997 natural escapement of spring chinook (based on spawning ground surveys) ranged from 63 (1908, 1982) to 1180 (1988) adults, with a mean of 244 adults (WSCC 1999). The total run size estimated in 2003 was roughly 4000 fish of which 172 were considered "wild" fish. Harvest in 2003 was estimated at 926 fish caught in the tribal fishery, "fair" numbers harvested in the sport fishery, and an unknown number

caught in the ocean fisheries
(http://wdfw.wa.gov/fish/creel/spring_chinook/jun062703.htm).

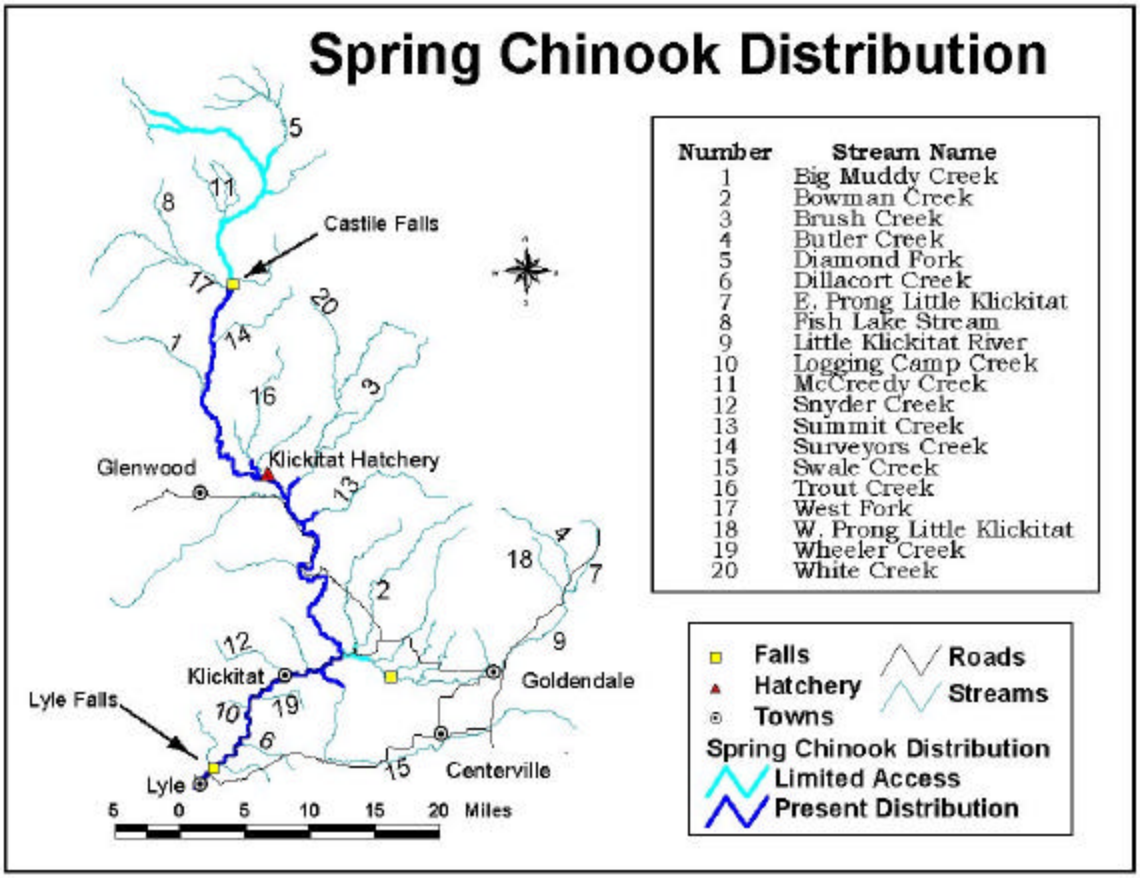


Figure 3-2. Distribution of spring chinook in the Klickitat River Subbasin (from: Sharp et al. 2000).

3.5.1.2 Fall (Tule) Chinook

Historically, Lyle Falls (RM 2.2) was considered impassable during low water conditions in the spring and fall. As a result, fall chinook were largely blocked from habitats above Lyle Falls (National Marine Fisheries Service 1998). In 1952 Washington Department of Fisheries removed rock and constructed two fishways at the falls providing year round access to the watershed (WSCC 1999). Fall chinook were first planted in the watershed in 1946 and the Klickitat Hatchery began releasing fish in 1952 (WSCC 1999). Hatchery releases stopped in 1986 and production has been totally natural although the fish are believed to be primarily hatchery strays from the Klickitat Hatchery (WSCC 1999).

Tule fall chinook migrate into the Klickitat watershed during September and October. Figure 3-2 illustrates the know distribution of fall chinook. They spawn almost exclusively along the Mainstem Klickitat River. The primary spawning area is between

Maddock Springs/ Twin Bridges (RM 16.8) to the Hatchery (RM 42.2), additional spawning has been observed below Maddock Springs/ Twin Bridges to the mouth (WSCC 1999).

Spawning occurs shortly after arrival on the spawning grounds (WSCC 1999). There is no watershed specific information on juvenile life histories; it is assumed juvenile fall chinook rear in all the spawning areas (WSCC 1999).

According to WDF & WDW, (1993) tule fall chinook are identified as a healthy stock. From 1964 to 1997 natural escapement (based on spawning ground surveys) has ranged from 53 (1985) to 14,934 (1964) adults, with a mean of 2617 adults (WSCC 1999).

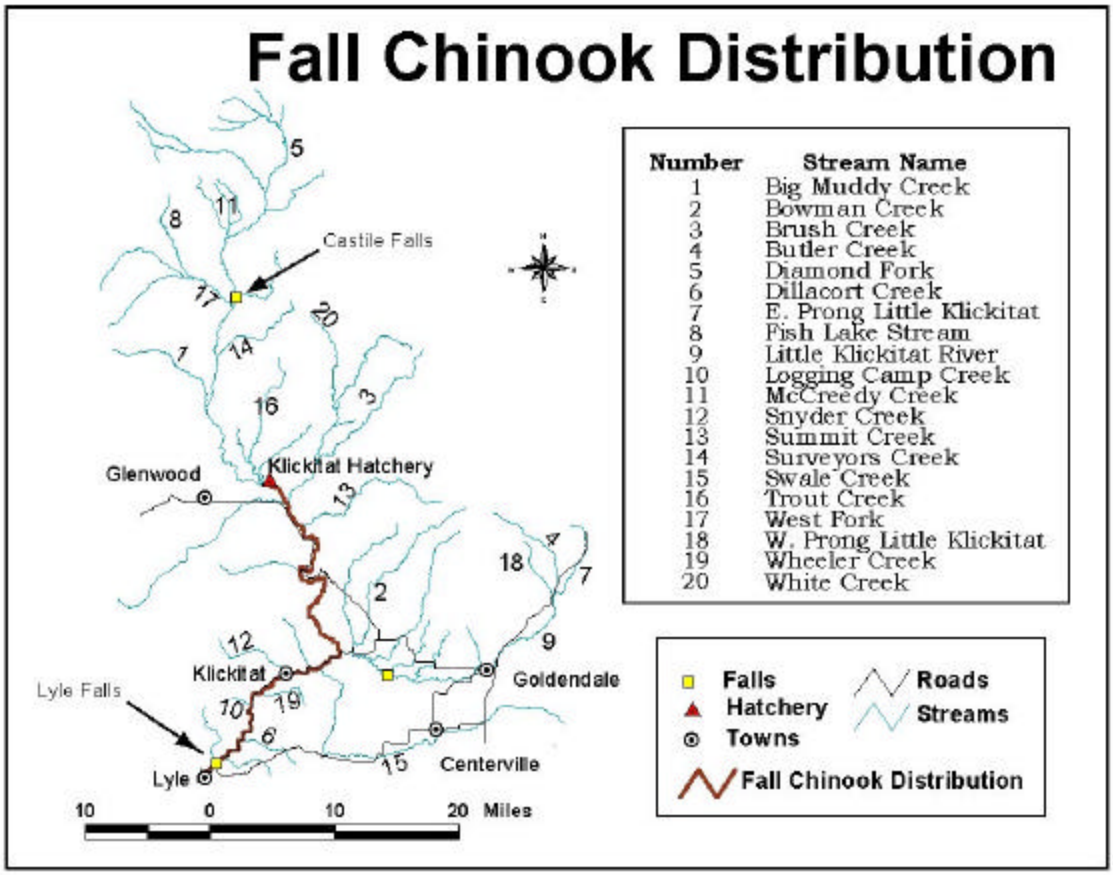


Figure 3-3: Distribution of fall chinook in the Klickitat River Subbasin (from: Sharp et al. 2000).

3.5.1.3 Fall Upriver Bright (URB) Chinook

This chinook stock was released in the watershed starting in 1987 using eggs from Priest Rapids and Bonneville upriver bright stocks (WSCC 1999). Very few adults from these

releases have returned to the hatchery, preferring to spawn in the lower river (WSCC 1999). Naturally spawning fish were discovered in 1989.

Adults migrate into the Klickitat River from mid-August to mid-October and hold in the Mainstem until they spawn in October and November (WSCC 1999). The primary spawning area is between Maddock Springs/ Twin Bridges (RM 16.8) to the Hatchery (RM 42.2), additional spawning has been observed below Maddock Springs/ Twin Bridges to the mouth (WSCC 1999).

There is no watershed specific information on juvenile life histories; it is assumed juvenile fall chinook rear in all the spawning areas (WSCC 1999).

According to WDF & WDW, 1993 upriver bright fall chinook are identified as a healthy stock. From 1989 to 1997 natural production (based on spawning ground surveys) has ranged from 253 (1989) to 5,699 (1997) adults, with a mean of 2,636 adults (WSCC 1999).

3.5.1.4 Summer Chinook

According to Sharp et al. (2000), the electrophoretic analysis completed by Busack in the 1990s indicated the existence of a distinct summer chinook race in the Klickitat Basin. There are no natural production estimates and the spawning distribution is assumed to be similar to that of the tule fall chinook.

3.5.2 Coho (*Onchorynchus kisutch)*

Historically Lyle Falls (RM 2.2) was considered impassable to coho during low water conditions in the spring and fall. In 1952, Washington Department of Fisheries removed rock and constructed two fishways at the falls providing year round access to the watershed (WSCC 1999). Hatchery releases began prior to 1952 from the Klickitat Hatchery. Early run (type S) from local hatchery returns and Toutle River stock and late run (type N) from local hatchery return and Cowlitz River stock have both been released (WSCC 1999). Evidence of natural juvenile production has been sporadic; smolt production is dominated by the hatchery component (WSCC 1999).

Distribution of coho in the Klickitat is illustrated in Figure 3-4. Early run coho enter the watershed late August and move upstream with the fall rains in late September through October. These early run fish spawn in late October (WSCC 1999) (Figure 3-1). Late run coho migrate into the watershed from late October through November. Spawning occurs between November and March with a peak in December and early January (WCSS 1999).

There is limited information of the spawning distribution. Spawning has been observed in the Mainstem between Maddock Springs/ Twin Bridges (RM 16.8) to the Hatchery (RM 42.2), additional spawning has been observed at the lower ends of a number of tributaries including Dofner Creek (RM .3), Swale Creek (RM 17.2), the Little Klickitat

River and Bowman Creek (RM 19.8)(WSCC 1999). Spawning may also occur in Summit Creek (RM 37.3) and White Creek (RM 39.6) (WSCC 1999). Adult and juvenile coho have also been observed at low densities in Outlet Creek (Thiesfeld et al. 2001). There is no watershed specific information on juvenile life histories. It is assumed juvenile coho rear in all the spawning areas (WSCC 1999).

According to WDF & WDW, 1993, coho are identified as a depressed stock due to chronically low adult returns to the hatchery. There is no data on natural production. Natural spawning is presumed to be very low and subsequent juvenile production is far below potential (WSCC 1999). In 1999-2000, 761 coho were reported caught in sport catches in the Klickitat River (http://wdfw.wa.gov/fish/harvest/99sport.pdf). Note that coho were introduced to the watershed starting in the 1940s and early 1950s and are not a native stock.

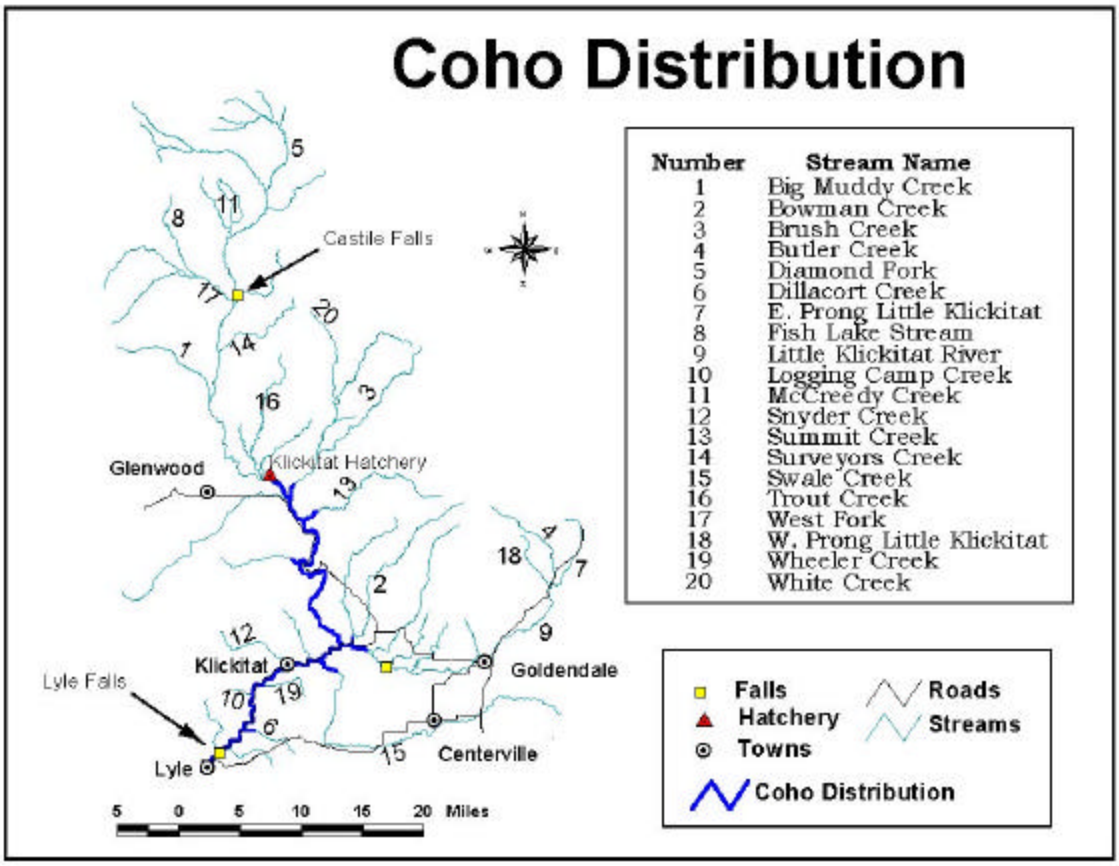


Figure 3-4: Distribution of coho in the Klickitat River Subbasin (from: Sharp et al. 2000).

3.5.3 Steelhead (*Onchorynchus mykiss*)

This Klickitat River steelhead stock is listed as threatened under the Endangered Species Act as a part of the Mid-Columbia Evolutionarily Significant Unit (ESU) (NMFS 1996). The interim targeted run size for naturally spawning fish identified by NMFS is 3,600 naturally spawning fish (NMFS 2003).

3.5.3.1 Summer Steelhead

Summer steelhead were historically documented in the watershed (Bryant 1949). This stock is sustained by natural production. There is no steelhead production at the hatchery, but summer steelhead from the Skamania hatchery have been planted since 1980 (WSCC 1999). In 2001, 101,800 smolts were stocked in the river (WDFW 2004). There is some concern about interbreeding between the hatchery and wild stocks (WDF & WDW 1993).

Distribution of steelhead in the Klickitat is illustrated in Figure 3-5. Steelhead migrate into the watershed between April and December with a peak between July and October. They hold in the Mainstem or tributaries until spawning which occurs between January and early April (WSCC 1999). Spawning occurs throughout the Mainstem Klickitat and in the lower reaches of most of the major tributaries, including Swale Creek (RM 17.2), Little Klickitat River and Bowman Creek (RM 19.8), Summit Creek (RM 37.3), White Creek (RM 39.6), Trout Creek (RM 43.4), Piscoe Creek (RM 75.1) and Diamond Fork (RM 75.1) (WSCC 1999). Limited spawning occurs above Castille Falls (RM 64) due to difficult access (WSCC 1999).

Juvenile life history information is inferred from nearby stocks and smolt sampling on the Mainstem conducted by WDW in 1990 (WSCC 1999). Fry are believed to emerge starting in April through mid-June and will rear for two years (Myers et al 2003). Smoltification and outmigration occur in April and May peaking in May (WSCC 1999). Very limited information exists on juvenile rearing, steelhead juveniles are assumed to be rearing in all areas where spawning occurs (WSCC 1999).

According to WDF and WDW (1993), summer steelhead stock status is unknown. Limited spawner surveys conducted between 1980 and 1985 indicate very low utilization of the spawning habitat. Estimated escapement based on these surveys ranged from 1335 (1985) to 5972 (1981) adults, with an average escapement of 2712 adults; natural escapement was estimated to be one-third of total escapement (WSCC 1999). The updated status review completed by NMFS indicates that the recent 5-year mean population abundance in the Klickitat River is 250+ fish (NMFS 2003). Recent harvest, however, has been substantially higher than this estimate. Total harvest of steelhead in the Klickitat River for the period from May 1, 2001 to April 30, 2002 was 3,896 fish (WDFW 2004). The number of fish that escaped to spawn in the river and the number of fish not of hatchery origin are unknown.

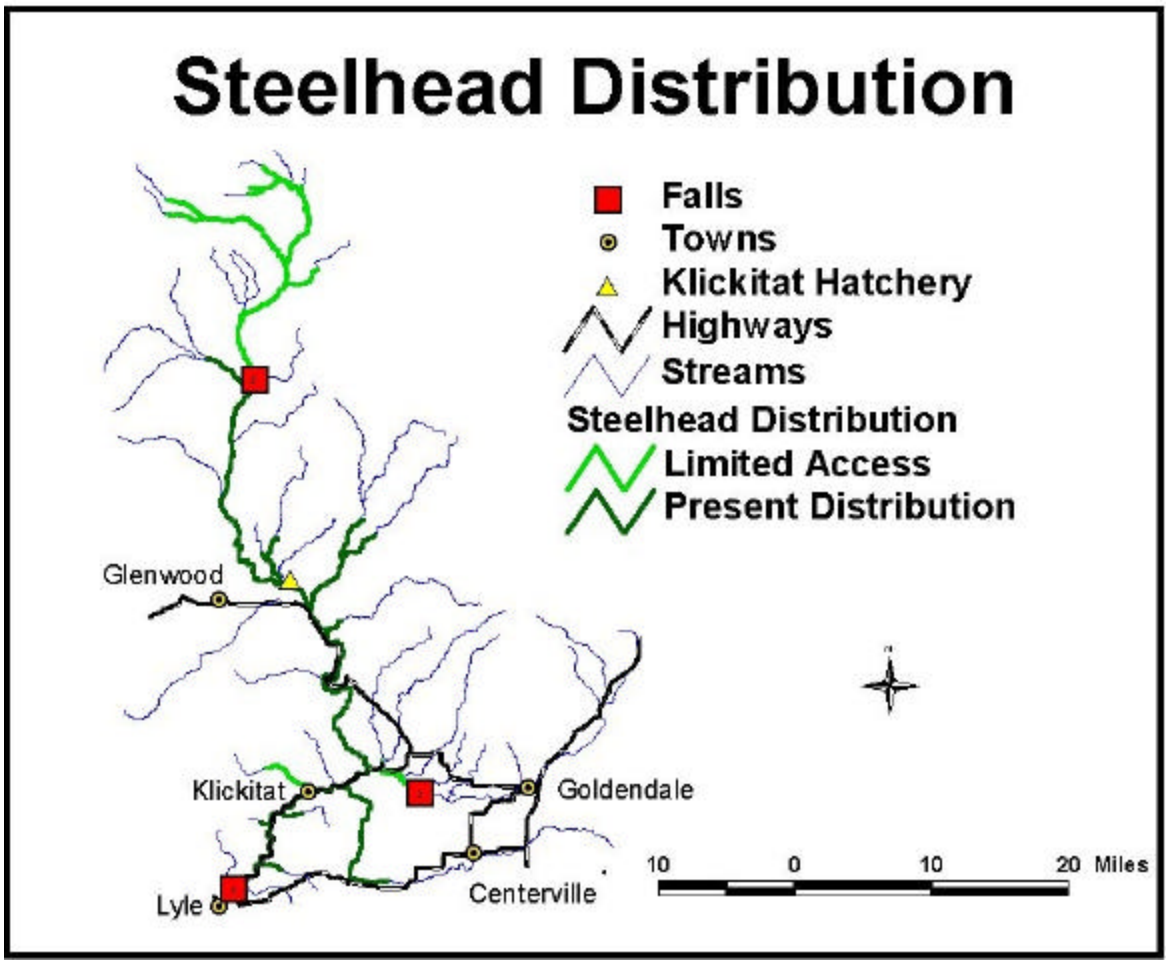


Figure 3-5: Distribution of steelhead in the Klickitat River Subbasin (from: Sharp et al. 2000).

3.5.3.2 Winter Steelhead

Winter steelhead is sustained by natural production. There is no steelhead production at the hatchery. The historic presence of this stock in the watershed has been inferred from bright steelhead observed in late winter and early spring steelhead catches (WSCC 1999).

Winter steelhead migrate into the watershed between January and May with a peak in March. They hold in the Mainstem or tributaries until spawning which occurs between March and June (WSCC 1999). No information exists on spawning locations. It is believed they spawn in the lower Mainstem perhaps as far upstream as Castille Falls (RM 64).

Juvenile life history information is inferred from nearby stocks (WSCC 1999). Fry are believed to emerge starting in April through mid-June and will rear for two years.

Smoltification and outmigration occur in April and May peaking in May (WSCC 1999). No information exists on juvenile rearing, steelhead juveniles are assumed to rear in all areas where spawning occurs (WSCC 1999).

According to WDF & WDW, (1993) winter steelhead stock status is listed as unknown. No escapement or natural production information exists, both are considered small (WSCC 1999). In the period from November 1, 2001 to April 30, 2002, 233 fish were reported harvested in the sport fishery in the Klickitat River (WDFW 2004). These include predominately hatchery fish as unmarked fish are to be released (4 unmarked fish were recorded as harvested).

3.5.4 Bull Trout (*Salvelinus confluentus*)

The status of the bull trout / Dolly Varden population stock in the Klickitat River is unknown (WDFW 1998). Bull Trout are listed as "Threatened" under the Endangered Species Act (Sharp et al. 2000).

Thiesfeld et al. (2001) surveyed 71 stream sections (9,000m) of the main Klickitat River and tributaries during the summer and fall 2001 to determine the distribution of bull trout in these areas. Streams were sampled using primarily electroshocking methods and some snorkeling in the West Fork Klickitat, Diamond Fork, upper Klickitat above Diamond Fork, and the Little Klickitat River near Goldendale. Bull trout were found in Trappers, Clearwater and Little Muddy Creeks, and, in Two Lakes Stream and a tributary to Fish Lake Stream (tributaries to the West Fork Klickitat River) (Thiesfeld et al. 2001).

It appears the West Fork population of bull trout is isolated from the Mainstem due to the falls at RM 0.3 which is a likely upstream passage barrier. Additional sampling below the barrier will help determine if bull trout attempt upstream migration (Thiesfeld et al 2001).

There is evidence there may be both resident and adfluvial bull trout in the watershed. Two bull trout were captured at the mouth of the Klickitat River in 1998 CRITFC tribal pikeminnow gillnets. An additional bull trout was reported at the mouth in May 2000 at the Pikeminnow Sport-reward station (Sharp 2000).

3.5.5 Cutthroat Trout (*Oncorhynchus clarki*)

Coastal cutthroat trout are known to occur in the Klickitat River but the historic and current status and distributions are unknown (Sharp et al. 2000). Observations of coastal cutthroat have generally been downstream of the confluence of the Little Klickitat River with the mainstem (Sharp et al. 2000).

During the limited fish census work in the 1980s, resident cutthroat were observed in McCreedy and Summit Creeks (Sharp et al. 2000). Known locations of resident cutthroat were resampled in the 1990s and no cutthroat trout were observed (Sharp et al. 2000). Headwater fish presence/absence surveys completed by WDNR in 1997 found cutthroat trout in Idlewild Creek, a tributary to the Little Klickitat River (Raines et al. 1998).

3.5.6 Resident Rainbow Trout (*Oncorhynchus mykiss)*

Resident rainbow trout are found throughout the Klickitat subbasin. Theisfeld et al. (2001) sampled rainbow/ steelhead juveniles at almost all sites. Rainbow trout were found at all sampling locations (Raines et al. 1998).

The Yakama Nation has planted hatchery 'catchable' rainbow trout in some of the western high mountain lakes and in two river locations (Sharp et al. 2000). Currently the on reservation 'catchable' program releases 10,000 rainbow trout, 95 % of these fish are released into the high mountain lakes (Sharp et al. 2000). In addition, the Washington Department of Fish and Wildlife releases hatchery 'catchable' rainbow trout into the Little Klickitat River for a youth-only fishery within the city limits of Goldendale (Sharp et al. 2000).

3.5.7 Brook Trout (*Salvelinus fontinalis*)

Brook trout were introduced into the Klickitat basin. .In the late 1970s and 1980s, brook trout were planted into high mountain lakes (Sharp et al. 2000). During the extensive sampling for bull trout in 2001, Thiesfeld found brook trout in the upper Klickitat mainstem and headwater tributaries. Brook trout were also sampled below Castile Falls, in Outlet Creek, throughout the West Fork drainage, and the Diamond Fork drainage. No Brook trout were found in the Little Klickitat drainage during the 2000 sampling effort (Thiesfeld et al. 2001) nor were brook trout found in previous sampling efforts (Raines et al. 1999). The presence of brook trout in the West Fork drainage is of concern because of the potential for hybridization and competitive interaction with bull trout (Sharp et al. 2000).

3.5.8 Pacific Lamprey (*Lampetra tridentatus*)

The historic and current distribution and status of pacific lamprey in the Klickitat subbasin is unknown. According to Sharp et al. (2000), adult pacific lamprey have been observed at RM 57.0 and juvenile outmigrants have been collected at the rotary screw trap at RM 6.0. Fine sediment from the glacial rivers provides preferred rearing conditions during the ammocoete life stage of the pacific lamprey (Sharp et al. 2000).

3.5.9 Other Fish Species

Table 3-2 lists other native fish species, about which little basin-specific population information is known other than their presence in the fish assemblages of the Klickitat basin, or within forested ecosystems of the Pacific Northwest (Wydoski and Whitney, 1979). These native and introduced species will not be discussed further.

Table 3-3. Native species known or suspected to be present in the Klickitat watershed. (Wydoski and Whitney, 1979).

Fish Species	Scientific name
Northern pikeminnow	*Ptychocheilus oregonensis*
Three-spine stickleback	*Gasterosteus aculeatus*
Largescale sucker	*Catostomus machrocheilus*
Whitefish	*Prosopium spp.*
Reticulate sculpin	*Cottus perplexus*
Torrent sculpin	*C. rhotheus*
Riffle sculpin	*C. golosus*
Prickly sculpin	*C. asper*
Pacific lamprey	*Entosphenus tridendatus*
River lamprey	*Lampetra ayresi*
Western brook lamprey	*L. richardsoni*
Longnose dace	*Rhinichthys cataractae*
Speckled dace	*R. osculus*
Redside shiner	*Richardsonius balteatus*

3.6 SUMMARY OF HABITAT CONDITIONS

This section presents and summarizes available fish habitat information in the Klickitat basin. Analyses and conclusions presented are those of the original publication authors. Reported data is subject to the comments regarding data quality and documentation presented in section 3.2.

The primary factor controlling fish distribution and natural production in the subbasin are the falls blocking and/or limiting fish passage into several subbasins. The presence of the falls has had a significant impact on the historic fish species composition and continues to make for difficult passage into portions of the subbasin for almost all species. These are discussed in each of the watersheds where they occur, the impact on fish distribution in the subbasin as a whole is significant.

3.6.1 Impassable Culverts

There was no comprehensive overview of impassable culverts available. Following are brief summaries of information that was reviewed.

Raines et al. 1998 identified 55 crossings of type 3 fish bearing streams in the Little Klickitat WAU. Twenty-eight of these crossings were surveyed. Eight of the 28 surveyed crossings were identified as impassable. Specific locations of these culverts were mapped within the document. A substantial portion of these culverts have subsequently been addressed through Boise Cascade road improvement activities.

Sampson and Fast (2000) report on the Klickitat Fish Passage Obstruction Inventory Assessment completed in the summer of 2000. Initial results of 59 culverts inventoried 49 (83%) constituted fish passage barriers. No additional information was available on this project. The locations of these culverts were not reported.

3.6.2 Ecosystem Diagnosis and Treatment (EDT) Analysis

Sampson and Fast (2000) report on the progress of applying the EDT model to diagnose the fundamental environmental factor limiting natural production and to estimate the relative improvements in production that would result from a combination of habitat enhancement and supplementation. No information about the status of the model efforts, participants, or the data used to calibrate the model is included in the progress report.

3.6.3 Subbasin Summaries

The habitat conditions in all subbasins in the Klickitat where information was available are discussed below.

Columbia Tributaries

No information on the Columbia tributaries was available in the reviewed documents. Generally, the tributaries tend to be steep streams. Most are dry or have little flow in the summer. They are unlikely to contain significant fish habitat.

Swale Creek

Swale Creek flows through the driest portion of the watershed. During summer, stream flow is reduced to less than 0.25 cfs (Appendix C) stream temperatures exceed 21°C (70°F) (Appendix F). This reduces available habitat to a series of isolated pools preventing any migration (WSCC 1999). The lower 12 miles of the stream appears to contain good spawning habitat (WSCC 1999), however summer habitat in this portion of the stream has little flow and is isolated from the mainstem of the Klickitat River.

Inter-Fluve, Inc. (2002) conducted a study in the Swale Creek canyon (lower12 miles) to assess potential for habitat enhancement in the area. The report included estimates of potential habitat within the Swale Creek canyon and provided numerous suggestions for enhancement projects. However, the assessment was based upon assumptions regarding stream flow that resulted in overestimates of actual potential flow. The evaluation of potential habitat should be revisited in light of the additional information collected since that report was written regarding flow potential and stream temperature (Appendices B, C, and F).

Lower Klickitat

Lyle Falls, located at river mile 2.2, creates difficult passage for salmon and steelhead stocks entering the Klickitat River. The road SR 142 and an abandoned rail line encroach in the floodplain along much of the Mainstem Klickitat.

In the Snyder Creek watershed at the Old Champion Mill, a 2400 foot concrete sluiceway forms a depth and/or velocity barrier to all anadromous species (WSCC 1999). Three or four miles of high quality habitat for coho and steelhead are above the barrier (WSCC 1999). Thiesfeld et al. 2001 examined several tributaries to Snyder Creek in late October these streams were dry (<.25 cfs). No other specific habitat data was available for this watershed.

Little Klickitat

This watershed is on the drier side of the Klickitat basin. Here there is less snowpack for runoff and streams tend to have lower flows. Additionally, water temperatures tend to be warmer. Data collected in support of the Little Klickitat River TMDL (Brock and Stohr 2002) indicate water temperatures in much of the subbasin exceed state water quality standards. The TMDL estimates reductions in temperatures are possible with increased shade, thereby improving fish habitat; however the state water temperature criteria is unlikely to be met in several areas despite the increases in shade.

The greatest number of recorded water rights, and the greatest cumulative volume of allocated rights (34,000 acre-feet/year), occur within the Little Klickitat Subbasin (Chapter 6). The estimated mean and low flows in June are 74 and 30 cfs respectively and in January the estimated mean and low flows are 178 and 46 cfs (Chapter 5). Between river miles 15.0 to 17.0, there are diversions resulting in low flows of 1 to 3 cfs between June and January (WSCC 1999). These flows are low enough that there are areas of intermittent flow preventing fish movements through the mainstem during portions of the year.

This watershed is a mix of small private land ownership in the lower basin and private timber lands in the upper portion of the basin. The main Little Klickitat has some diking and channelization between river miles 10 and 18 (WSCC 1999). There are parcels along the main little Klickitat with grazing above river mile 12 and more extensive rural residential developments above river mile 17.4. These land uses impact riparian conditions and floodplain development (WSCC 1999). North of the town of Goldendale, Highway 97 parallels the stream resulting in some floodplain encroachment (WSCC 1999).

The Little Klickitat Falls is located at river mile 6.1. This is a 14 to16 foot falls that provides difficult passage for steelhead and is likely impassable for coho (WSCC 1999, WDOE 1998, Caldwell and Hirschey 1990)). The frequency that the falls is passable to steelhead is unknown.

Downstream of the falls, the river is generally low gradient (approximately 1.3 percent) with a cobble bottom (Caldwell and Hirschey 1990). The dominant habitat in the lower reaches is pool/glide habitat. Further upstream, near river mile 9.6, the stream gradient is roughly 0.8 percent and gravel and cobble dominate the substrate (Caldwell and Hirschey 1990).

Mill Creek and Bowman Creeks are the only two tributaries to the Little Klickitat River where anadromous fish have been found (WDOE 1998). The confluences of both of these tributaries are located downstream of the falls at river mile 6.1.

Information regarding habitat in Bowman Creek was reported for two sites by Thiesfeld et al. (2001) who conducted sampling in two locations and for one additional site at river miles 3.5 by Caldwell and Hirschey (1990). The creek has a drainage area of 23 square miles. A canyon runs from the mouth to river miles 2.6 (Caldwell and Hirschey 1990). At river mile 3.5, the stream was reported to be 8 feet (2.4 meters) wide with a boulder substrate and thick riparian vegetation. At Theisfeld et al.'s lower Bowman Creek Camp, the stream was low gradient and 3 to5 meters wide, with some large woody debris and pools. At Theisfeld et al.'s upper Bowman Creek Camp, stream gradients were low and steam widths 1.5 to 3 meters wide, with lots of large woody debris and some pools. Stream gradients range from 5.0 percent in the canyon reach to 3.4 percent upstream of the canyon.

Mill Creek also runs through a canyon in the lower 2.6 miles (Caldwell and Hirschey 1990). The average gradient of the canyon reach was reported to be 5.2 percent. Gradients upstream of the canyon are reported to average 4.1 percent. The only specific information available for Mill Creek was at a site just downstream of the Highway 142 Bridge (river mile 3.9). Here, the creek is generally narrow with steep banks and a sand and cobble substrate (Caldwell and Hirschey 1990).

Blockhouse, Bloodgood, and Spring Creeks all enter the Little Klickitat River upstream of the falls. Blockhouse Creek has a 56-foot falls at either river mile 0.1 (WDOE 1998) or river mile 0.2 (Caldwell and Hirschey 1990). A canyon extends upstream for a distance of 1.8 miles. Average gradient of the canyon reach is 5 percent and the average gradient of the creek upstream of the canyon is 1.3 percent. At river mile 2.5, the creek has a cobble substrate and is 10 to 12 feet wide (Caldwell and Hirschey 1990).

Bloodgood Creek has an average gradient of 2.2 percent (Caldwell and Hirschey 1990). At river mile 2.2, it is 10 to 12 feet wide with a sand and gravel substrate and heavy riparian vegetation.

Spring Creek has a number of cascades between river mile 0.1 and 0.2 and has an average gradient of 1.1 percent (Caldwell and Hirschey 1990). The substrate at river mile 0.7 is gravel and mud. Thick riparian vegetation is present at that site.

An IFIM study has been completed for the Little Klickitat River and the tributaries listed above (Caldwell and Hirschey 1990). This study addressed spawning, juvenile, and adult

habitat for coho, chinook, steelhead, and rainbow trout. No instream flows have been set as a result of this study.

Calibration sites for the mainstem included two sites. Only one calibration site was used for the tributaries. The model was completed using 4 flow measurements for the mainstem and one flow measurement for the tributaries. Reported indicators of model accuracy included mean error and a velocity adjustment factor (VAF). The VAF is only applicable as a measure of accuracy for the Little Klickitat River sites.

VAF values indicate that the model accuracy was poor at the upper Little Klickitat site and marginal at the lower site. The range of reported mean errors included values that are higher than is normally considered acceptable at the upper Little Klickitat site, Bowman Creek, and Mill Creek. No mean error was calculated for Bloodgood Creek.

The results of the study indicate that virtually all the species included in the evaluation would be benefited by higher summer flows in the Lower Little Klickitat River, Mill Creek, and Bowman Creek (Caldwell and Hirschey 1990). Rainbow trout would be benefited by higher summer flows in the upper river and its tributaries. Other species, if they were present, would also benefit from higher summer flows upstream of the falls.

The results of the IFIM study should be interpreted with caution. The high error rates and the low number of representative sites contribute to uncertainty in the results. Additionally, the use of the one-flow method in the tributaries is a further source of potential error.

In 1999, a watershed analysis was completed by Raines et al. This analysis only included the portion of the Little Klickitat watershed upstream of the town of Goldendale. The analysis found a lack of suitable sized spawning gravels. Many of the stream channels had large substrates which appeared to be subject to scour at high flows. In addition many of the lower elevation reaches near the Mainstem of the Little Klickitat River had documented high temperatures (Raines et al. 1999). A 50 foot waterfall is present on the West Prong (RM 4.35) limiting upstream fish distribution (Raines et al. 1999, Thiesfeld et al. 2001). Also noted were a high degree of channel entrenchment, general lack of large woody debris, and limited pools and off channel refuge areas (Raines et al. 1999). The upper Little Klickitat, lower East Prong and portions of upper Butler had fair to good large woody debris, pools, and off channel refuge areas. The analysis also found erosion from roads and skid trails resulted in sediment inputs that averaged 300% over background levels. As part of the fish passage assessment the analysis identified impassable culverts in the East Prong, West Prong, Idlewild, and Butler Creeks. Considerable effort has gone into addressing impassable culverts and surface erosion from roads since the time the watershed analysis was completed (E. Keller, personal communication, 2002). Hence, the information regarding sediment and impassable culverts is likely outdated.

Subbasin 5. Middle Klickitat

There was no specific information available on this portion of the subbasin. Thiesfeld et al. (2001) sampled in Outlet Creek and described the channel conditions as spring fed (30 to 50 cfs), with a gradient of 5%, almost no large woody debris. The highest density of *O. mykiss* (steelhead and/or rainbow trout) were found in the middle Klickitat area during the 2000 Klickitat bull trout sampling effort conducted by Thiesfeld et al. (2001).

Subbasin 6. Upper Klickitat

Castile Falls at river mile 64.0 historically blocked all anadromous fish passage. There have been efforts to improve fish passage which have been partially successful. Additional efforts to improve passage are currently underway (WSCC 1999, Sampson and Fast 2000).

This portion of the subbasin has numerous tributaries and very limited data was available. Thiesfeld et al. (2001) sampled a number of tributaries and made observations on habitat conditions. Observations include:

- Low levels of large woody debris below Castille Falls
- Low gradient, moderate large woody debris, and good pools above McCormick Meadow
- Eroded and compacted streambanks at McCormick Meadow with grazing impacts in meadow habitat RM 77 to 85
- Naturally generated glacial sediments in Muddy Creek
- Evidence of high velocity scour, no LWD, few pools, high fine sediment, and no fish in Muddy Creek
- Cedar Creek has low gradient good pools, lots of LWD, and intermittent fall flow
- West Fork of the Klickitat River has falls located at river miles 0.3 and 4.8.
- Clearwater Creek is spring fed with a high stream gradient, good clear flow, and very high quantities of large woody debris. The falls at RM 0.2 limits upstream fish distribution.
- Trappers Creek has a gradient of 1-5 percent, high volumes if large woody debris, and a small falls at river mile 2.1 that apparently is a fish barrier
- Fish Lake Stream has a low gradient, is 4 to 6meters wide, and has good pools and large woody debris. It also has many brook trout.
- Huckleberry Creek has a falls at RM 0.55 with a vertical drop of 25 to 30 meters which limits fish distribution

APPENDIX A

Chapter 4: Water Quality

Table of Contents

4.1 Water Quality Overview ***4-1***

4.2 Water Quality Criteria and Impaired Water ***4-1***

4.3 Pollution Sources ***4-5***

4.4 Methods ***4-8***
4.4.1 Surface Water *4-8*
4.4.2 Groundwater *4-11*

4.5 Surface Water Quality ***4-11***
4.5.1 Middle Klickitat Subbasin *4-11*
4.5.1.1 Data Sources *4-12*
4.5.1.2 Surface Water Quality *4-12*
4.5.2 Lower Klickitat Subbasin *4-12*
4.5.2.1 Data Sources *4-13*
4.5.2.2 Surface Water Quality *4-13*
4.5.3 Little Klickitat *4-17*
4.5.3.1 Data Sources *4-18*
4.5.3.2 Surface Water Quality *4-19*
4.5.4 Swale Creek *4-23*
4.5.4.1 Data Sources *4-23*
4.5.4.2 Surface Water Quality *4-24*

4.6 Groundwater Quality ***4-24***
4.6.1 Data Sources *4-24*
4.6.2 Data Summary *4-25*
4.6.2.1 Nitrates *4-25*
4.6.2.2 Chloride *4-27*
4.6.2.3 Fecal Coliform Bacteria *4-27*
4.6.2.4 Other Water Quality Parameters *4-28*
4.6.3 Other Water Quality Issues *4-29*
4.6.4 Conclusion *4-29*

4.7 Data Gaps and Reccommendations ***4-29***

List of Tables

Table 4-1. Waters within WRIA 30 designated for char aquatic life, core salmon/trout aquatic life, and extraordinary primary contact recreation under WAC 173-201A. _____ 4-2

Table 4-2. 1997 Washington State Water Quality Criteria _____ 4-2

Table 4-3. 2003 Washington State bacteria criteria for freshwater._____ 4-3

Table 4- 4. 2003 Washington State Water Quality Criteria _____ 4-4

Table 4-5. 303(d) Listed Water Segments in WRIA 30 (1996 and 1998 listings). _____ 4-6

Table 4- 6. Municipal and Industrial NPDES and State Permit Holders in WRIA 30, excluding those that discharge to the Columbia River._____ 4-7

Table 4- 7. Summary of WDOE's Monitoring Data for the Klickitat River near Pitt. The criteria used for this table is the 1997 criteria. _____ 4-15

Table 4-8. Comparison of WDOE's Monitoring Data for the Klickitat River near Pitt._____ 4-15

Table 4-9. Summary of WDOE's Monitoring Data for the Klickitat River near Lyle. _____ 4-16

Table 4-10. Summary of WDOE's Monitoring Data for the Little Klickitat River near Wahkiacus. __ _____ 4-20

Table 4-11. Comparison of WDOE's Monitoring Data for the Little Klickitat River near Wahkiacus. _____ 4-20

Table 4-12. Number of August Days the Maximum Daily Temperature Met or Exceeded 15°C. in the Little Klickitat, its Tributaries, and Swale Creek._____ 4-21

Table 4-13. Identification and Description of Major Water Quality Data. _____ 4-31

List of Figures

Figure 4- 1. Surface Water Quality Monitoring Stations in WRIA 30._____ 4-10

Chapter 4: Water Quality

4.1 WATER QUALITY OVERVIEW

The available surface water quality data for WRIA 30 is somewhat sparse. One station on the Klickitat (representing the Lower Klickitat subbasin) and one on the Little Klickitat were the only locations for which the period of record and seasonal coverage were adequate for evaluating, with confidence, the condition of the water. There is no notable coverage for surface water quality in other subbasins or tributaries, with the exception of some temperature data.

Most groundwater data are collected by water purveyors as part of their routine monitoring of water supply wells. Since the mid-1990s, one time testing of newly constructed residential wells is also completed. There is no large-scale ground water monitoring plan in place that can be used to evaluate potential effects of land use on ground water quality or long-term trends in water quality. The ground water quality assessment is, therefore, focused on drinking water quality standards, rather than on possible evidence of land use or other human caused impacts. The available data indicate that most groundwater and monitored water supplies are well within drinking water standards, although many aquifers have high concentrations of sediments and the alluvial aquifer in the Swale Creek area has elevated nitrate levels. There is some evidence of elevated, but still acceptable, copper and lead concentrations in tap water near the major cities. This is likely to be associated with the distribution system rather than the original water supply.

4.2 WATER QUALITY CRITERIA AND IMPAIRED WATER

Water quality standards have been set for all surface waters in the State of Washington (WAC 173-201A). These standards define the criteria that are used to determine whether the water body is meeting acceptable conditions. There are two sets of water quality standards that are currently of interest. The water quality standards that are currently applicable within the State of Washington are those standards that were adopted in 1997. This set of standards has been under review and revision. As of June 30, 2003, a new set of water quality standards was legally adopted by the state and forwarded to EPA for approval. This new set of water quality standards applies for all actions within the state. The adopted changes cannot be used for federal Clean Water Act actions until the EPA has approved them. Hence, Ecology has indicated that "the 1997 standards and criteria should be used as a basis for decision-making until approval is received" (www.ecy.wa.gov/programs/wq/swqs/rev_rule.html). The expected time for EPA approval is around February, 2004. Further information regarding the rules, the adoption process, the applicable standards and other related information can be found at: www.ecy.wa.gov/programs/wq/swqs.

Washington State water quality criteria vary within WRIA 30. Under the 1997 water quality standards, the Klickitat River is classified by WDOE as Class AA from its headwaters to the Little Klickitat River confluence (RM 19.8) and Class A (Excellent) for the lower 19.8 miles. The Little Klickitat and Swale Creek are also Class A waters. These Classes and associated criteria are summarized in Table 4-2.

The new water quality standards are "use-based" standards. The applicable criteria for various water segments are defined by the use of that water. All surface waters of the Klickitat watershed (WRIA 30) are to be protected for the designated uses of salmon and trout spawning, noncore salmonid rearing, salmonid migration, primary contact recreation, domestic, industrial, and agricultural water supply, stock watering, wildlife habitat, harvesting, commerce and navigation, boating, and aesthetic values. In addition to these designated uses that apply to all state waters without special designation, 11 water bodies within the WRIA have been specifically designated for char, core salmon/trout, and/or extraordinary primary contact recreation (Table 4-1). Applicable water quality standards for surface waters are summarized in Tables 4-3 and Table 4-4.

Table 4-1. Waters within WRIA 30 designated for char aquatic life, core salmon/trout aquatic life, and extraordinary primary contact recreation under WAC 173-201A.

Water	Char	Core Salmon/ Trout	Extraordinary primary contact
Clearwater Creek and Trappers Creek: All waters above the junction	√		√
Cougar Creek and Big Muddy Creek: All waters above the junction	√		√
Diamond Creek and Caitlin Creek: All waters above the junction	√		√
Diamond Fork's unnamed tribs at longitude -121.1562 and latitude 46.4205	√		√
Diamond Fork's unnamed tribs at longitude -121.1590 and latitude 46.4355	√		√
Fish Lake stream and all tributaries	√		√
Frasier and Outlet Creek: All waters above the junction	√		√
Klickitat River from Little Klickitat River to Diamond Fork		√	√
Klickitat River and all tribs above the junction with Diamond Fork	√		√
Little Muddy Creek and all tributaries	√		√
McCreedy Creek and all tributaries	√		√

Table 4-2. 1997 Washington State Water Quality Criteria

Class	Temperature [(1)]	DO	Bacteria
AA	shall not exceed 16°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	greater than or equal to 9.5 mg/L	Fecal coliform bacteria shall not exceed a geometric mean of 50 colonies/100mL and shall not have > 10% of all samples exceeding 100 colonies/100mL
A	shall not exceed 18°C from human conditions or if >18°C exists naturally, no temp increase >0.3°C	greater than or equal to 8.0 mg/L	Fecal coliform bacteria shall not exceed a geometric mean of 100 colonies/100mL and shall not have > 10% of all samples exceeding 200 colonies/100mL

[(1)] Instantaneous temperature

Table 4-3. 2003 Washington State bacteria criteria for freshwater.

Category	Bacteria indicator
Extraordinary primary contact recreation	Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100ml, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies/100 ml.
Primary contact recreation	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100ml, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies/100 ml.
Secondary contact recreation	Fecal coliform organism levels must not exceed a geometric mean value of 200 colonies/100ml, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 400 colonies/100 ml.

Table 4- 4. 2003 Washington State Water Quality Criteria

Designated Use	Temperature [1]	DO [2]	Turbidity	pH
Char	12°C (53.6°F); 9°C (48.2 °F) during spawning and incubation	9.5 mg/L	• 5 NTU over background when the background is 50 NTU or less • A 10% increase in turbidity when the background turbidity is > 50 NTU	6.5-8.5 with human caused variations within the above range of less than 0.2 units
Salmon and trout spawning, **core** rearing, and migration	16°C (60.8°F); 13°C (55.4 °F) during spawning and incubation	9.5 mg/L	Same as above	Same of above
Salmon and trout spawning, **noncore** rearing, and migration	17.5°C (63.5°F)	8.0 mg/L	Same as above	6.5-8.5 with human caused variations within the above range of less than 0.5 units
Salmon and trout rearing and migration **only**	17.5°C (63.5°F)	6.5 mg/L	• 10 NTU over background when the background is 50 NTU or less • A 20% increase in turbidity when the background turbidity is > 50 NTU	Same as above
Non-anadromous interior redband trout	18°C (64.4°F)	8.0 mg/L	• 5 NTU over background when the background is 50 NTU or less • A 10% increase in turbidity when the background turbidity is > 50 NTU	Same as above
Indigenous warm water species	20°C (68°F)	6.5 mg/L	• 10 NTU over background when the background is 50 NTU or less • A 20% increase in turbidity when the background turbidity is > 50 NTU	Same as above

[1] Temperature is measured by the 7-day average of the daily maximum temperatures
[2] Lowest one-day minimum

The standards recognize that some locations will naturally exceed the specified criterion (for example, stream temperature). The full text of the rules addresses this issue and limit increases associated with land use to a specified amount over natural background. The standards presented in Tables 4-3 and 4-4 provide only the state criteria and do not address natural exceedance of those criteria.

On a biennial basis the EPA creates a list of impaired waterways in the U.S. This is called the 303(d) List of Impaired Waterbodies, often referred to as "the 303(d) list". Although there are numerous ways that a waterbody can be justified for inclusion in this list, the most frequently used method in Washington State is a simple assessment of whether water quality criteria are being met. If criteria aren't met, the waterbody will be added to the list. Once a stream is listed as impaired, it becomes the State's responsibility to develop or support a plan for handling the problem. One tool used for developing strategies to improve water quality is a Total Maximum Daily Load (TMDL) study. The technical report in support of a temperature TMDL for the Little Klickitat River was completed in July 2002 (Brock and Stohr, 2002).

Nine streams and stream segments in WRIA 30 have been included on the 1998 303(d) list (Table 4-5). With one exception (Swale Creek), all of the listings are in the Little Klickitat Subbasin. The identified impairments include segments impaired due to temperature and those impaired due to low stream flows. It should be noted that some unmonitored streams or stream segments may fail to meet the state standards. In situations where data are not sufficient to determine whether standards are met, the streams or stream segments are not included on the 303(d) list. A new 2002 list is currently being prepared and should be available before the end of the year.

4.3 POLLUTION SOURCES

Point source discharges of water or waste effluent to surface waters are regulated through the National Pollutant Discharge Elimination System (NPDES). An NPDES permits is issued that permits the discharge of runoff or effluent into natural water systems, such as rivers and streams. Traditionally NPDES permits were associated with discharge from wastewater treatment facilities (WWTPs) (previously called sewage treatment plants (STPs)) or industrial plants. NPDES permits often establish a limit on the volume of effluent that can be discharged by a permit holder and may also set maximum pollutant concentrations. These permits provide a means for controlling the amount of waste discharged to a river or stream. State waste discharge permits may also be issued. These permits address land applications of waste and focus on impacts to groundwater rather than surface water.

Table 4-5. 303(d) Listed Water Segments in WRIA 30 1998 listings).

Water body Segment ID.	Name (Township, Range, Section)	Subbasin	Parameters Violating Water Quality Standards	
			Instream Flow	Temperature
D95ML	Blockhouse Creek (04N, 15E, 17)	Little Klickitat	X	
XU61DO	Bloodgood Creek (04N, 16E, 17)	Little Klickitat	X	
TN94DB	Bowman Creek (05N, 14E, 35	Little Klickitat	X	
YU86SG	Butler Creek (05N, 17E, 17)	Little Klickitat		X
AY21LB	Little Klickitat River	Little Klickitat		
	(04N, 14E, 09)		X	X
	(04N, 15E, 28)		X	
	Little Klickitat River, East Prong	Little Klickitat		
AG85MX	(05N, 17E, 16)			X
PW77VQ	(05N, 17E, 10)			X
	(05N, 17E, 03)			X
	(05N, 17E, 09)			X
PU81CT	(06N, 17E, 35)			X
XU61ED	Little Klickitat River, West Prong (05N, 17E, 18)	Little Klickitat		X
FF43IZ	Mill Creek (04N, 15E, 05)	Little Klickitat	X	
XN32HN	Swale Creek (04N, 14E, 19)	Swale Creek	X	X

Table 4-6 contains a list of the permitted discharges within the basin and was developed from the Permit Compliance System (PCS) database (EPA, 2002) and from personal communications with regional WDOE staff. Two of the permits are associated with fish hatcheries. Although there are waste materials associated with production of hatchery fish, the discharge water is generally considered to be clean and does not represent a major concern for water quality deterioration.

There are six permitted wastewater treatment plants (WWTPs) in WRIA 30; three of these discharge directly to the Columbia River. The City of Goldendale's WWTP has recently been updated to meet current standards for treatment. The Dallesport facility, which discharges into the Columbia River, is new and meets state treatment standards. The other WWTPs in the WRIA are generally too old to meet new standards for treatment and have been slated for upgrade or replacement (Linden, 1994). The Town of Glenwood holds a State permit to discharge waste to the ground surface. These point sources of pollution may contribute nutrients and bacteria to the rivers and to cause some heating. Heavy metals and other priority pollutants may also be discharged in small quantities.

The major anthropogenic sources of potential non-point pollution in this WRIA are from dryland and irrigated agriculture, animal keeping, on-site septic systems, and forest practices (Linden, 1994). These may be causing increased erosion and sediment loading, modification of riparian vegetation, and increased stream temperatures, as well as increases in nutrient, chemical, and bacteria input.

Table 4- 6. Municipal and Industrial NPDES and State Permit Holders in WRIA 30, excluding those that discharge to the Columbia River.

Facility Name	Description of site	Flow[1] (MGD)	Receiving Water
City of Goldendale[2]	WWTP	1.5	Little Klickitat
Klickitat County PUD #1[2]	Klickitat WWTP	0.046	Klickitat
Klickitat[3]		NA	Klickitat
Glenwood[4]	WWTP	NA	Klickitat
Klickitat Salmon Hatchery[3]	Hatchery	NA	Klickitat
Goldendale Hatchery[3]	Hatchery	NA	Klickitat

[1] NA = Not Available
[2] Source: Frye, Pers. Comm.
[3] Source: Linden, 1994
[4] Source: Greg Schuler, Pers. Comm.

4.4 METHODS

4.4.1 Surface Water

Almost 50 reports and data sources were reviewed initially to determine whether they contained surface or groundwater data and whether they met criteria for more detailed assessment. An overview of the reports and water quality related data contained in each is summarized in Table 4-13 at the end of this report. The Yakama Nation also has water quality data for this WRIA; however, this data was not available for review.

Water quality data from WDOE's Ambient Monitoring Program can be a valuable source of data because there is often a long period of record, consistency in sampling locations, and standardized collection and analytical techniques. There is little of this type of data available for WRIA 30. The Ambient Monitoring database contains data from three stations in the WRIA; two of these were in the Lower Klickitat (Stations at Lyle and Pitt, Washington) and one was in the Little Klickitat subbasin (Station at Wahkiacus).

The datasets for one of the stations on the Lower Klickitat (Klickitat at Lyle, Washington) has only a short period of record (two years; 24 dates). The Little Klickitat dataset is also minimal; one year was monitored in the mid-70s and two years in the mid-90s (for a total of 48 dates). The WDOE dataset for the Lower Klickitat station at Pitt is much more extensive. It contains data from almost a 20-year period. Unfortunately, the last monitoring occurred at this station in 1980, thus there is no recent data available. None of the stations have data beyond 1995. Station locations are shown on the basin map (Figure 4-1).

The EPA STORET database website (http://www.epa.gov/storpubl/legacy/query.htm) was queried to obtain additional data on the WRIA. Within the database there were several different sources of data including the WDOE ambient stream monitoring data, EPA monitoring data, and ground water quality data. Three database files were downloaded from the site for analysis. The files included Klickitat River below Glenwood (EPA), Klickitat River near Pitt (EPA), and Klickitat River at the WDFW Fish Hatchery (US Bureau of Reclamation). In addition to these larger surface water database files there was minimal data available on several tributaries to the Klickitat including Outlet, White, and Summit Creeks. EPA also conducted a small (1-2 samples) metals study on sediments from the Klickitat River near Pitt. The groundwater data files are discussed in the groundwater section of this report. The applicable EPA surface water data are primarily a subset of the WDOE dataset and therefore are not summarized separately.

Temperature data are available for a number of stations in the watershed. Much of this is raw data from continuous automated recorders. Some of this data has been provided as a summary of 5 day – 24 hour maximum and minimum temperatures by the Central Klickitat Conservation District (CKCD). This includes stations in the Little Klickitat and Swale Creek subbasins. The five-day maximum temperature data are summarized in the discussion of results (Section 4.5) below. Boise Cascade also provided stream

temperature data. This information is summarized as daily maximum temperatures. Sample sites are primarily in the Little Klickitat subbasin.

Depending upon the station and date, each database contains information on many physical and chemical measurements. Parameters that are most closely linked to the objectives of this watershed planning effort were selected for the focus of this analysis. These include temperature, dissolved oxygen (DO), total phosphorus (TP), total suspended solids (TSS) and/or turbidity, and fecal coliform (FC) bacteria. Parameters were selected for analysis because a) they were directly related to fish habitat (dissolved oxygen and temperature), b) they were appropriate indicators of water pollution (total phosphorus and total suspended solids), and/or c) they have been considered to be important to public health (FC bacteria) and water supply issues. This is not meant to imply that other pollutants are not a concern in the watershed.

Where data was available, data tables were created for two different seasons of interest. Data for July and August were used to represent the period when high solar radiation is coincident with low steam flows. This is the period when water temperature and dissolved oxygen are most likely to violate standards. Fecal coliform bacteria can also be high during the summer depending upon the source. Data from November through March was used to represent the period of high surface runoff and pollutant loading. TSS, turbidity, TP and FC bacteria are the parameters of most concern during this critical period. It is important to note that by splitting the dataset to allow for seasonal comparisons, the number of data points becomes extremely small. Thus, confidence that the information presented represents the true condition is in many cases low.

To assess trends in water quality over time, WDOE's Ambient monitoring data was evaluated. Only one station located on the Klickitat River at Pitt, Washington; had a long enough period of record to justify evaluating different data periods. There was one study (Joy, 1986) where multiple stations were monitored that allowed assessment of downstream trends or differences. This information is presented in pertinent subbasin discussions below in tabular and graphic form.

The following paragraphs describe some of the guidelines used for this assessment.

- DO, temperature, fecal coliform bacteria, and pH are compared against existing and proposed State water quality standards. Due to the difficulty of trying to apply the turbidity standard, no direct assessment is made of criteria exceedance.

- There are no State standards for phosphorus. MacKenthun (1973) suggests that total phosphorus (TP) should not exceed a concentration of 0.05 mg/l in a stream at the point at which it enters a reservoir or lake. For other flowing streams, TP concentrations of no more than 0.1 mg/L were recommended (MacKenthun, 1973). A background level of 0.1 mg/l TP was also reported by the USGS (Mueller and Helsel, 1996). The USEPA adopted these concentrations as guidelines (USEPA, 1986). These guidelines are provided for comparison purposes.

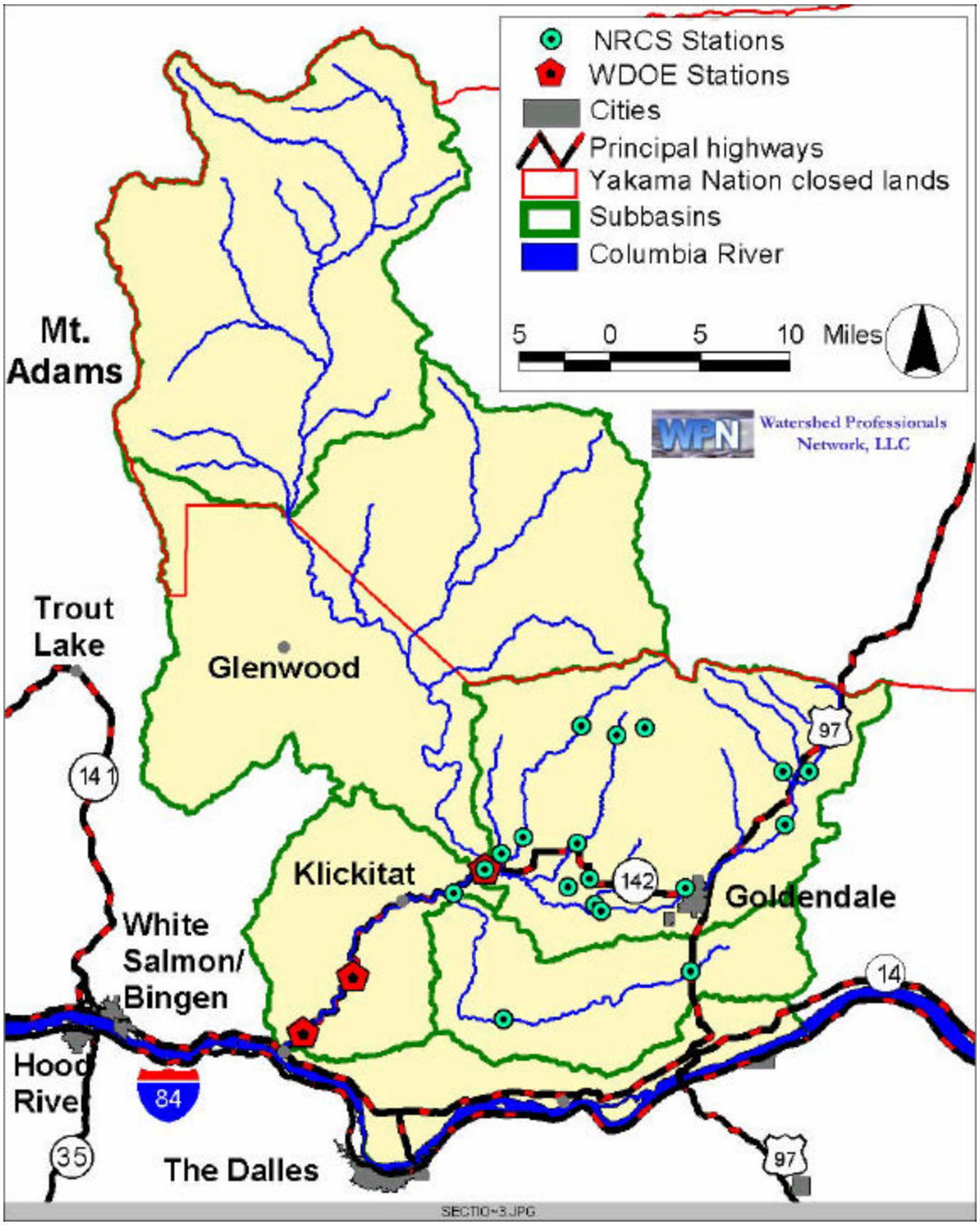


Figure 4- 1. Surface Water Quality Monitoring Stations in WRIA 30.

- No water quality standard exists for total suspended solids (TSS), although it is somewhat related to turbidity, for which there is a standard. TSS measurements have an advantage over turbidity because they can be used to calculate pollutant loads and yields and typically are more directly comparable to other pollutants measured.

- No statistical comparisons have been made for any of the data sets or trend evaluations, due to the poor data record.

WDOE's ambient monitoring data from the Pitt station on the Klickitat and the station at Wahkiacus on the Little Klickitat was used to calculate TP and TSS loads and yields. (Appropriate data were not available for any other rivers or stations.) Loading was calculated by multiplying the average annual concentration (mg/l) by the average annual flow (cfs) from the USGS gage stations, and adjusting for unit differences. Annual yield was calculated by adjusting the annual load by the size of the watershed.

4.4.2 Groundwater

The quality of groundwater in the Klickitat Basin was evaluated by reviewing available studies, databases, and reports. Nitrate, chloride, and fecal coliform bacteria were assessed. Each of these parameters is associated with potential human health impacts and may be associated with land use impacts.

The State of Washington developed water quality standards (WAC 173-200) to protect drinking water and in turn groundwater for existing and future beneficial uses. The state primary drinking water standard for nitrate is 10 mg/L and for fecal coliforms is 0 coliforms/100 ml. The secondary state drinking water standard for chloride is 250 mg/L. Concentrations above these limits are considered potentially harmful to public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other uses.

4.5 SURFACE WATER QUALITY

4.5.1 Middle Klickitat Subbasin

For the purpose of this assessment, the Middle Klickitat Subbasin is considered to be the segment of the Klickitat watershed that lies between the southern boundary of the Yakama Nation closed lands and the confluence with the Little Klickitat River; incorporating roughly river miles 53.7 through 19.8 or the mainstem Klickitat River. Mean annual precipitation ranges from 30 to 40 inches over most of the subbasin although annual precipitation levels as high as 70 inches or greater occur near the peak of Mount Adams. Over half of the subbasin (approximately 55%) lies within the rain-on-snow dominated precipitation zone and the majority of the remainder (over 30%) lies in the snow-dominated zone (Section 2.0). The highest flows will occur during warm winter storms and spring snowmelt.

The majority of the land in this subbasin is forested uplands (85%). Another 8% is described as "transitional", which refers to land that currently has sparse vegetation (Section 2.5). These "transitional" areas may include agricultural lands, lands with naturally sparse vegetation, grazing lands, agricultural lands that are converting to a forestry use, and forest lands recently harvested and currently regrowing. Within the transitional area, anthropogenic effects in the area may be related to any of these land uses. Within the forested lands, anthropogenic surface water quality issues are largely limited to forestry activities and runoff from unpaved roads. The State of Washington has recently adopted new forest practices rules (WAC 222). One of the objectives of those rules was to meet state water quality standards. The rules include restrictions on the use of chemicals, protection of riparian habitats, and reductions in sediment discharges, including those delivered by forest roads. The effectiveness of the new forest practices rules has yet to be tested. The adaptive management program that was built into those rules is intended to test the effectiveness of the rules and modify them if deemed necessary. Future effects of forest practices on water quality are expected to be reduced.

Although most of the subbasin consists of soils with moderate conditions for infiltration and transmission, a fairly large area near Glenwood has a high water table and therefore high runoff potential. This area is a rural area where septic systems and irrigation are common. Poorly located and/or constructed septic systems can potentially affect water quality. Irrigation run off can potentially affect water quality through the transport of sediment and chemicals to streams.

The Town of Glenwood, located near the center of the Middle Klickitat subbasin, is the only sizable community in this subbasin. Glenwood is located on a small tributary to the Klickitat. The Town of Glenwood has a State permit to discharge waste to the ground. The Klickitat Salmon Hatchery has the only NPDES permit in this subbasin. The hatchery discharges to the Klickitat River. There are no 303(d) listed segments on this portion of the Klickitat River.

4.5.1.1 DATA SOURCES

There were no significant water quality data sources or reports identified for this subbasin.

4.5.1.2 SURFACE WATER QUALITY

Due to the lack of data, the water quality situation in this subbasin is unknown. Since the largest land use is forestry it can be expected that issues commonly related to forestry practices may exist. Agriculture and rural development in the subbasin likely also have effects on water quality.

4.5.2 Lower Klickitat Subbasin

The Lower Klickitat Subbasin consists of the area that lies below the confluence with the Little Klickitat. The drainage area has been estimated at 128 mi^2. The Towns of

Wahkiacus, Klickitat, Pitt and Lyle are all located in the Lower Klickitat subbasin. All are located directly adjacent to the mainstem of the river.

Almost 70% of this subbasin is in the rain dominated precipitation zone, the remainder is in the rain-on-snow zone. The majority of the land in this subbasin is forested uplands (75%), however, the Lower Klickitat also contains a significant amount of land that is shrubland (11%) and grasslands (9%). Irrigated farming is included in the grasslands category. The soils in this subbasin consist of a mixture of those with moderate to slow infiltration rates.

The major water quality problems identified are elevated stream temperatures, periodic high sediment loads, elevated fecal coliform bacteria, and nutrient loading. The bacteria source has been attributed to nonpoint pollution sources such as the numerous home sites and related septic system and cattle grazing that occurs along the mainstem and tributaries (Cusimano, 1993). An analysis of stream temperatures relative to natural background temperatures has not been conducted. Hence, the degree of effect of land use on current temperature situations is unknown.

There is one NPDES permit associated with this subbasin for the Klickitat WWTP. (There are also NPDES permits for the WWTPs for Lyle, Wishram, and Dallesport however, these facilities discharge to the Columbia River.) Three of these WWTPs are not able to meet their current permit discharge requirements (Frye, Pers. Comm.). The problems stem from the age of the existing WWTPs rather than operating techniques. The facilities are well over 20 years old and need to be upgraded or replaced. The lack of available grants in recent years and small customer and tax bases has made these very difficult issues to solve. The Dallesport facility is new and meets current treatment standards.

There are no 303(d) listed segments for the Lower Klickitat subbasin as of the 1998 listing.

4.5.2.1 DATA SOURCES

Water quality information is limited for this subbasin. There are two important data sources for conventional water quality measurements. WDOE monitored at a station located near Lyle, Washington for two years in the mid-1990s. A station near Pitt, Washington was also monitored by WDOE from the mid-1960s until 1980. The USGS has also monitored the site near Pitt from 1967 to 1986. The EPA database (Storet) contains data for the Klickitat River; however, a review of this data source indicated that the data of interest to this assessment was the data collected by WDOE's ambient monitoring program.

4.5.2.2 SURFACE WATER QUALITY

Tables 4-7 through 4-9 summarize WDOE's ambient monitoring data for the stations located at Pitt and Lyle, Washington. Table 4-7 contains a seasonal summary of the most recent data for the Pitt station, as well as a summary of the data from the entire data set

for this station, which extends from 1966 to 1980. Seasonal summaries are provided to assess the worse case conditions for the river. Late summer (July and August) represents the worst period for temperature and dissolved oxygen because stream flows are lowest while solar input is highest. Conversely, winter can represent worse conditions for fecal coliform bacteria, turbidity, suspended solids, and phosphorus if these are associated with nonpoint pollution sources.

This summary indicates that temperature fails to meet the water quality numeric criteria a large portion of the time during the critical late summer period. There is no estimate available of the natural background summer water temperatures. The state water temperature standard can default to the natural background temperature where the natural background has been technically substantiated. Hence, it is unknown whether the state standards are exceeded. The measured water temperatures fall within a range that allows for good growth and survival rainbow trout (Hokanson et al, 1977; Cherry et al, 1977; Currie et al, 1998; Raleigh et al, 1984; Cherry et al, 1975; Elliott, 1981). Warmer temperatures than those that have been recorded may, however, introduce stress to fish. Recorded summer water temperatures are somewhat in excess of the temperatures preferred by juvenile and adult chinook, but are not within a lethal range (Armour 1991; Raleigh, 1986; Bjornn and Reiser, 1991; Pennell and Barton 1996, Brett et al, 1982). Lethal temperatures, however, have been documented as low as 22°C for chinook, which is only slightly higher that the range that has been recorded.

Dissolved oxygen also fails to meet the water quality criteria a large portion of the time during the critical late summer period. Recorded dissolved oxygen levels are, however, well out of the range of lethal levels (Davis, 1974; Bjornn and Reiser, 1991), although lower values likely cause some stress in fish populations.

Many of the samples were instantaneous samples, and do not represent the trends in water quality through the season. Warmer water temperatures and lower dissolved oxygen levels may occur during the summer although such situations are not recorded in the instantaneous samples. More frequent measurements or continual measurements such as made with an automated monitoring device would provide a more accurate representation of water quality in the subbasin.

Determining percent exceedance for turbidity is difficult because it requires first establishing a baseline condition. The WDOE data indicates little difference between the mean summer and winter turbidity values; however, high values have been measured during the winter and some very high values (170 NTU) are in the dataset. This indicates there are episodic high turbidity events. Although this is somewhat characteristic of rural watersheds, the glacial source of water in the watershed likely contributes substantial amounts of turbidity. Muddy Creek, which drains off glaciers on Mount Adams, often runs very silty during the early to mid-summer. Anecdotal information from several residents indicates that this turbidity plume can often be seen many miles down the mainstem Klickitat River. Occasional glacial outbursts, floods, and landslides may also contribute to the high sediment loads in Muddy Creek.

Table 4- 7. Summary of WDOE's Monitoring Data for the Klickitat River near Pitt. The criteria used for this table is the 1997 criteria (see Tables 4-2 through 4-4 for summary of applicable criteria).

Parameter	Summer[1]			Winter[2]			Complete Dataset[3]	
	Range	Mean[4]	% Not Meeting Criteria[5]	Range	Mean[4]	%Not Meeting Criteria[5]	Range	% Not Meeting Criteria[5]
DO (mg/L)	7.0-10.4	9.2	50%	11.5-15.0	13.1	0%	7.0-15.0	5%
Temp (C)	15.8-19.7	18.3	75%	0.1-7.8	4.8	0%	0.1-20.5	4%
FC (#/100mL)	-	-	-	-	-	-	2-23	0%
pH	7.4-8.2	-	-	6.6-7.8	-	-	6.3-8.4	-
Turbidity (NTU)	1.1-13.0	6.0	-	0.6-41.0	7.4	-	0.4-170.0	-
TSS (mg/L)	4.0-6.0	5.0	-	-	-	-	1.0-171.0	-
TP (mg/L)	0.03-0.06	0.04	-	0.02-0.16	0.06	-	0.02-0.68	-

[1]Summer range calculated using July and August data for 1978-1979(N = 4).
[2]Winter range calculated using November through March data for water year 1978-1980 (N = 13).
[3]All data (all years, all dates) collected from 1966 through 1980 (N = 159).
[4]Arithmetic mean calculated for all parameters, with the exception of FC, which was calculated as the geometric mean value.
[5]Based on the percent of samples not meeting Class A Water Quality Criteria.

Table 4-8. Comparison of WDOE's Monitoring Data for the Klickitat River near Pitt.[1]

Parameter	1966-1969		1972-1975		1978-1980	
	Range	Mean	Range	Mean	Range	Mean
DO (mg/L)						
Summer	9.4-10.1	9.8	9.5-10.8	10.2	7.0-10.4	9.2
Winter	10.5-14.2	12.4	12.4-14.6	13.2	11.5-15.0	13.1
Temp (C)						
Summer	16.2-20.1	18.1	14.4-18.4	16.3	15.8-19.7	18.3
Winter	3.2-7.2	5.3	1.1-7.1	4.7	0.1-7.8	4.8
FC (#/100mL)						
Summer	-	-	-	-	-	-
Winter	-	-	-	-	-	-
PH						
Summer	7.4-7.9	-	7.6-8.2	-	7.4-8.2	-
Winter	6.8-7.8	-	7.0-8.0	-	6.6-7.8	-
Turbidity (NTU)						
Summer	-	-	3.0-20.0	8.0	1.1-13.0	6.0
Winter	-	-	1.0-30.0	7.5	0.6-41.0	7.4
TSS (mg/L)						
Summer	-	-	-	-	4.0-6.0	5.0
Winter	-	-	-	-	-	-
TP (mg/L)						
Summer	-	-	0.03-0.08	0.05	0.03-0.06	0.04
Winter	-	-	0.03-0.15	0.06	0.02-0.16	0.06

[1]Summer range calculated using July and August data. Winter range calculated using November through March data. 1996-1969 (Summer N = 6, Winter N = 16), 1972-1975 (Summer N = 6, Winter N = 17), 1978-1980 (Summer N = 4, Winter N = 13)

Table 4-9. Summary of WDOE's Monitoring Data for the Klickitat River near Lyle

Parameter	Summer[1]			Winter[2]			Complete Dataset[3]	
	Range	Mean[4]	% not meeting criteria[5]	Range	Mean[4]	% not meeting criteria[5]	Range	% not meeting criteria[5]
DO (mg/L)	9.6-11.4	10.3	0%	12.1-15.2	13.8	0%	9.6-15.2	0%
Temp (C)	11.9-17.2	14.3	0%	0.7-9.7	4.0	0%	0.7-17.2	0%
FC (#/100mL)	16-150	32	25%	4-25	8	0%	2-150	9%
PH	7.8-8.4	-	-	7.3-8.2	-	-	-	-
Turbidity (NTU)	3.4-20.0	9.2	-	1.2-7.7	3.8	-	1.2-20.0	-
TSS (mg/L)	4.0-38.0	14.0	-	2.0-22.0	8.0	-	2.0-38.0	-
TP (mg/L)	0.03-0.08	0.05	-	0.03-0.05	0.04	-	0.02-0.08	-

[1]Summer range calculated using July and August data for 1994-1995 (N = 4).
[2]Winter range calculated using November through March data for water year 1993-1995 (N =10).
[3]All data (all years, all dates) collected from 1993 through 1995 (N = 24).
[4]Arithmetic mean calculated for all parameters, with the exception of FC, which was calculated as the geometric mean value.
[5]Based on the percent of samples not meeting Class A Water Quality Standards.

Although there are no criteria for total phosphorus (TP) and total suspended solids (TSS), both indicate that conditions are generally good. However, similar to turbidity results, these, too, are occasionally very high. The TP and TSS concentrations are slightly higher than what is typical for the White Salmon basin (Envirovision, 2002), the next watershed to the west.

Table 4-8 is a summary of water quality conditions over the almost 20 year monitoring period. This data summary indicates that low dissolved oxygen concentrations have only been measured in the most recent data year, but that temperature numeric criteria have been exceeded as long ago as the late 1960s. The data are not adequate for any of these periods (i.e., 1966-69, 1972-75, and 1978-80) to confidently determine the frequency that the criteria are exceedance during critical time periods.

As previously described, the USGS also collected data at the site near Pitt, Washington. Since this dataset included some more intensive (more frequent) monitoring in the early 1980s and included data as recent as 1986 it was also reviewed for this assessment. Only temperature, DO, pH, and fecal coliform bacteria data had more than a few entries during this time period. Although there were almost 60 sampling dates between 1980 and 1986, only 7 of these occurred during the critical July/August period. On two of those seven occasions water temperature exceeded the State numeric criteria. There was no other evidence of possible water quality problems. DO ranged from 9.2 to 13.8 mg/L and the range in fecal coliform bacteria was quite low (<1 to 40). TSS and TP data were not assessed since there were only three and six data entries, respectively.

Last, there is also ambient monitoring data for the station at Lyle, Washington (Table 4-9). Lyle is located near the confluence with the Columbia River. Therefore it represents the condition of the Klickitat River before it flows into the Columbia. According to this

dataset there are no notable water quality exceedance situations. Dissolved oxygen and temperature met the numeric criteria. There was one relatively high summer period exceedance of fecal coliform bacteria concentration, but overall the bacteria concentrations met both parts of the water quality standard for this parameter (Tables 4-1 through 4-4). Turbidity, TSS, and TP did not show any strong seasonal difference and no episodically high levels were measured, such as occurred at the upstream station.

This apparent difference between the results for the upstream (Pitt) and downstream (Lyle) stations might be a reflection of the difference in weather patterns during the monitoring periods. The Pitt site was monitored from 1966 through 1977 and the Lyle site was monitored in 1993-1995. The earlier period was characterized by a wet/cool climatic cycle (Section 2.0), while the later period occurred during a warm/dry climatic cycle. Changes in watershed condition over the 15 plus years that lapsed between the monitoring programs may also affect the measured water quality parameters.

Using the Pitt, Washington gage site as the reference, the calculated unit area runoff for the Klickitat River is 1.24 cfs/mi^2. This is compared to a value of 0.61 cfs/mi^2 estimated for the Little Klickitat (see next section) and a value of 2.85 cfs/mi^2 for the mouth of the White Salmon. This unit runoff estimate can be expected to represent an overestimate of the rate for the entire subbasin. That is, if adequate data were available for a station at Lyle near the mouth, the unit runoff would be lower. However, it would still likely fall between the values estimated for the next major subbasins to the east and west.

The average annual concentration of TSS at Pitt ranged from 5.5 to 25.9 mg/L. For TP the average annual concentration ranged from 0.045 to 0.113 µg/L. These equate to average pollutant loads of 67.9 and 0.30 tons per day for TSS and TP, respectively. The resultant yield estimate is 19.11 and 0.08 tons/yr/mi^2 for TSS and TP, respectively.

The yield of TSS was more than six times higher than estimated for the Little Klickitat (see Section 4.5.3 below), reflecting the glacial influence on sediment inputs to the mainstem. There were only two years (1976-77 and 1977-78) of TSS data available for the Klickitat and they had widely different average concentrations. The average concentration was 5.5 mg/l in 1976-77 and 25.9 mg/l in 1977-78.

4.5.3 Little Klickitat

The Little Klickitat River drains an area of 280 mi^2. It flows in a southwesterly direction from the southwest flank of the Simcoe Mountains (elevation 5,823 feet), to its confluence with the mainstem of the Klickitat River (elevation 600 feet) just north of the Wahkiacus. The river flows southwest across the Munson Prairie to the town of Goldendale (RM 16.3). At RM 8.3 the river enters a 4.5 mile long canyon area. Principle tributaries include, Butler Creek (RM26), Jenkins Creek (RM20.2), Bloodgood Creek (RM 14.9), Spring Creek (RM 8.6) Blockhouse Creek (RM6.3), Mill Creek (RM 3.6), Bowman Creek (RM 1.2) and Dry Canyon Creek (RM 1.2).

The surface water resource primarily consists of streams and rivers (Raines et al., 1999). In the upper part of the watershed, wetlands comprise less than 1% of the basin area and

were usually associated with streams. No lakes were identified in the upper watershed, and ponds were primarily associated with stock watering or other agricultural use (Raines et al., 1999).

There are two NPDES permits for discharge to the Little Klickitat. These include the City of Goldendale permit previously described and a permit associated with the Goldendale fish hatchery. The city of Goldendale put a new tertiary waste water treatment plant into operation in 2002. This system is designed to meet NPDES requirements without the need for instream dilution.

There are twelve segments of the Little Klickitat that are contained on the 303(d) list as impaired. Six of these are listed due to exceedance of the state temperature criteria and the remainders are listed for low instream flows. A Technical Report for a TMDL was completed in July of 2002 (Brock and Stohr, 2002). This plan addresses temperature problems in this subbasin.

4.5.3.1 DATA SOURCES

The only data source for conventional water quality measurements is WDOE's Ambient Monitoring Program. A station located close to the confluence with the Klickitat (near Wahkiacus) was monitored for one year in the mid-1970s and then for a two year period in the mid-1990s.

Two studies to assess operations and impacts from the Goldendale Wastewater Treatment Plant (WWTP) were done in the early- and mid-1980s; one previous to an upgrade of the plant and one after that upgrade. Since the time of these studies, the WWTP has been once again upgraded, this time to tertiary treatment. Therefore, the data collected in these studies is no longer representative of current conditions and is not included here. The City will begin monitoring of temperature and flow in the Little Klickitat subbasin starting in December, 2003 (personal communication, Dave Griffith, October, 2003)

There is a fair amount of temperature data available from the Little Klickitat River and its tributaries. The Natural Resources Conservation Service (NRCS) through the Central Klickitat Conservation District (CKCD) has installed temperature recorders and is collecting continual temperature measurements during the low flow period at multiple stations on four tributaries to the Little Klickitat River, as well as on the river itself. The synthesized temperature data from the KCD for the Little Klickitat subbasin includes data from two stations on Blockhouse Creek, three stations on Mill and Bowman Creeks, and one station on Bloodgood Creek. WDOE also established four continual temperature monitoring stations in the Little Klickitat Watershed in preparation for development of the temperature Total Maximum Daily Load (TMDL) study. The WDNR database that supported the development of the temperature nomograph used in the forest practices rules includes data from the Yakama Nation and data was also available from Boise Cascade. There are other temperature data for this subbasin, but it either was not made available for this assessment or was in raw data form. Details of these information sources are provided in the TMDL technical report for the subbasin (Brock and Stohr, 2002)

A Draft Watershed Management Plan was prepared in 1999 (Clayton, 1999). For development of this plan, temperature and flow data were collected at 14 sites in the lower Little Klickitat and its tributaries. The management plan also includes a set of recommendations for restoring the streams.

A Watershed Analysis was performed for the Upper Little Klickitat watershed. A minimal amount of water quality data was collected for this effort; however, the analysis contains qualitative data that can be used to infer water quality conditions.

The Central and Eastern Klickitat Conservation Districts did a watershed inventory in the vicinity of the Little Klickitat in the early 1990s (KCD, 1991). The inventory included sites on a number of tributaries to the Little Klickitat as well as on the Little Klickitat itself. The inventory process included field assessment of land use, riparian and stream channel condition, and collection of a few water quality measurements.

4.5.3.2 SURFACE WATER QUALITY

The Little Klickitat River and its tributaries are a Class A (Excellent) water, as defined by the 1997 Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A-030). (Tables 4-3 and 4-4 summarize applicable water quality criteria.)

Temperature

As was mentioned earlier, six stream segments are listed on Ecology's 303(d) list due to exceedances of the state water quality criteria for temperature. Three of these six, are on the East Prong tributary and the balance are on the mainstem of the Little Klickitat River. Exceedance of the state temperature criteria have been confirmed by recent and ongoing monitoring which have demonstrated that for 18 of 20 segments monitored, temperatures exceeded the Class A numeric standard more than 50% of the time during July and August of 2000 (WDOE, unpublished data; Tables 4-10, 4-11, and 4-12).

A watershed inventory done in the early 1990s (KCD, 1991) included some water quality data from sampling done on two dates in early to mid summer. Data was collected for the mainstem Little Klickitat and for 16 tributaries. The numeric criteria for temperature were exceeded at three sites in the Little Klickitat as well as at sites in Luna, Bowman, Mill, West Prong, Sheep, and Butler Creeks. Although this indicates that temperature is elevated in summer throughout the watershed, the report is careful to note that these elevated temperatures may be natural since these are naturally very low flow systems (some are only intermittently flowing) and summer air temperatures in the region are high. Hence the temperature standard, which includes natural background temperatures, may or may not be exceeded in these areas

Table 4-10. Summary of WDOE's Monitoring Data for the Little Klickitat River near Wahkiacus. Data is compared to the 1997 water quality criteria.

Parameter	Summer[1]			Winter[2]			Complete Dataset[3]	
	Range	Mean[4]	% not meeting criteria[5]	Range	Mean[4]	% not meeting criteria[5]	Range	% not meeting criteria[5]
DO (mg/l)	10.2-11.7	10.7	0%	11.2-14.3	13.0	0%	9.4-15.0	2%
Temp (C)	12.6-19.9	16.3	25%	0.4-6.3	2.9	0%	0.3-27.5	15%
FC (#/100ml)	18-400	53	25%	4-210	20	9%	2-400	8%
pH	7.3-9.0	-	-	7.5-8.2	-	-	7.2-9.4	-
Turbidity (NTU)	2.5-10.0	5.0	-	1.4-12.0	5.8	-	1.0-12.0	-
TSS (mg/l)	3.0-13.0	6.3	-	1.0-9.0	4.4	-	1.0-13.0	-
TP (mg/l)	0.05-0.10	0.06	-	0.04-0.09	0.06	-	0.04-0.18	-

[1]Summer range calculated using July and August data for 1994-1995 (N = 4).
[2]Winter range calculated using November through March data for water year 1993-1995 (N = 10).
[3]All data (all years, all dates) collected from 1976 through 1995 (N=48).
[4]Arithmetic mean calculated for all parameters, with the exception of fecal coliform, which was calculated as the geometric mean value.
[5]Based on the percent of samples not meeting Class A Water Quality Standards.

Table 4-11. WDOE's Monitoring Data for the Little Klickitat River near Wahkiacus.

Parameter	1976-1977		1993-1995	
	Range	Mean[4]	Range	Mean[4]
DO (mg/l)				
Summer	12.3-13.2	12.7	10.2-11.7	10.7
Winter	11.4-15.0	12.9	11.2-14.3	13.0
Temp (C)				
Summer	20.6-27.5	24.5	12.6-19.9	16.3
Winter	0.3-11.3	5.93	0.4-6.3	2.9
FC (#/100ml)				
Summer	6-400	20	18-400	53
Winter	2-8	4	4-210	20
pH				
Summer	8.7-9.4	-	7.3-9.0	-
Winter	8.1-8.7	-	7.5-8.2	-
Turbidity (NTU)				
Summer	2.0-4.0	2.8	2.5-10.0	5.0
Winter	2.0-5.0	3.8	1.4-12.0	5.8
TSS (mg/l)				
Summer	-	-	3.0-13.0	6.3
Winter	-	-	1.0-9.0	4.4
TP (mg/l)				
Summer	0.09-0.12	0.11	0.05-0.10	0.06
Winter	0.12-0.13	0.13	0.04-0.09	0.06

[1]Summer range calculated using July and August data. Winter range calculated using November through March data. 1976-1977 (Summer N = 4, Winter N = 6), 1993-1995 (Summer N = 4, Winter N = 10)

Table 4-12. Number of August Days the Maximum Daily Temperature Met or Exceeded 15°C. in the Little Klickitat, its Tributaries, and Swale Creek. (Source: KCD database)

Stream Site	1998		1999		2000		2001	
	No. Days Max. Temp. was Exceeded	Total No. Days Monitored	No. Days Max. Temp. was Exceeded	Total No. Days Monitored	No. Days Max. Temp. was Exceeded	Total No. Days Monitored	No. Days Max. Temp. was Exceeded	Total No. Days Monitored
Blockhouse 1	10	10	-	-	-	-	-	-
Blockhouse 2	30	30	25	30	30	30	30	30
Bloodgood	25	30	10	30	5	30	20	30
Bowman 1	10	10	20	25	25	30	30	30
Bowman 2	30	30	30	30	30	30	30	30
Bowman 3	30	30	15	30	30	30	30	30
Mill 1	30	30	25	30	30	30	30	30
Mill 3	20	30	5	30	15	30	20	30
Little Klickitat 1	30	30	-	-	30	30	-	-
Little Klickitat 2	30	30	30	30	30	30	30	30
Little Klickitat 4	30	30	20	30	15	30	30	30
Little Klickitat 7	30	30	30	30	30	30	30	30
Little Klickitat 8	30	30	-	-	30	30	30	30
Swale 2	30	30	30	30	30	30	30	30
Swale 3	30	30	30	30	30	30	25	25

A Watershed Analysis was prepared for Boise Cascade Corporation (Raines et al., 1999) for the Upper Little Klickitat; as defined as the area upstream of Goldendale. Although there is little specific water quality data in this report, it provides a qualitative assessment of features and functions that are directly related to water quality concerns. The report found that forest roads were contributing the largest source of land use related sediment to streams. These roads are currently being addressed through road management plans developed per RCW 222. As a result, sediment inputs from roads are expected to decrease over time.

The watershed analysis also looked at shade levels on forested lands as it affects stream temperature. The report concluded that forest practices have resulted in insufficient canopy closure to maintain summer stream temperatures in 22% of the fish-bearing streams and non-forest related activities have reduced shade below target levels for 10% of the fish-bearing stream length. It was also noted that shade was low due to naturally sparse canopy closure along 19% of the fish-bearing streams. To the limits that environmental conditions allow, shade is expected to increase over time in forested areas to the point of at least meeting state water quality criteria under the current forest practices rules.

A Technical Report in support of the development of a TMDL was completed for the Little Klickitat River in June, 2002 (Brock and Stohr, 2002). In this analysis, effective shade was used as a surrogate measure of heat flux affecting temperature. Load allocations for effective shade were developed using modeling techniques. Load allocations were set between 50 and 95 percent shade for all perennial streams in the subbasin. The TMDL technical report also noted that additional reductions may be achieved through reductions in stream width in some areas. Those stream segments that were not modeled were assigned a load allocation of 73 percent shade. The load allocation for the Wastewater Treatment Plant was established at 18.3^{o}C. Other recommendations in the TMDL technical report included reduction of sediment loads and promotion of water use efficiency.

Dissolved Oxygen

The lowest dissolved oxygen (DO) levels are typically found in late summer (July and August) when stream flows are lowest and solar input and water temperatures are highest. Most of the DO concentrations measured by the state were within state standards (Tables 4-10, 4-11, and 4-12). Three sites had DO levels which failed to meet the standard. These were associated with extreme low flows; however irrigation return flows were also identified as a possible contributing factor at one site.

The watershed analysis conducted by Raines et al (1999) addressed water quality in the upper Little Klickitat Subbasin. The analysis found that summer period dissolved oxygen concentrations fell between 8 to 10 mg/L. Additionally, no potential problems with lack of aeration or excessive biological oxygen demand were identified.

Bacteria

Bacteria data available in this subbasin was primarily collected at WDOE's monitoring site near Wahkiacus. At this location, average fecal coliform bacteria in both summer and winter are well under the state standard. However, peaks in bacteria concentration were frequently measured that exceeded the criteria. The criterion was exceeded roughly 25 percent of the time in summer and 9 percent of the time in winter over the entire period of record (Table 4-7). Data from 1993–1995 indicate substantial increases in bacteria levels relative to levels measured in the 1970s (Table 4-8).

Turbidity and Suspended Solids (TSS)

Turbidity, and TSS levels are low and do not indicate any seasonal problems (Table 4-10). These load and yield values are very low when compared to other nearby subbasins, at least partially reflecting the absence of a glacial source of water in the subbasin. However, in all of these cases the estimates were based on only one to two years of data collected roughly once a month and may not be representative of typical conditions.

Nutrients

Phosphorus concentrations at the WDOE monitoring site near Wahkiacus are moderate to low and are similar to the concentration range measured in the Klickitat River (Tables 4-10 and 4-11). No evidence of nutrient problems has been found in the headwaters of the subbasin (Raines et al, 1999).

Time Trends

Table 4-11 is provided as a means of directly comparing data from the mid-70s to more recent data to assess whether there are trends that may be apparent from these limited datasets. Interestingly, all of the parameters indicate some difference. In the more recent dataset, summer period dissolved oxygen was higher and temperatures were lower, phosphorus and pH was also lower. The differences in temperature are particularly notable given that the warmer temperatures were measured in the mid-70s which was a period of cool/wet weather (Section 2.4.2). More recently we have been in a warm/dry climatic period. Factors unrelated to weather, such as changes in land use, may contribute to the observed differences in measured water quality parameters.

4.5.4 Swale Creek

Swale Creek is included in the 1998 303(d) list due to temperature and flow conditions. No State or NPDES discharge permits are listed for this subbasin.

4.5.4.1 DATA SOURCES

Available water quality data for this subbasin are limited to temperature measurements (Table 4-13). The NRCS through the Central Klickitat Conservation District (CKCD) has maintained a continuous temperature recorder at two to three stations on Swale Creek since 1995.

The Central and Eastern Klickitat Conservation Districts did a watershed inventory in the early 1990s that included one station on Swale Creek (KCD, 1991). The inventory process included field assessment of land use, riparian and stream channel condition, and collection of a few water quality measurements.

4.5.4.2 SURFACE WATER QUALITY

A summary of five-day average daily maximum values for the two sites that have more recent data was included in Table 4-13. As shown, both stations exceeded the 16 ^{o}C criterion 100% of the time.

A watershed inventory done in the early 1990s (KCD, 1991) included sampling done on one day in mid summer at one station on Swale Creek. The temperature and DO criterion was exceeded at this site. However, it was noted that this was related to extremely low flows and high daytime temperatures, as well as from the influence of irrigation return flows. It was further noted that the site may have been dry had there not been any irrigation flow.

The 303(d) list database provides a description of the basis for listing Swale Creek for instream flow problems. Essentially there is little to no flow in the lower 3.5 miles of this stream, and this was at least partially attributed to irrigation withdrawals. The local geology also contributes to this situation. Deep deposits of alluvium result in infiltration of water into subsurface flow. This is further discussed in Section 5.2 of this report.

4.6 GROUNDWATER QUALITY

The following is a summary of groundwater quality in the Klickitat River Basin (WRIA 30). Nitrate, chloride, and fecal coliform bacteria were selected for this initial assessment because they are common groundwater problems, have associated health impacts, and may be directly related to human caused contamination.

4.6.1 Data Sources

This assessment is based on personal communications with knowledgeable sources in the basin, reports, the Washington State Department of Health (WDOH) database for WRIA 30, and the EPA STORET database.

The WDOH database analyzed for this report contained information collected between 1993 and 2001 on 23 wells located throughout the Klickitat Basin. The databases contain information on 42 water quality parameters; however, the majority of the entries are for copper and lead. The WDOH database did not have information on fecal coliform bacteria and there was minimal data on nitrate and chloride (91 entries and 43 entries, respectively).

The Geology and Water Resources of Klickitat County (Brown, 1979) contains some baseline groundwater data for the basin. The report contains information collected

between 1930 and 1974, on 85 wells and 14 springs in Klickitat County. The report includes nitrate and chloride data but no fecal coliform data.

Groundwater quality is monitored at the Klickitat Horsethief Landfill as required by WAC 173-304. Groundwater monitoring wells were installed at the landfill in 1989 and 1993. Samples were collected from the wells three to four times a year for analysis. Samples are tested for nitrate, chloride, fecal coliform, and eleven other water quality parameters. Annual reports are completed for the landfill. The 1999 report (Technico, 1999) contains information collected from 1993 through 1999 on four wells. This information is summarized. However, since it is specific to a known pollutant source it should not be viewed as representing the general condition of the groundwater in the WRIA.

The Comprehensive Water Plan for the City of Goldendale (Wellman Assoc., 1985) contains information on fecal coliform in two springs (Bloodgood and Simcoe) between 1980 and 1985.

As part of WWTP receiving water studies done by WDOE (Joy, 1986) one municipal well was sampled once in August 1985. Eighteen parameters were measured. This included nitrate and chloride.

The EPA STORET database contains data files for 4 springs in the Klickitat basin. The Cascade, Riverside, Wonder, and Kidder springs data files contain entries on 49 water quality parameters tested once at each site in 1988 or 1989. Chloride is included in these data sets, but not fecal coliform. Nitrate concentration is not reported directly, however the combination of nitrite plus nitrate is reported.

4.6.2 Data Summary

4.6.2.1 NITRATES

Elevated nitrate concentrations can indicate contamination of groundwater from septic leachate, animal wastes or fertilizer applications. The State drinking water standard for nitrate is 10 mg/l. Concentrations above this limit can inhibit the oxygen-carrying capacity of blood and may cause methemoglobenemia (blue baby syndrome) in infants, although the relationship between nitrates in drinking water and methemoglobenemia is not clear.

Wells

The WDOH database contained 91 nitrate entries for WRIA 30. Of the 91 entries, five were below the detection limit (<0.01 mg/L) of the study. The remaining 86 entries ranged in concentration from <0.1 mg/L to 9.4 mg/L. All but two of the 86 entries had concentration below 5.0 mg/L.

In the other reports and data sets reviewed for this study, 90 wells were tested for nitrate. These wells were spread throughout the WRIA and sampled on many different dates. All

but one of the results was below the drinking water standard. This sample, collected in the Goldendale area, was right at the drinking water standard of 10 mg/L.

As part of the groundwater quality monitoring at the Klickitat Horsethief Landfill, 108 samples were collected at four wells located in the landfill. The samples were analyzed for several parameters including nitrate. The samples ranged in concentration from <0.01 mg/L to 9.9 mg/L, and therefore all met the drinking water standard. Results for all but 19 samples were below 5.0 mg/L. Seventeen of the samples with concentrations above 5.0 mg/L were from the same well.

Although existing published data does not indicate nitrate levels of concern, several sources of unpublished data suggest that nitrate levels in shallow wells within the Swale Creek subbasin may exceed the state criteria. One well on a farm recently purchased by Goldendale Energy had nitrate levels a 28 ppm, which is high enough to cause significant concern (T. Flynn, personal communication, January 3, 2003).

Subsequent to the completion of the first draft of this document, an in-depth sampling program for nitrate was conducted by Klickitat County, supported by the WRIA 30 Planning Unit. Nitrates were found to be elevated in several wells in the area overlying the Swale Creek alluvium (See Appendix D for the full report). No wells drawing water from depths greater than 150 feet had nitrate concentrations in excess of the state standard. The concentrations of nitrate correlated with the concentration of chloride in the samples, suggesting a septic source for the pollutants.

Springs

The Geology and Water Resources of Klickitat County Report (Brown, 1979) contained nitrate data from 10 springs located within the WRIA. Each of the springs was sampled once in 1973 or 1974. The nitrate concentrations ranged from 0.05 mg/L to 2.0 mg/L, well below the State drinking water standards. The concentration of nitrate plus nitrite was measured once in the Kidder, Cascade, Riverside, and Wonder Springs. The concentrations for the combined compounds reported in EPA's STORET database were all less than 0.10 mg/L.

Summary

In summary, the data reviewed does not indicate that nitrate is excessively high in WRIA 30. In all the resources analyzed for this report only one entry was at the State drinking water standard, the majority of the entries were below half the standard. Subsequent studies (Appendix B), however, have found that high levels of nitrate in the Swale and the southern portions of the Little Klickitat subbasins. Higher concentrations are found primarily in shallow (<150 feet) wells and appear to be related to septic inputs.

4.6.2.2 CHLORIDE

Elevated chloride concentrations in groundwater are often attributed to sources such as landfill leachate, and septic effluent although elevated concentration can also exist naturally. The State drinking water standard for chloride is 250 mg/L.

Wells

The WDOH database contained 43 entries for chloride. The concentration ranged from below detection (zero) to 45 mg/L, well below the drinking water standard.

Chloride concentrations for 86 wells were found in other reports and datasets reviewed for this analysis. All the entries were below the State drinking water standard and ranged in concentration from 0.3 mg/L to 30 mg/L.

The Klickitat Horsethief Landfill well data had chloride concentrations (2.71 mg/L to 115 mg/L) well below the State drinking water standards. Of the four wells tested, Well 3 consistently had the highest concentrations of chloride and a range of between 32 mg/L and 115 mg/L.

Springs

Within the miscellaneous reports and datasets, a total of 18 chloride samples were found for springs. These too were low. The samples ranged in concentration from 0.05 mg/L to 49 mg/L, well below the State drinking water standard.

Summary

In summary, all samples analyzed for chloride were well below the State drinking water standard. Chloride does not appear to be a concern in this watershed.

4.6.2.3 FECAL COLIFORM BACTERIA

Although fecal coliform bacteria are ubiquitous in the surface water environment, elevated concentrations in groundwater are indicative of contamination. Typical sources of contamination include septic leachate, wastewater discharges, pets and farm animals, animal waste management practices, improperly constructed or improperly decommissioned wells, and wildlife. Locally, improperly constructed or improperly decommissioned wells are commonly found to be a source of bacteria (personal communication, Kevin Barry, Klickitat County, 2003). The drinking water standard for fecal coliform is 0 fecal coliform/100 ml.

Wells

The only fecal coliform data available in any of the reports and databases reviewed for this assessment were from the landfill site. Of the 108 samples collected at the four wells in the Horsethief Landfill most (101) met the State drinking water standards, no fecal coliforms were detected. The remaining 7 samples had fecal coliform concentrations

ranging from 2 to 23 coliforms/100 ml. A subsequent study conducted primarily in the Swale and Little Klickitat subbasins (but also included samples from the middle and lower Klickitat subbasins) found no detectable fecal coliform concentrations in groundwater samples drawn from wells (Appendix B).

Springs

In a past study (Wellman Associates, 1985), some elevated values for fecal coliform bacteria were measured in both the Bloodgood and Simcoe springs. Nine fecal coliform samples were collected at Bloodgood spring and 36 at Simcoe spring between 1980 and 1985. A more recent three-year study of the springs (Taylor Engineering, 1995) indicated that drinking water standards are met. No fecal coliform bacteria have been present in either spring and the maximum Total Coliform value measured was 23/100mL. Monitoring of these springs has continued and, as of a 1998 report (Gray & Osborne, 1998), no bacteria had been detected for 10 years.

Contamination of groundwater from fecal coliforms does not appear to be a problem in WRIA 30. All wells constructed since 1998 and approved by the health department are required to be tested for nitrates and fecal coliform bacteria (O'Donoghue, Pers. Comm.). Therefore more data will be available in the future that may be useful for assessing spatial trends.

4.6.2.4 OTHER WATER QUALITY PARAMETERS

The WDOH database contained 23 entries for copper and lead. The samples were taken from 21 public water systems all at different points of use (i.e. private residences, public and private buildings, waste water treatment plants, etc.) in 1993 through 2001. It appears that the majority of the samples were taken from a faucet or tap. The average concentration for the copper was 0.060 mg/L; none of the entries exceeded the State drinking water standard for copper (1.3 mg/L).

The average concentration for the lead samples was 0.002 mg/L; six entries had a concentration greater than the State drinking water standard of 0.015 mg/L for lead. It is likely these elevated concentrations are a reflection of the distribution system (i.e. pipes and plumbing) or local geology.

Iron is a commonly occurring constituent of groundwater in Washington as it is derived naturally from the weathering of minerals within the groundwater flow system. Iron is a secondary (aesthetic) contaminant to drinking water, with a water quality standard of 0.3 mg/L. Concentrations of iron above the standards are generally not considered a health problem, but it will impair the taste and can encrust plumbing and stain laundry. Although elevated concentration of iron exist within the basin (Yinger, Renolds, Sherwood, Pers. Comms.) none of the data sources reviewed for this study reported concentrations above the drinking water standard.

Deeper wells within the basin often have high total dissolved solids (TDS), manganese and iron levels, however, the majority of the domestic wells are located in shallow aquifers where there are not as many water quality issues (Flynn, Pers. Comm).

Aesthetic problems with drinking water are also reported at the Klickitat PUD's Town of Klickitat water supply. Drinking water at that site meets but taste and sediment are elevated (Reynolds, Pers. Comm.). Due to these aesthetic problems, Klickitat PUD has installed a new "test" well that currently produces high quality water (Reynolds, Pers. Comm.). This well is being considered as an alternate water supply. The PUD is also in the process of getting approval to build a water treatment plant.

4.6.3 Other Water Quality Issues

Contaminants have been found in the soil around the old Klickitat Sawmill, located in the town of Klickitat. The sawmill was reportedly constructed around 1904 and was closed in 1995 (WDOE 2003). Site investigations conducted in August and September of 2001 found petroleum and lead in the soils. Klickitat County and Ecology have partnered in the remedial actions at the site. In 2002, 529 cubic yards of petroleum and lead contaminated soil were removed and 11 monitoring wells were installed to monitor the water quality of aquifers. The latest monitoring results found diesel in well number 4 and arsenic in several wells. The concentrations of these both of these contaminants exceed groundwater cleanup levels.

Ecology and Klickitat County have recommended a No Further Action determination for petroleum and lead in the soils. The remaining untreated locations will be left intact because existing structures are present or the areas are paved. Ecology and Klickitat County have recommended restrictive covenants be placed in these areas. They have also indicated that additional cleanup may be required if the sites are disturbed in the future.

4.6.4 Conclusion

In terms of meeting drinking water standards, existing published data indicates that groundwater quality is good throughout the Klickitat Basin. However, there is some indication that nitrate levels may be high in shallow wells in the Swale Creek subbasin and possibly the Little Klickitat subbasin.

Meeting the drinking water standard does not mean that concentrations of constituents are not elevated, as expressed for iron and manganese by several sources in the basin (Yinger, Renolds, Sherwood, Pers. Comms.). Although not a water quality concern, these constituents can affect aesthetics and taste.

4.7 DATA GAPS AND RECOMMENDATIONS

There is very little surface or groundwater quality data available for the WRIA. The available data is sparse in terms of the period of record at surface water quality stations that are monitored routinely and very sparse in terms of spatial representation. Additionally, some of the data is old and may not be representative of current conditions. There is more recent temperature data for multiple sites, but the Lower and Middle

Klickitat subbasins are not represented. Monitoring temperature over time will provide not only baseline information, but also provide information regarding changes over time and the effectiveness of various mitigation measures put in place throughout the watershed.

Temperature is known to exceed the state standard in many streams within the WRIA. The temperature data that currently exists in raw data files should be thoroughly mined and used to depict a more comprehensive picture of the temperature situation in the basin. Additional studies could be conducted to evaluate natural background temperatures, which would help clarify where the state standard is not being met. An evaluation of shading and flow effects could help set long term goals and prioritize areas for action. (Appendix D provides information for the Swale Creek Canyon that partially fills this gap).

Further analysis of spatial trends in groundwater quality may also be merited. The existing public water quality data should be input to a database that can be used to do a spatial analysis (aquifer depth and location) of the results. Differences in aquifer quality may become evident (e.g., areas where aesthetic problems already exist or where hardness or chloride are high). This would facilitate the development of a cost effective long term monitoring program to address the effects of changes in water withdrawals on water available over time. Water quality data can also be used to help define the connectivity between groundwater aquifers and groundwater/surface water sources. (Appendix C provides information that at least partially fills this data gap).

No comprehensive strategy exists for collecting and assessing the condition of the water resource in WRIA 30. A limited monitoring program could be developed and instituted that would meet the following needs; determine baseline conditions, evaluate the condition of critical segments or tributaries, and allow investigative monitoring of source areas.

- Surface water monitoring should focus on temperature, nutrients, TSS, and bacteria. The monitoring program design should include a system of "key" and "auxiliary" stations, emphasize critical periods, and should be phased in over a multi-year period to minimize budget considerations. The purpose and intent of the monitoring would be to evaluate long term trends in these parameters.

- Flow monitoring at key stations or long term temperature monitoring stations is needed to adequately address temperature/flow relations in late summer and to develop more useful yield estimates.

- Groundwater monitoring should include a long term program for collecting well depth information at sites located as to allow a spatial analysis of the information. This data would provide a basis for evaluating the effect of long term climate and water use patterns on water depth within the aquifers. Such information would provide a better understanding of the volume of groundwater available for allocation.

Table 4-13. Identification and Description of Major Water Quality Data.

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
SURFACE WATER DATA													
1	66-69	1	38	Lower Klick	X			X			X	Alkalinity, Cond., Barometric, Color, Metals, hardness, pH	30B070 (Pitt)
	70-78	2	75-94		X	X	X-some	X		X	X		30A070 and 30B070 (no 1971 data)
	79-80	1	26	Lower Klick	X	X		X	X		X		30B070 (Pitt)
	76-77	1	24	Little Klick	X		X	X	X		X		30C070 (Little Klick)
	93-95	3	14-24	Lower Klick, and Little Klick	X	X	X	X	X	X	X		30A070 (no 93 data), 30B060 (Lyle) and 30C070 (only 3 sampling dates in 93 for both)
2	11/90-8/91	1	9	Little Klick		X		X	X		X	Benthic Macroinverts, pH, Cond., oxygen, Alkalin, hard, ortho-P, NH3+N, Persulfat-N, Total organic Carbon (Data from USFS, USGS, and Ecology Ambient Data)	
3	85-86	1	2	Little Klick		X			X	X	X	Depth, sludge	2 samples days (1 wet/1dry) lagoon samples (WWTP-outflow)

Table 4-13. Identification and Description of Major Water Quality Data (continued).

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
4	1981	7	2	Little Klick – Bloodgood Creek	X	X	X	X		X	X	Total residual chlorine, pH, specific cond, BOD, COD, Ortho-P (WWTP – outfall)	
5	1985	6	1	Little Klick – Bloodgood Creek	X	X	X	X			X	PH,Cond.	WWTP outfall
6	Prior to 1993	-	-	Col. River Tribs									Summary of other findings/reports
7	85,86	6	2	Little Klick - Goldendale	X	X	X	X			X		WWTP
8	6/00-11/00	3	15 min intervals	Little Klick	X								
9	-	-	-	Col. River Tribs									General Sewer Plan
10	91, 95-97	8-20		Little Klick (upper)		X		X	X		X	Class A, pH	Summaries of several repts/data sources (KCD, DOH, NRCS)
11	63-68	2	Mon-avg	Col. River Tribs	X					X			
12	90-93, 5-10/95, 11/96-00	2-day (TMDL)		Little Klick				X					

Table 4-13. Identification and Description of Major Water Quality Data (continued).

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
13	95-98	11	Continual (some gaps)	Lower Little Klick	X			X					KCD
14	5-7/90	23	~11	Klick/C. R.		X		X			X	pH, CO, hard	
15	Btwn 1909-1985	10		Mid Klick/ Little Klick	X			X				Gradient, substrates, chemistry	Overview no data (Ecology ambient data)
	80-85	1	42	Lower Klick	X	X	X	X	X		X	Spec. Cond., pH, hard, Alkalin, sodium, sedimt discharge	Table II-2, V-1 flow data
16	(5-10) 95-98	3	~6/month (5-day 24hr)	Swale Ck, Little Klick	X			X				Air temp	Files: blockhouse1, mill2, swale1
	(5-10) 98-02	1	~6/month (5-day 24hr)	Little Klick	X			X					File: Blockhouse2
	(5-10) 95-02	6	~6/month (5-day 24hr)	Little Klick	X			X				Air Temp	Files: Bloodgood, Bowman1, Bowman3, Littleklick4, mill3, Spring1
	(5-11) 95-02	4	~6/month (5-day 24hr)	Little Klick, Swale Ck	X			X				Air Temp	Files: Bowman2, Littleklick7, Mill1, Swale3b

Table 4-13. Identification and Description of Major Water Quality Data (continued).

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
	(5-10) 95-00	1	~6/month (5-day 24hr)	Little Klick	X			X				Air Temp	File: Littleklick1
	(5-12) 95-02	1	~6/month (5-day 24hr)	Swale Creek	X			X				Air Temp	File: swale2b
	(5-10) 95-01	2	~6/month (5-day 24hr)	Little Klick	X			X					File: Littleklick2, Littleklick8
17	1973-1986	1	4-24 per year	Klickitat	X						X	Alkalinity, bicarbonate, carbonate, biological, ions, trace-elements, sed, carbon, radiochemical	USGS Pitt station
18	-	-	-										Project forecast
19	10/99-9/00	3	Daily avg.	Mid Klick, Lower Klick	X								
20	-	-	-										No WQ data (use)
21	-	-	-										GIS Data
22	-	-	-										GIS Data

Rable 4-13. Identification and Description of Major Water Quality Data (continued).

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
23	-	-	-										Stream stations/303d/etc.
24													
24	-	-	-										Streamflow (USGS), 303(d)
25	Predates 93, 95-96	26	1 max temp	All				X					No date or year info.
26	-	-	-										No WQ Data
27	-	-	-										No WQ Data
28	1973	1	1	Mid Klick			X	X	X		X	Nutrients, Physical	
	1971-1972	1	25	Klickitat	X	X	X	X	X		X	Metals, Nutrients, Physical	
	1988-1989	1	9	Klickitat	X	X		X	X		X	Metals, Nutrients, Physical	

Table 4-13. Identification and Description of Major Water Quality Data (continued).

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
GROUNDWATER DATA													
1	6/93-10/95	5	11	Horsethief landfill			X-total col				X	Spec Conduct, pH, Metals, sulfate, tot organic carbon	Groundwater
2	6/93-11/99	4	27	Horsethief landfill			X					Spec Conduct, pH, Metals, sulfate, tot organic carbon	Groundwater
3	95	>5	?no dates	Klick/Col. River							X		No data just summary (Landfill)
4				Yak/Klick	X	X	X	X	X	X	X	Toxicant, chemicals,	Temp -flow (springs) Summaries no data
5	-	-	-	All									Overview
6	80-85	2	9-36	Little Klick - Goldendale			X						Springs, 36 samples-Simcoe, 9samples-Bloodgood (DOH)
7	-	-	-	-									303(d) list
8	4/74, 9/88, 2/91	5		Little Klick and Col. River Tribs			X		X			Hard, pH, Fe, Mn, Pb, cond.	Groundwater (spring) (DOH)

Table 4-13. Identification and Description of Major Water Quality Data (continued).

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
9	-	-	-	Col. River Tribs									Well logs, Water Well Reports (DOH)
10	90-92	4	147	Little Klick - Goldendale			X		X			Organics, Corrosiveity	Groundwater (DOH)
	69, 75, 78, 80, 86, 87, 89, 92	Between 1-4	Between 1-4						X		X	Metals, pH, Hard, cond., color	DOH
11	-	-	-										Phone log-notes
12	-	-	-										Phone log-notes
13	-	-	-										Phone log-notes
14	-	-	-										Phone log-notes
15	-	-	-										Phone log-notes
16	93, 96-00	58	Sporadic	All							X	Metals, color, chlorine, fluoride, etc.	Lots of copper and lead data
17	-	-	-										Phone log-notes
18	-	-	-										Phone log-notes
19	-	-	-					X				Sediments	Phone log-notes

Table 4-13. Identification and Description of Major Water Quality Data (continued).

Data Source	Period of Record	# of Stations	# of Sampling dates	Subbasin(s)	Flow	DO	FC Bact.	°C	Turbidity	TSS	TP, N+N, SRP, NH_3	Other	Notes
20	1982-83 1995	8		Columbia River Trib	X			X			X	Metals	
21	1988-1989	4	4					X			X	Metals, chloride	Springs
	1979	4	4					X			X	Metals, Nuts	Wells

Surface Water

1. WDOE Ambient Data
2. Timber/Fish/Wildlife – Ecoregion Bioassessment Pilot Project (1992-1993)
3. WDOE – Memorandum – WA-30-1010
4. WDOE – Memorandum – WA-30-1020 (83e25)
5. WDOE – Memorandum – WA-30-1020 (85e20)
6. Horsehaven/Klickitat Water Quality Management Area WA-30-1030 (93-e08)
7. WDOE – Memorandum – WA-30-1020 (86-e22)
8. WDOE – Flow Summary at three seasonal gauging stations on the Little Klickitat River (01-03-006)
9. Klickitat County Dallesport Area – General Sewer Plan Jan 1999
10. Boise Cascade Corporation – Upper Little Klickitat Watershed Analysis July 1999
11. WDOE – Water in Horse Haven Hills – Water Supply Bulletin 51 1982
12. WDOE – Little Klickitat River Watershed Temperature TMDL Technical Report March 2002
13. Central Klickitat Conservation District – Lower Little Klickitat River – Draft Watershed Management Plan June 1999
14. Central and Eastern Klickitat Conservation District – Watershed Inventory Project – January 1991
15. Columbia Basin System Planning Draft Klickitat Subbasin May 1989
16. NRCS files (Raw Hobo data and 5-day 24-hour maximum and minimum temperature data files).
17. USGS National Stream WQ Monitoring Networks (http://water.usgs.gov/pubs/dds/wqn96cd/html/wqn/wq/region17/14113000.htm)
18. Economic Action Programs (www.fs.fed.us/r6/coop/programs/rca/stories/wa_klickitat_2001.pdf)
19. USGS – 2000 Annual Data Report (wa.water.usgs.gov/realtime/adr/2000/
20. Columbia Gorge National Scenic Area Management Plan (www.co.multnomah.or.us/dscd/landuse/CRGNSAPlan/Home/NSAMP_Home.html

21. www.reo.gov/crg/crgnsa_data_www.htm
22. www.reo.gov/reo/data/data.htm
23. www.ecy.wa.gov/watershed/30.html
24. EPA – Surf your watershed (http://cfpub.epa/gov/surf/huc.cfm?huc_code=17070106
25. Boise Cascade-Yakima Tribe (File: Klickitat Temperature Data)
26. Draft FY2001-2003 Columbia Gorge Province Work Plan (File: Columbia Gorge)
27. NWPPC – Draft Klickitat Subbasin Summary Nov 2000 (File: NWPPC Klickitat subbasin plan – draft, Appendix A, B, C)
28. EPA STORET database (http://www.epa.gov/cgi-bin/)

Groundwater

1. Klickitat Horsethief Landfill – 1995 Annual Water Quality Report March 1996
2. Klickitat Horsethief Landfill – 1999 Annual Water Quality Report December 1999
3. Watershed Approach to Water Quality Management – Water Quality Plan of Action for the Horseheaven/Klickitat Watershed July 1997
4. Environmental Assessment – Yakima-Klickitat Production Project April 1990
5. WDOE Watershed Approach to Water Quality Management Needs Assessment for the Horseheaven/Klickitat Watershed June 1994
6. Comprehensive Water Plan for the City of Goldendale April 1985
7. WDOE – 303(d) listing for WRIA 30
8. City of Goldendale Watershed Management Plan Oct 1998
9. Klickitat County Dallesport Areas – Water System Plan Jan 1999
10. Comprehensive Water System Plan for the City of Goldendale Feb 1995
11. Personal Communication with Mark Yinger July 17, 2002
12. Personal Communication with Bruce Sherling Southwest WA Health Dept. July 17, 2002
13. Personal Communication with Dan O'Donaghue – Klickitat County Health July 17, 2002
14. Personal Communication with Lorane Reynolds – Klickitat PUD July 18, 2002
15. Personal Communication with Dave Clayton – Conservation District July 19, 2002
16. DOH – IOC data
17. Personal Communication with Kim Sherwood – Yakima WDOE July 19, 2002
18. Personal Communication with Tim Flynn – ASPECT July 22, 2002
19. Personal Communication with Jim Mathews – Yakima Indian Nation July 23, 2002
20. Groundwater Quality Characterization and Nitrate Investigation of the Glade Creek Watershed – WDOE Publication No. 96-348 (November 1996)
21. EPA STORET database (http://www.epa.gov/cgi-bin/)

APPENDIX A

Chapter 5: Water Quantity

Table of Contents

5.1 Surface Water ***1***
5.1.1 Stream flow Estimates *1*
5.1.1.1 Upper Klickitat Subbasin *5*
5.1.1.2 Middle Klickitat Subbasin *6*
5.1.1.3 Little Klickitat Subbasin *10*
5.1.1.4 Lower Klickitat Subbasin *10*
5.1.1.5 Swale Creek and Columbia Tributaries *14*
5.1.1.6 Confidence in Stream flow Estimates *14*
5.1.2 Trend Analysis *15*
5.1.2.1 Stream Flow Trend Analysis *15*
5.1.2.2 Residual Variation Trend Analysis *18*
5.1.2.3 Summary of Trend Analyses *25*
5.1.3 Peak Flows *26*

5.2 Groundwater ***26***
5.2.1 Groundwater Recharge and Discharge *28*
5.2.1.1 Groundwater Recharge *28*
5.2.1.2 Groundwater Discharge *32*
5.2.2 Groundwater Occurrence and Flow Directions *33*
5.2.3 Groundwater Conditions and Hydraulic Continuity by Subbasin *34*

List of Tables

Table 5-1. USGS stream gages in WRIA 30. *5-3*

Table 5-2. Subbasin characteristics considered when selecting representative stream gages. *5-5*

Table 5-3. Summary of trend analysis results. *5-16*

Table 5-4. Regression results for equations predicting stream flow based on precipitation and residual trend analysis results. *5-20*

Table 5-5. Estimated peak discharge at USGS stream gages within WRIA 30 by recurrence interval. *5-27*

Table 5-6. Estimated Annual Recharge Volumes by Subbasin *5-31*

List of Figures

Figure 5-1. USGS stream gages in WRIA 30. Data Sources: USGS (2002a). 5-2

Figure 5-2. Timelines of the 12 USGS stream gages located within WRIA 30 that have mean daily flow data. 5-4

Figure 5-3. Mean Annual Flow Time Series at the Klickitat River gage near Glenwood 5-6

Figure 5-4. Monthly median and low flows at the Klickitat River gage near Glenwood. 5-7

Figure 5-5. Mean monthly stream flows, expressed as unit-area runoff at two gages in the Middle Klickitat subbasin..... 5-8

Figure 5-6. Comparison of mean monthly stream flows at the Klickitat River gage near Pitt for the water years 1997 through 2000 and long-term time periods. ... 5-9

Figure 5-7. Estimated median and low flows by month for the Middle Klickitat subbasin. 5-9

Figure 5-8. Mean monthly stream flows, expressed as unit-area runoff at three gages in the Little Klickitat subbasin for the time period from August 1964 through September 1970..... 5-11

Figure 5- 9. Mean annual flow time series for the stream gage on the Little Klickitat River near Wahkiacus. 5-11

Figure 5-10. Estimated median and low flows by month for the Little Klickitat subbasin. 5-12

Figure 5-11. Mean annual flow time series at the Klickitat River gage near Pitt 5-13

Figure 5- 12. Median and low flows by month at the Klickitat River gage near Pitt... 5-13

Figure 5-13. Estimated median and low flows by month for stream flow inputs in the Lower Klickitat subbasin excluding inputs from upstream subbasins..... 5-14

Figure 5-14. Frequency of annual low flows by month at the Little Klickitat River gage near Wahkiacus and the Klickitat River gage near Pitt..... 5-17

Figure 5-15. Annual low flows at the Klickitat River gage near Pitt..... 5-17

Figure 5-16. Annual low flows at the Little Klickitat River gage near Wahkiacus..... 5-18

Figure 5-17. Relationship between mean annual discharge at the Little Klickitat River gage near Wahkiacus and annual precipitation at the Goldendale/Goldendale 2E station. 5-20

Figure 5-18. Temporal distribution of residual variation in relationship between mean annual discharge at the Little Klickitat River gage near Wahkiacus and annual precipitation at the Goldendale/Goldendale 2E station. 5-21

Figure 5-19. Relationship between annual low flow at the Little Klickitat River gage near Wahkiacus and the precipitation index at the Goldendale/Goldendale 2E station. 5-21

Figure 5-20. Temporal distribution of residual variation in relationship between annual low flow discharge at the Little Klickitat River near Wahkiacus gage and precipitation index at the Goldendale/Goldendale 2E station..... 5-22

Figure 5-21. Relationship between mean annual discharge at the Klickitat River gage near Pitt and annual precipitation at the Goldendale/Goldendale 2E station. 5-23

Figure 5-22. Temporal distribution of residual variation in relationship between mean annual discharge at the Klickitat River gage near Pitt and annual precipitation at the Goldendale/Goldendale 2E station. 5-23

Figure 5-23. Relationship between annual low flow discharge at the Klickitat River gage near Pitt, and precipitation index at the Goldendale/Goldendale 2E station. 5-24

Figure 5-24. Temporal distribution of residual variation in relationship between annual low flow discharge at the Klickitat River gage near Pitt and precipitation index at the Goldendale/Goldendale 2E station. 5-24

Figure 5-25. Relationship between annual low flow discharge at the Klickitat River gage near Pitt, and maximum snow pack at the Lost Horse SNOTEL site..... 5-25

Figure 5-26. Estimated Annual Groundwater Recharge Rates.. 5-30

Figure 5- 27. Groundwater Elevations and Inferred Flow Directions in the Grande Ronde Basalt. 5-34

Figure 5-28. Groundwater Elevations and Inferred Flow Directions in the Wanapum Basalt..... 5-36

(This page left intentionally blank)

Chapter 5: Water Quantity

Surface and ground water contribute to the total amount of water available within each subbasin and across the WRIA. This section provides an overview of what is known about water volume in the basin. Section 5.1 covers surface water and Section 5.2 covers ground water distribution and abundance as well as the interactions between surface and ground water.

5.1 SURFACE WATER

5.1.1 Stream flow Estimates

Fifteen USGS stream gages are, or were, located within WRIA 30 (Figure 5-1, Table 5-1). Not all stream gages are currently active, and several contain records that are too short to be of any practical use. Additionally, several of the stations only have records for peak stream flows. Daily stream flow records are available from twelve of the USGS stream gages in WRIA 30 (Table 5-1).

Estimates of stream flow in terms of cubic feet per second (cfs) were made for each subbasin using selected gage records. Caution should be used in interpreting these results, as they do not truly represent a "natural", or pre European-settlement condition. All of the gages have had some degree of land use change in their upstream contributing areas which may affect stream flow and most have had some amount of water diversion during the period or record. Although it is not possible to quantify (at least at Level I) what these changes from a "natural" condition are, it is reasonable to use estimated values derived from these gage records to assess current water availability.

Most of the stream flow gages in WRIA 30 are not currently active (Figure 5-2). This raises a question of whether a stream flow record that ended 20 years ago (e.g., gage #14112500) is representative of current conditions. The use of this "old" data is representative of current conditions provided that the conditions influencing stream flow at the time the data was recorded have not changed significantly from the period of record to the present day. This older data is also valuable in assessing flow patterns during wetter or drier periods than the present.

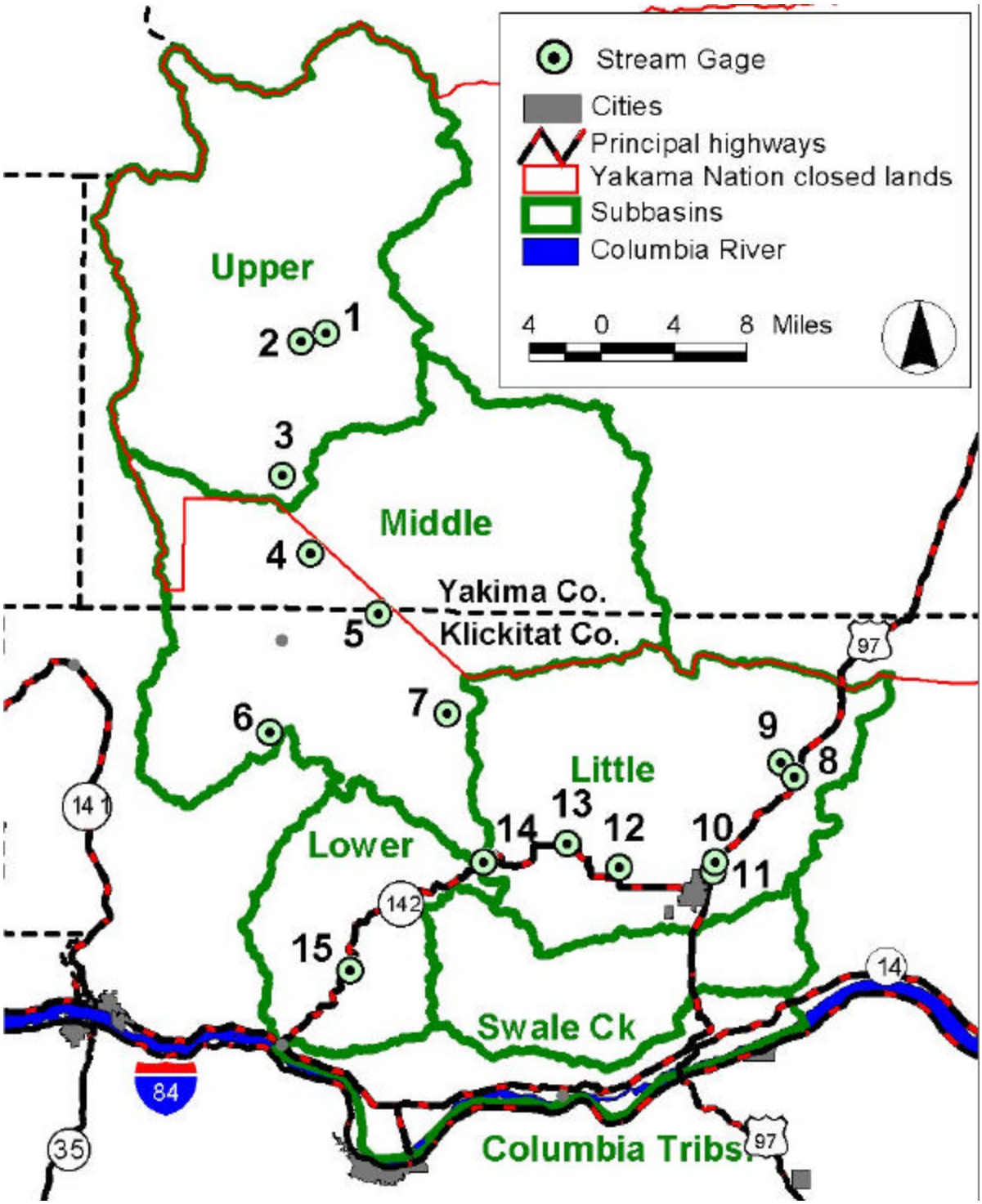


Figure 5-1. USGS stream gages in WRIA 30. Data Sources: USGS (2002a).

Table 5-1. USGS stream gages in WRIA 30. Map number refers to Figure 5-1.

Map #	Sta. #	Station Name	Drain. area (mi^2)	Daily Stream flow: Period of record	Daily Stream flow: Years	Peak Stream flow: Period of record	Peak Stream flow: Years	Remarks[1]
1	1410-7000	Klickitat R Abv West Fork Nr Glenwood	151	10/01/1944 - Current	42	1945-Current	43	No regulation or diversion
2	1410-8000	West Fork Klickitat R Nr Glenwood	87	07/01/1910 - 09/30/1948	8	n/a	n/a	Flows seasonally affected by snow melt or glacial-melt. No diversion.[3]
3	1410-9000	Big Muddy Cr Nr Glenwood	22.5	09/01/1916 - 09/30/1949	8	n/a	n/a	
4	1411-0000	Klickitat River Nr Glenwood	360	11/01/1909 - 09/30/1971	62	1909-1979	69	
5	1411-0500	Indian Ford Springs No. 1 Nr Glenwood	n/a	10/01/1946 - 09/30/1948	2	n/a	n/a	
6	1411-0700	Medley Canyon Cr Nr Glenwood	1.26	n/a	n/a	1970-1976	7	
7	1411-1400	Klickitat R Bl Summit Cr Nr Glenwood	n/a	10/01/1996 - Current	4	1997-Current	4	No regulation, some upstream diversion for irrigation
8	1411-1700	Butler Creek Nr Goldendale	11.6	8/1/1964 - 09/30/1968	4	n/a	n/a	
9	1411-1800	W Prong Little Klickitat R Nr Goldendale	10.4	n/a	n/a	1961-1975	15	
10	1411-2000	Little Klickitat R Nr Goldendale	83.5	10/01/1910 - 09/30/1970	20	1911-1912; 1945-1978	27	Small diversion for domestic use and irrigation of 35 acres. No regulation.[2]
11	1411-2200	Little Klickitat River Trib Nr Goldendale	0.71	n/a	n/a	1960-1988	29	
12	1411-2300	Spring Creek Near Blockhouse	2.75	08/01/1964 - 09/03/1968	4	n/a	n/a	Small diversions for fish hatchery and uses either for domestic, municipal or industrial sources.[3]
13	1411-2400	Mill Creek Nr Blockhouse	26.9	08/01/1964 - 10/12/1972	8	1965-1978	14	Small diversions for irrigation and uses either for domestic, municipal or industrial sources.[3]
14	1411-2500	Little Klickitat R Nr Wahkiacus	280	12/01/1944 - 10/14/1981	36	1945-1981	36	Small diversions above station for irrigation of 600 acres.[2]
15	1411-3000	Klickitat River Near Pitt	1,297	07/01/1909 - Current	75	1910-1912; 1929-2000	75	Diversions upstream for irrigation of 7,500 acres.

Notes: [1] All information from EarthInfo (1996) or USGS (2002a), unless otherwise noted.
[2] From USGS (1962)
[3] From Sinclair and Pitz (1999)
n/a = not available

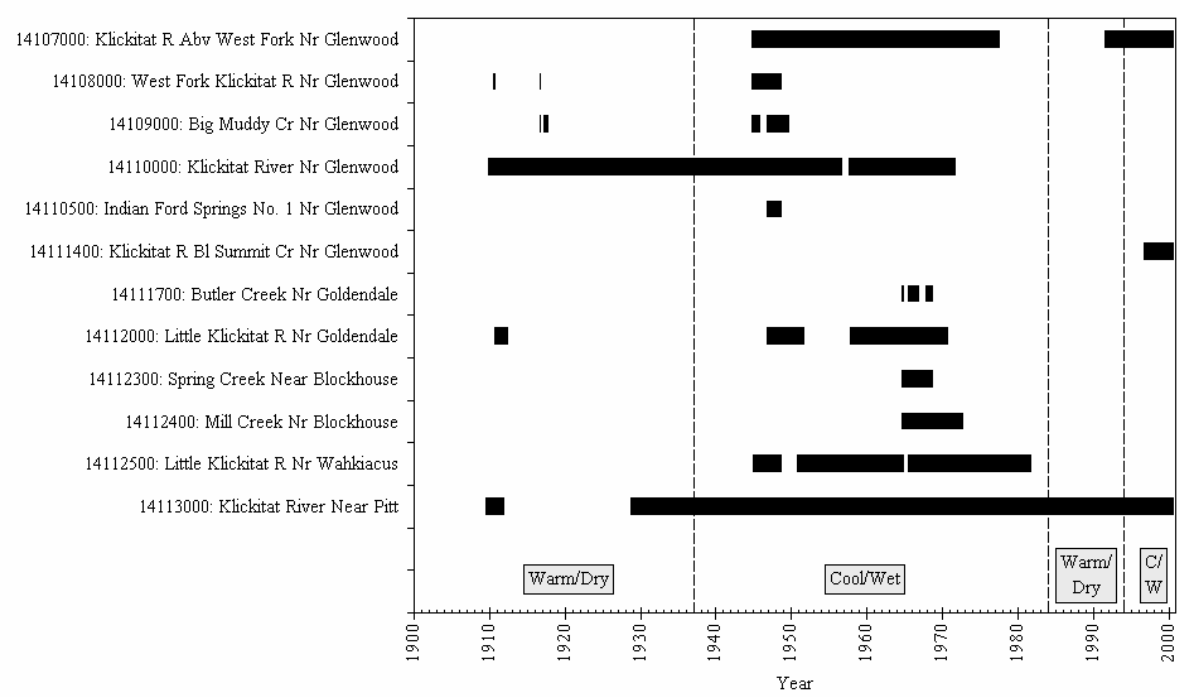


Figure 5-2. Timelines of the 12 USGS stream gages located within WRIA 30 that have mean daily flow data. Local Pacific Decadal Oscillation (PDO) cycles are shown as vertical dashed lines. Refer to Figure 5-1 and Table 5-1 for gage locations. Refer to Chapter 2.0 for further discussion of PDO cycles.

As discussed in greater detail in Chapter 2.0, the principal factor that we need to consider when examining long term precipitation patterns is the Pacific Decadal Oscillation, or PDO. The PDO consists of warm/dry and cold/wet phases that persist for 20 to 30 year periods. The four distinct PDO cycles that have occurred since 1910 are shown in Figure 5-2. When evaluating data from a particular gage, it is important to compare the proportion of the record that falls within these warm/dry and cold/wet PDO phases.

An additional factor to consider when evaluating the appropriateness of a particular gage record for representing current conditions is the change in land use patterns over the period of record (Table 5-2). Changes in land use may directly affect runoff through changes in watershed parameters affecting runoff (e.g., impermeable area associated with certain land uses, changes in vegetation patterns), as well as indirectly through the variable water demand associated with different water uses. No effort was made to evaluate how changes in land uses may have changed runoff characteristics as part of this Level I assessment; however this could be advanced as a Level II recommendation.

The information provided below summarizes the amount of surface water present by month in median and low stream flow years in each subbasin. The 50- and 90-percent

exceedance values were used to represent the median and low flows respectively[1]. Monthly exceedance flows were first calculated for each of the representative gages using mean daily flow values. The methods used to extrapolate from gage records to subbasins varied slightly, consequently, results are presented by subbasin below.

Table 5-2. Subbasin characteristics considered when selecting representative stream gages.

Subbasin Name	Drainage Area[1] (mi^2)	Elevation (ft): Median (Range)[1]	Median Subbasin Slope (%)[1]	Mean Annual Precip[1] (Inches)	Percent subbasin area in HSG[2] A&B[1]	Stream Flow Station Data
Upper Klickitat	350	4,518 (1,969-12,297)	16%	67	76%	14107000 14108000 14109000
Middle Klickitat	467	2,644 (558-9,397)	9%	51	88%	14110000 14110500 14111400
Little Klickitat	280	2,275 (558-5,824)	8%	26	75%	14111700 14112000 14112300 14112400 14112500
Swale Creek	126	1,785 (509-3,219)	5%	23	42%	None
Lower Klickitat	128	1,913 (75-3,166)	12%	26	70%	14113000
Columbia Tributaries	91	929 (75-3,215)	15%	20	42%	None

Notes: [1] From section 2.0 of this report
[2] Hydrologic soil group; see Section 2.0 for further discussion.

5.1.1.1 Upper Klickitat Subbasin

The Upper Klickitat subbasin was not included in this assessment due to an agreement between the WRIA 30 Planning unit and the Yakama Nation. However, it was necessary to approximate stream flows at the outlet of the Upper Klickitat subbasin. Stream flow data from the Klickitat River near Glenwood gage #14110000 (Figure 5-1, Table 5-1) were used in this analysis to approximate the flows coming out of the Upper Klickitat subbasin. Gage #14110000 is the obvious choice for representing stream flows at the outlet of the Upper Klickitat subbasin, as the drainage area of the subbasin (350 mi^2; Table 5-2) almost exactly matches the drainage area contributing to the stream gage (360 mi^2; Table 5-1). Approximately ½ the period of record coincides with a cool/wet PDO cycle and the remainder coincides with a warm/dry cycle (Figure 5-2). These cycles are

[1] Flows are larger than the 50% exceedance flow 50% of the time. Hence, the 50% exceedance flow represents a median flow. Flows are larger than the 90% exceedance flow 90% of the time. Hence, the 90% exceedance flow represents not the lowest flow seen in the basin, but a very low flow.

apparent in the yearly mean annual flows (Figure 5-3). Consequently, stream flow statistics calculated using this gage record should approximate average conditions. The monthly median flows (50% exceedance) at this gage range from 422 cfs in October to 1750 cfs in May (Figure 5-4). Mean low flows (90% exceedance) range from 307 cfs in October to 1050 cfs in May.

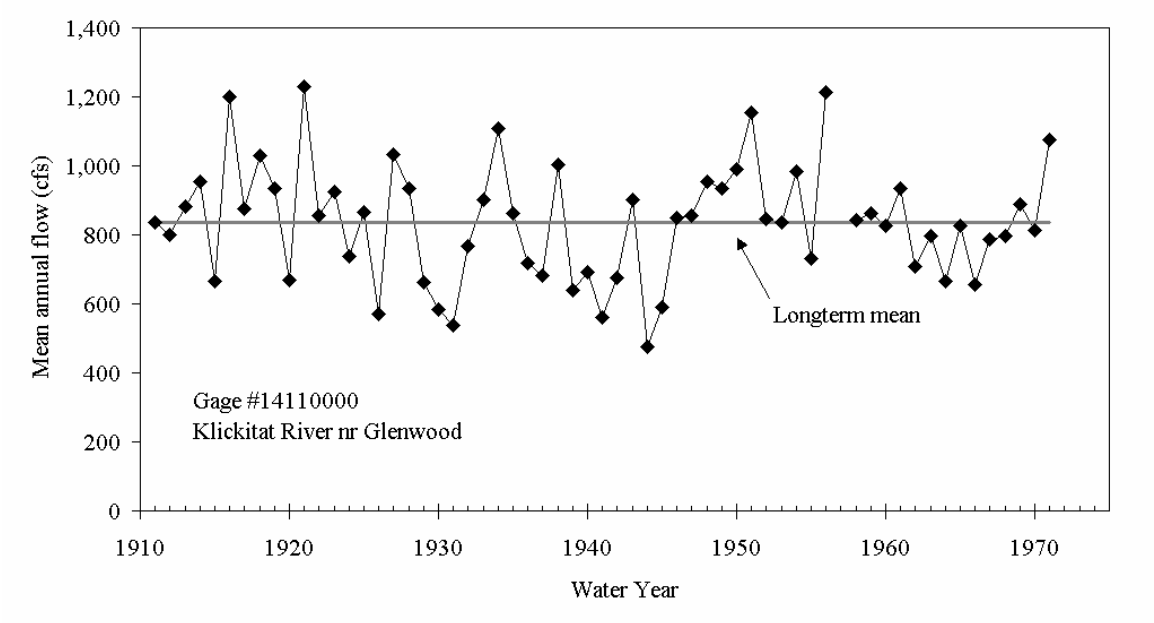


Figure 5-3. Mean Annual Flow Time Series at the Klickitat River gage near Glenwood

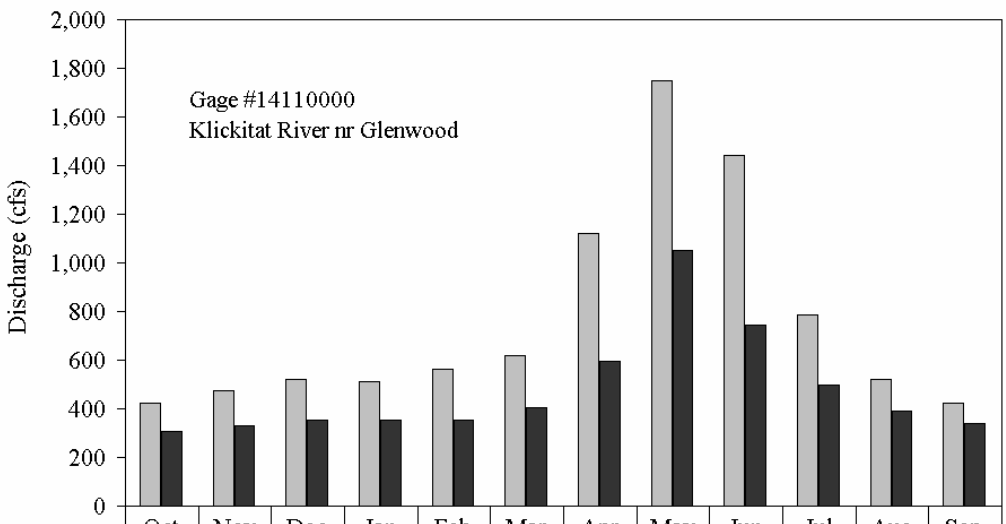
5.1.1.2 Middle Klickitat Subbasin

The Middle Klickitat subbasin drains 467 mi^2, approximately half of which is within Yakama Nation closed lands (Figure 5-1). Mean monthly flows for the two mainstem gages in this subbasin were converted to unit area[2] values to compare hydrologic patterns (Figure 5-5). The two stations do not have coinciding stream flow data. The upstream gage (#14110000) operated for 62 years ending in 1971. The downstream gage (#14111400) operated in Water Years[3] 1997 to 2000, which were wetter than normal years (Figure 5-2).

---

[2] Unit area runoff is the stream flow normalized by contributing watershed area. For example, if the mean monthly discharge was 45 cfs at a stream gage having a watershed area of 100 mi^2, the UAR would be 45cfs/100 mi^2 = 0.45 cfs/mi^2

[3] 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

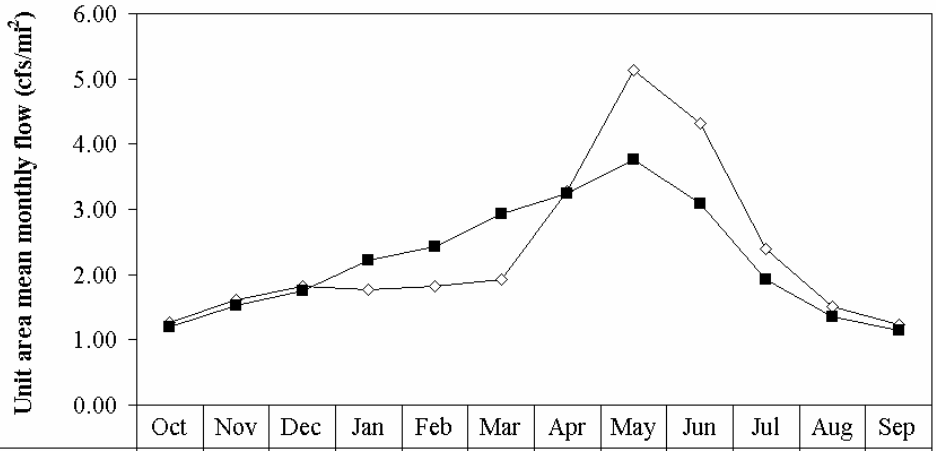


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
50% Exceedance Flow	422	476	522	511	562	619	1120	1750	1440	788	520	424
90% Exceedance Flow	307	328	352	355	355	404	595	1050	745	497	390	340

Figure 5-4. Monthly median and low flows at the Klickitat River gage near Glenwood

Comparison of the hydrographs at the two stations reveals different hydrologic patterns. The downstream gage records have relatively higher runoff in the winter months and lower runoff during the spring snowmelt season. Because the two stations were not in operation at the same time it was important to discern if the short record was representative of longer-term conditions.

The gage near the mouth of the Klickitat River (#14113000) has operated continuously from 1909, encompassing the period of record for both upstream gages. Comparison of recorded flows in the time period spanning water years 1997 through 2000 with the long-term mean flow recorded at gage #14113000 revealed that not only was the period from 1997 to 2000 wetter than normal, the pattern of runoff was shifted toward higher winter flows (Figure 5-6), suggesting that the short period of record does not reflect longer term hydrologic patterns. Based on this information, stream flow at the outlet of the Middle Klickitat subbasin was estimated using the unit runoff from the longer-term upstream gage (#14110000). Subbasin characteristics for both the Upper and Middle Klickitat subbasins are similar enough (Table 5-2) that estimated values for the Middle Klickitat subbasin based on gage #14110000 should be reasonable.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Gage #14110000: Klickitat River near Glenwood	1.26	1.61	1.83	1.77	1.82	1.93	3.27	5.14	4.31	2.39	1.51	1.23
Gage #14111400: Klickitat River below Summit Ck near Glenwood	1.19	1.53	1.76	2.22	2.42	2.93	3.25	3.77	3.09	1.92	1.35	1.15

Figure 5-5. Mean monthly stream flows, expressed as unit-area runoff (i.e., cfs/square mile), at two gages in the Middle Klickitat subbasin.

As discussed in the previous section, approximately ½ the period of record for gage #14110000 coincides with a cool/wet PDO cycle and the remainder coincides with a warm/dry cycle (Figure 5-2), consequently, stream flow statistics calculated using this gage record should approximate average conditions. Estimated median monthly flow (50% exceedance) ranged from 547 cfs in October to 2270 cfs in May (Figure 5-7). Estimated low flows (90% exceedance) ranged from 398 cfs in October to 1362 in May.

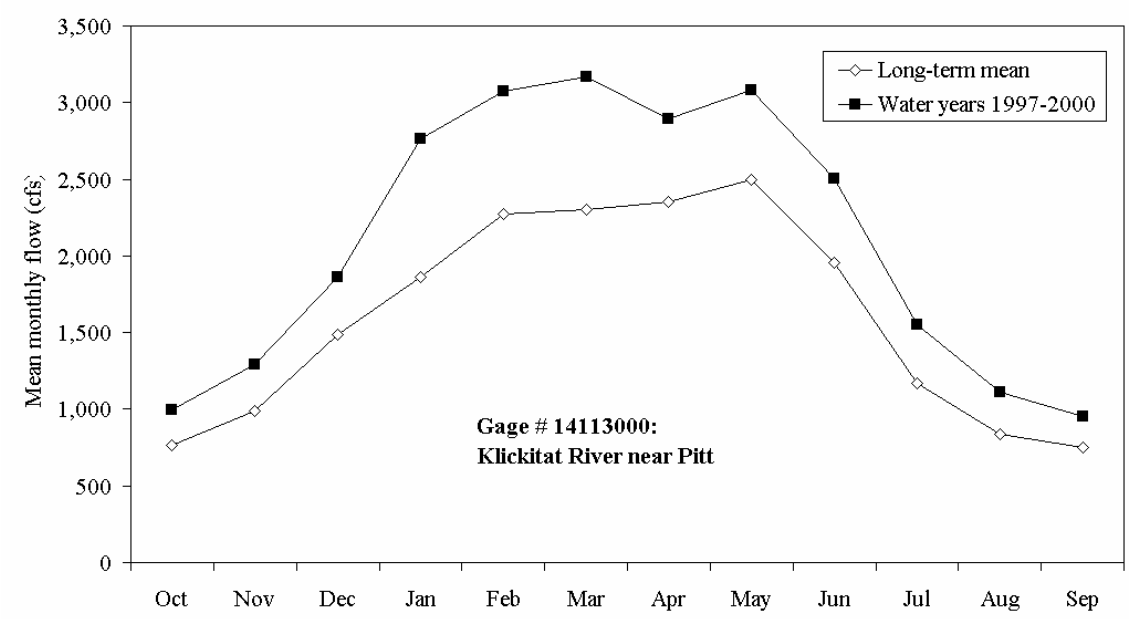
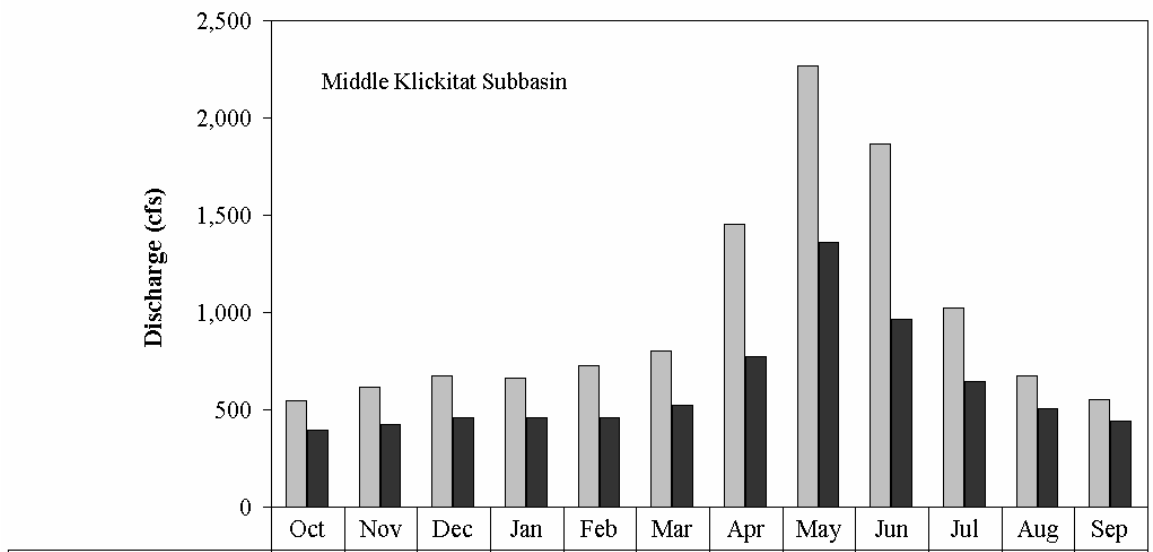


Figure 5-6. Comparison of mean monthly stream flows at the Klickitat River gage near Pitt for the water years 1997 through 2000 and long-term time periods.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
50% Exceedance Flow	547	617	677	663	729	803	1453	2270	1868	1022	675	550
90% Exceedance Flow	398	425	457	461	461	524	772	1362	966	645	506	441

Figure 5-7. Estimated median and low flows by month for the Middle Klickitat subbasin.

5.1.1.3 Little Klickitat Subbasin

Seven stream flow gages were operated historically within the Little Klickitat subbasin, five of which had mean daily stream flow records (Figure 5-1, Table 5-1). Mean monthly unit area stream flows were compiled for the three gages that had eight or more years of data (Figure 5-8) collected from August, 1964 through September, 1970. Hydrologic patterns vary between the three stations. The Little Klickitat near Goldendale data shows higher unit area flows in the winter months and lower unit area flows for the summer months than either of the other two gages. The hydrograph for the Mill Creek near Blockhouse gage has the highest monthly flow values later in the season than at the other two gage locations. These data exemplify the variability that exists within the Little Klickitat subbasin.

The Little Klickitat near Wahkiacus gage (#14112500; Figure 5-1, Table 5-1), located near the mouth of the Little Klickitat River, was used in this analysis to approximate the flows coming out of the Little Klickitat subbasin. Mean annual flow over the period of record is presented for perspective in Figure 5-9. Gage #14112500 is the obvious choice for representing stream flows at the outlet of the subbasin, as the drainage area of the subbasin (280 mi^2; Table 5-2) is the same as the drainage area contributing to the stream gage (280 mi^2; Table 5-1). The entire period of record coincides with a cool/wet PDO cycle (Figure 5-2). Consequently, stream flow statistics calculated using this gage record will overestimate average conditions. The median (50% exceedance) flow ranges from 24 cfs in August to 282 cfs in February (Figure 5-10). The 90% exceedance flow (low flow) ranges from 12 cfs in August to 104 cfs in March.

The City of Goldendale is implementing changes in water sources used to supply water to area residents and businesses. These changes will reduce the total amount of water withdrawn from the Little Klickitat and should increase flow in the river. Currently there is no gage on the Little Klickitat River; hence there is not sufficient information available to depict flow patterns on the Little Klickitat with these modifications in place. Therefore, the summaries of flows presented here do not reflect the changes in water use implemented by the City.

5.1.1.4 Lower Klickitat Subbasin

The longest-term gage in WRIA 30 (over 75 years) is gage #14113000, Klickitat River Near Pitt (Figure 5-1, Table 5-1), located near the mouth of the Klickitat River. Gage #14113000 drains 1,297 mi^2 of the 1,442 mi^2 in the basin. Upstream irrigation use affects the stream flows at the mouth. These irrigation depletions would typically occur during the late summer months depending on crops irrigated. Precise estimates of irrigation use are not available; however estimated use is discussed in Chapter 6.0 of this report.

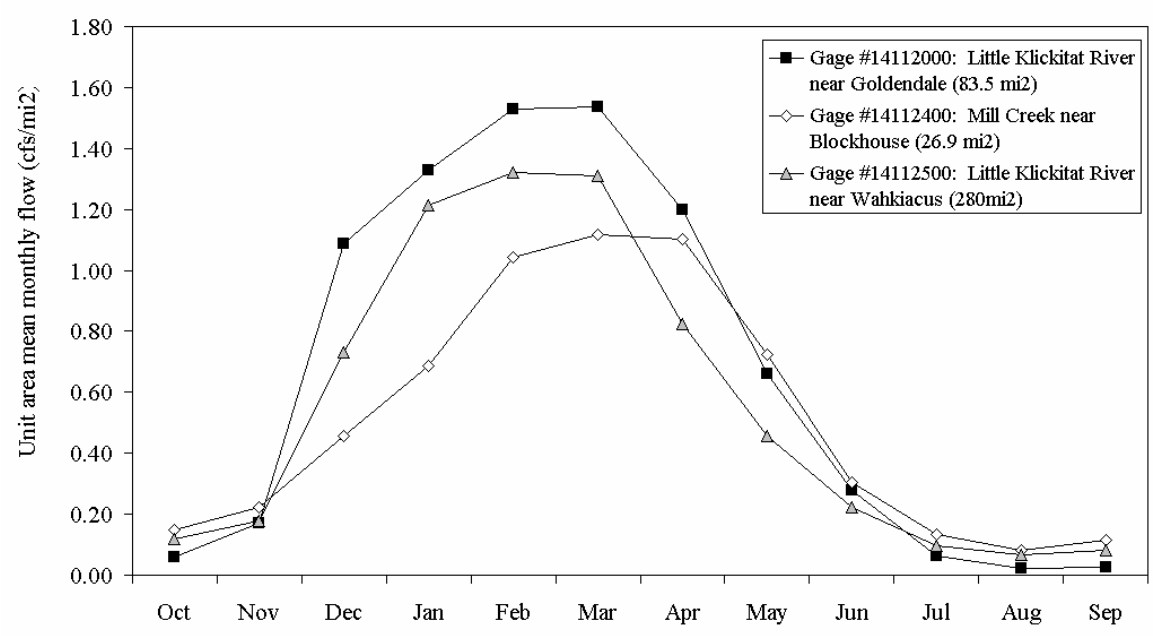


Figure 5-8. Mean monthly stream flows, expressed as unit-area runoff (i.e., cfs/square mile), at three gages in the Little Klickitat subbasin for the time period from August 1964 through September 1970.

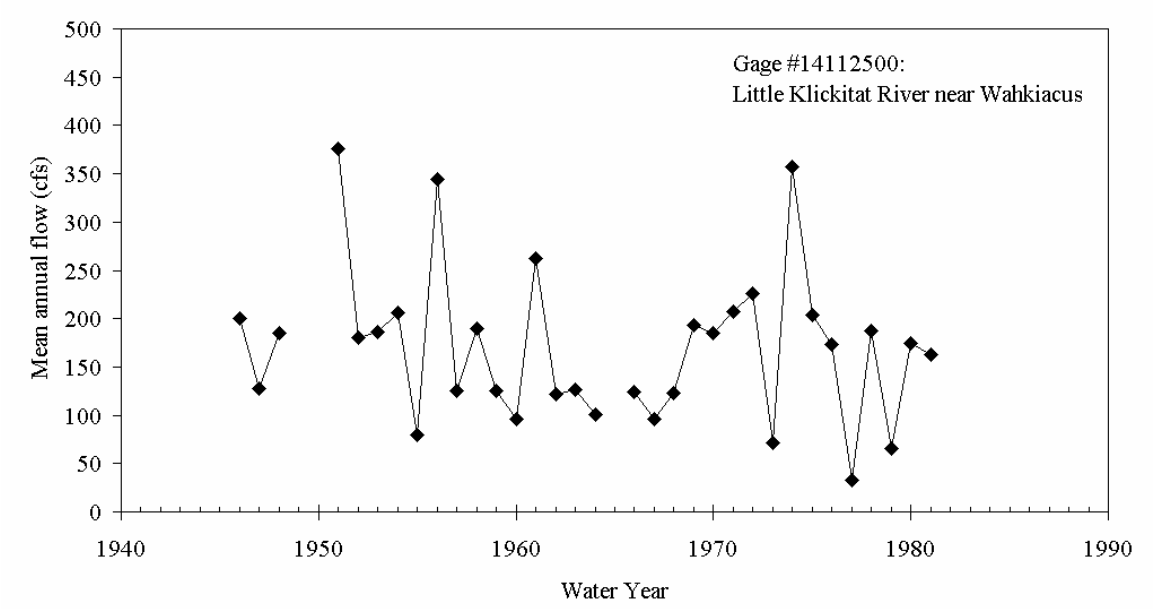
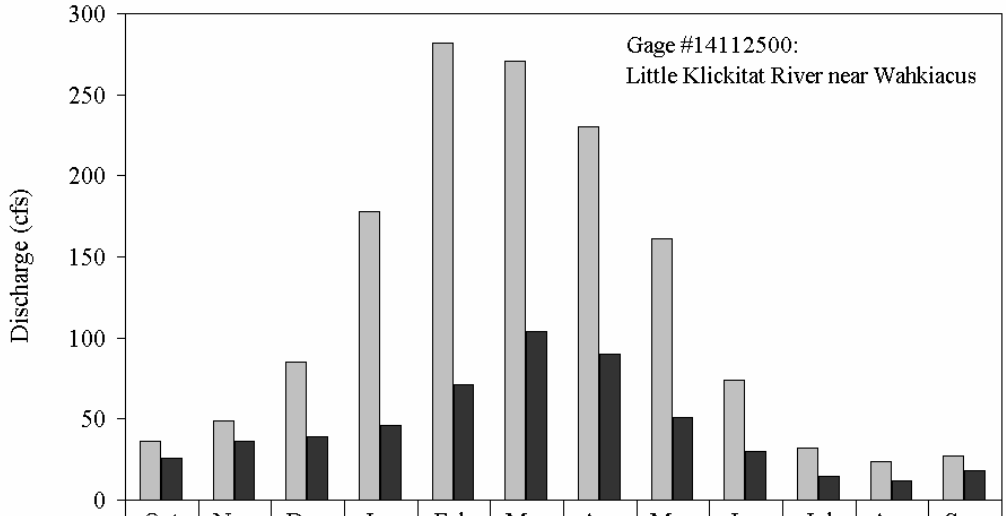


Figure 5-9. Mean annual flow time series for the stream gage on the Little Klickitat River near Wahkiacus.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
50% Exceedance Flow	36	49	85	178	282	271	230	161	74	32	24	27
90% Exceedance Flow	26	36	39	46	71	104	90	51	30	15	12	18

Figure 5-10. Estimated median and low flows by month for the Little Klickitat subbasin.

Mean annual flow over the 75 year record at gage #14113000 (Figure 5-11) reflects variations in the PDO cycles over time. The median average annual flow at the gage has been 1,604 cfs. The median monthly flows (50% exceedance) range from 737 cfs in September to 2390 cfs in May (Figure 5-12). The estimated monthly low flows (90% exceedance) range from 542 cfs in October to 1370 cfs in May.

The Klickitat River near Pitt gage (#14113000; Figure 5-1, Table 5-1) was used in this analysis to approximate the flows from the Lower Klickitat subbasin only, excluding flows coming into the subbasin from upstream subbasins. Approximately ¾ of the period of record coincides with a cool/wet PDO cycle (Figure 5-2). Consequently, stream flow statistics calculated using this gage record overestimate average conditions. Unit runoff values from gage #14113000 were used to estimate the flows actually generated from the 128 mi^2 area designated as the Lower Klickitat subbasin. Estimated median flows (50% exceedance) ranged from 73 cfs in September and October to 236 cfs in May (Figure 5-13). Estimated low flows (90% exceedance) ranged from 53 cfs in October to 135 cfs in May.

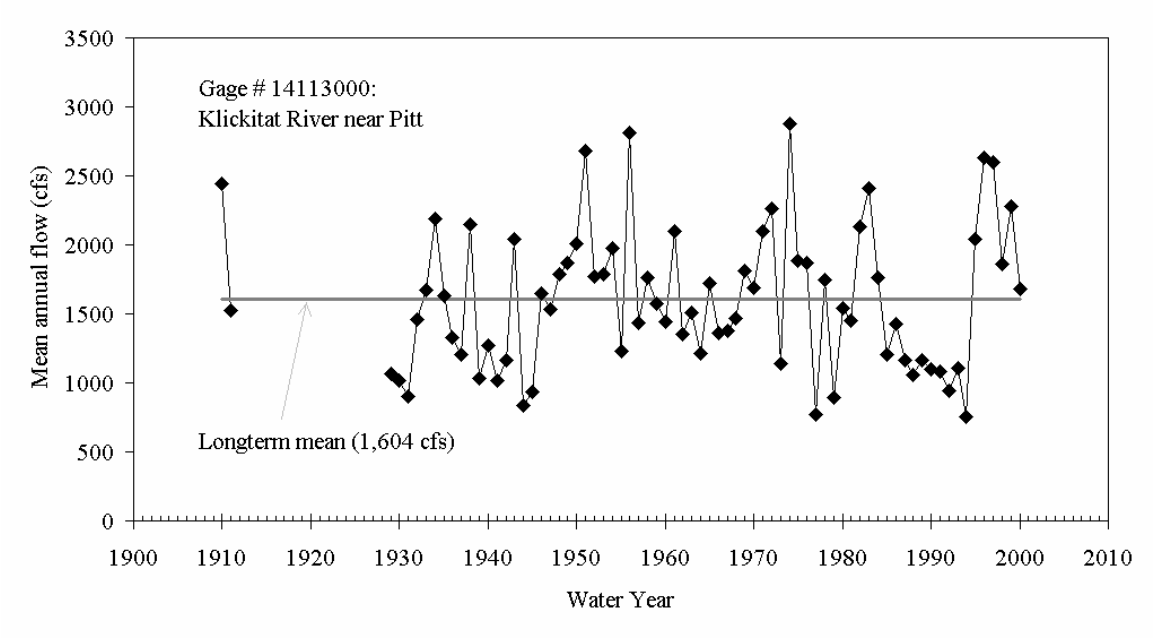
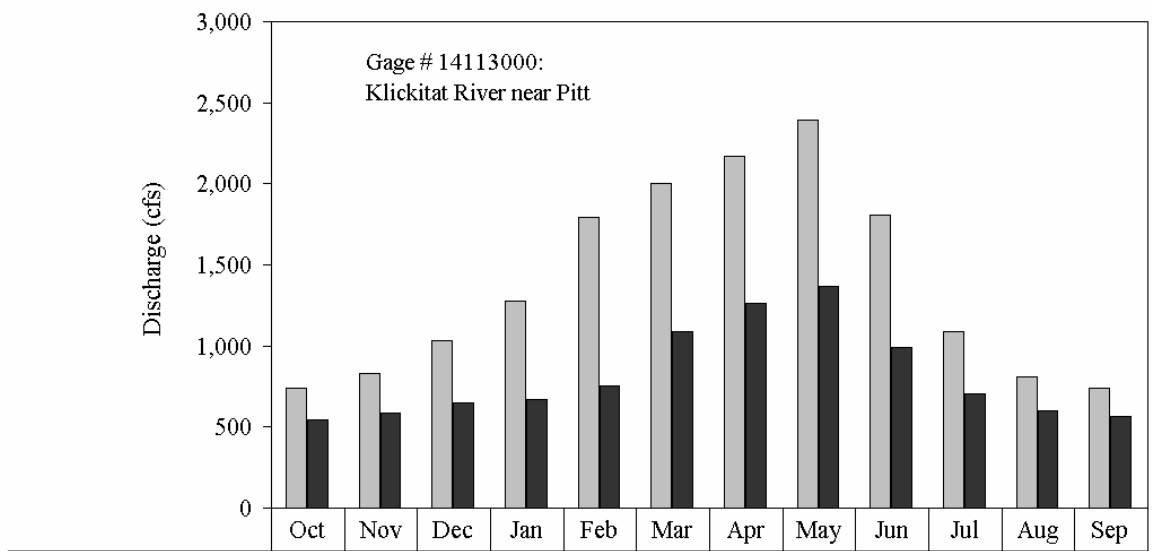


Figure 5-11. Mean annual flow time series at the Klickitat River gage near Pitt .



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
50% Exceedance Flow	742	833	1,030	1,280	1,790	2,000	2,170	2,390	1,810	1,090	808	737
90% Exceedance Flow	542	585	652	669	754	1,090	1,260	1,370	990	704	600	566

Figure 5- 12. Median and low flows by month at the Klickitat River gage near Pitt.

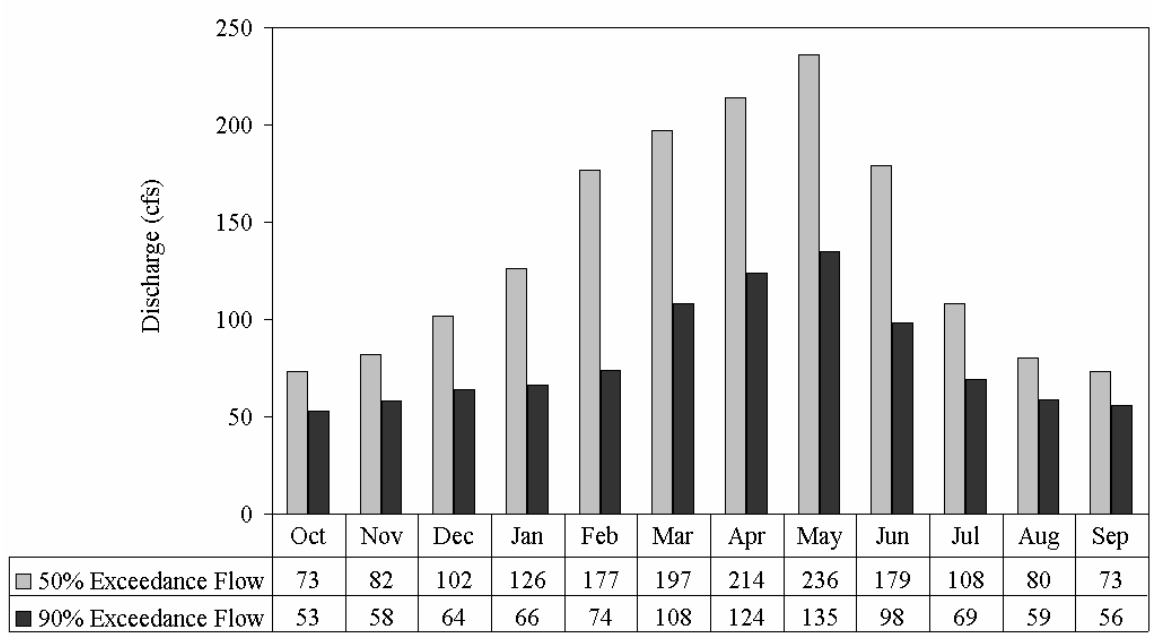


Figure 5-13. Estimated median and low flows by month for stream flow inputs in the Lower Klickitat subbasin excluding inputs from upstream subbasins.

5.1.1.5 Swale Creek and Columbia Tributaries

There were no available stream flow data for either the Swale Creek or Columbia Tributaries subbasins. The characteristics of both of these basins (Table 5-2) are quite different from other gaged basins in the vicinity of WRIA 30, making it difficult to obtain acceptable estimates of stream flow based on monthly unit runoff characteristics from another subbasin. Therefore, no estimates of stream flow were generated for either subbasin.

5.1.1.6 Confidence in Stream flow Estimates

One of the constraints in completing this level I assessment was to limit any analysis to available data resources. Consequently, this assessment of stream flow relied solely on the analysis of available stream flow records from WRIA 30. Relative to other watersheds in the region WRIA 30 has a fairly well distributed network of gages; most subbasins and mainstem reaches having at least one gage with ten or more years of data. However, the confidence in the results presented above is limited by the following:

- For several of the representative gages used in this assessment, the proportion of data was heavily weighted to cool/wet PDO phases. As a result, average stream flow conditions based on the gage record are overestimated in these areas. The average flow calculated for a given month is higher than it would have been had the proportion of cool/wet and warm/dry years been the same.

- No stream gages are located within either the Swale Creek or Columbia Tributaries subbasins. The characteristics of both of these subbasins are different enough from the other subbasins in WRIA 30 to preclude developing estimates of monthly stream flow values.

- Stream flow records are available for only a very short period for stream gage #14111400, Klickitat River Below Summit Creek Near Glenwood. A longer-term record is needed at this location to adequately characterize stream flow within the Middle Klickitat subbasin.

- No attempt was made to factor in possible impacts to stream flows from changing land use patterns over the period of record.

Potential future actions to increase the confidence in stream flow estimates could include:

1) Maintaining existing stream gages in the area,

2) Reactivating discontinued stations,

3) Installing gages in the Swale Creek and Columbia Tributaries subbasins,

4) Developing a stream flow model for the basin that incorporates changes in land use patterns.

5.1.2 Trend Analysis

The purpose of this portion of the assessment was to evaluate trends over time for both mean annual and annual low flows in WRIA 30. Two approaches were used. First, trends were investigated in the stream flow variables themselves. Secondly, trends were investigated in the residual variation after the influence of precipitation had been factored out.

Two stream gages were selected for this analysis; one gage to represent conditions in the tributary streams, and the second to represent conditions in the mainstem Klickitat River. The Little Klickitat River near Wahkiacus gage (#14112500) was selected as the representative tributary gage because it has the longest period of record of any tributary gage in WRIA 30 (Figure 5-2). The Klickitat River near Pitt gage (#14113000) was selected for analysis because it has the longest period of record of any gage in WRIA 30, and it provides the best available representation of conditions closest to the mouth of the Klickitat River.

5.1.2.1 Stream Flow Trend Analysis

A statistical trend analysis was performed to determine if significant time trends exist for mean annual flow and annual low flow at each of the two representative locations. Kendall's rank-order correlation (Kendall and Gibbons, 1990) was used to test for trends over time. Kendall's test is a non-parametric method of determining an increasing or

decreasing trend in a paired data set. Values of the trend coefficient range from –1.0, which indicates a perfect inverse correlation, to 1.0, which indicates a perfect positive correlation. For this analysis, significance was defined at the $p < 0.05$ level.

Mean annual flow showed no significant trends over the period of record at either the Klickitat River gage near Pitt or Little Klickitat River gage near Wahkiacus (Table 5-3, Figures 5-9 and 5-11). This suggests there is no long-term trend (either decreasing or increasing) in mean annual flows. The primarily limitation in this analysis is the discontinuity and relatively short period of record for the Little Klickitat River near Wahkiacus data set. Annual low flows occur primarily in the month of August at the Little Klickitat River gage near Wahkiacus, and in the months of September and October at the Klickitat River gage near Pitt (Figure 5-14). Annual low flows also showed no significant trends over the period of record at the Klickitat River gage near Pitt (Figure 5-15); however, a significant declining trend was observed in the data from the Little Klickitat River gage near Wahkiacus (Figure 5-16, Table 5-3).

Table 5-3. Summary of trend analysis results.

Stream flow variable		Period of record (water year)	n	Trend coefficient	Significance
Mean annual flow:	Klickitat River near Pitt (#14113000)	1910-1911 1929-2000	74	0.026	0.7404
Mean annual flow:	Little Klickitat River near Wahkiacus gage (#14112500)	1946-1948 1951-1964 1966-1981	33	-0.129	0.2921
Annual low flow:	Klickitat River near Pitt (#14113000)	1910-1911 1929-2000	74	0.021	0.7938
Annual low flow:	Little Klickitat River near Wahkiacus gage (#14112500)	1946-1948 1951-1964 1966-1981	33	-0.381	0.0024

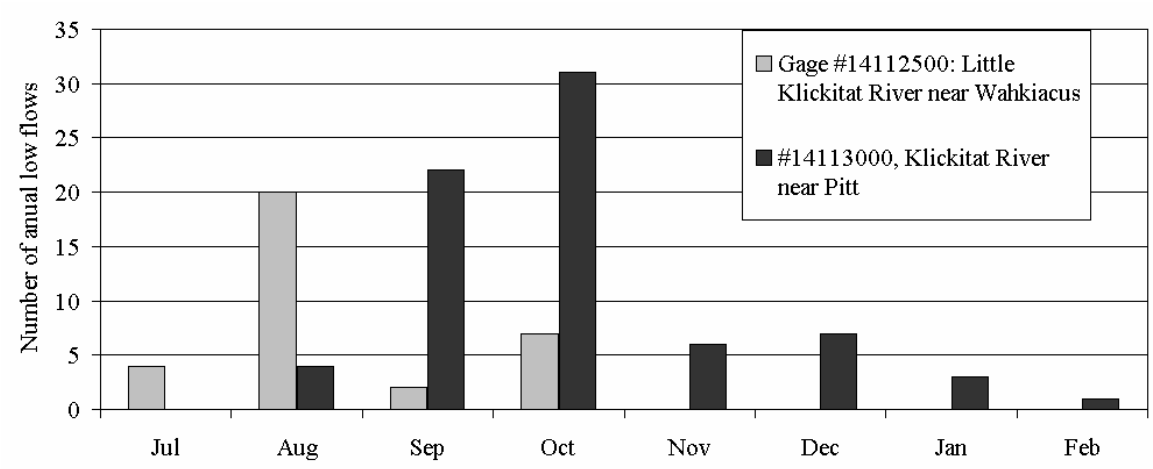


Figure 5-14. Frequency of annual low flows by month at the Little Klickitat River gage near Wahkiacus and the Klickitat River gage near Pitt.

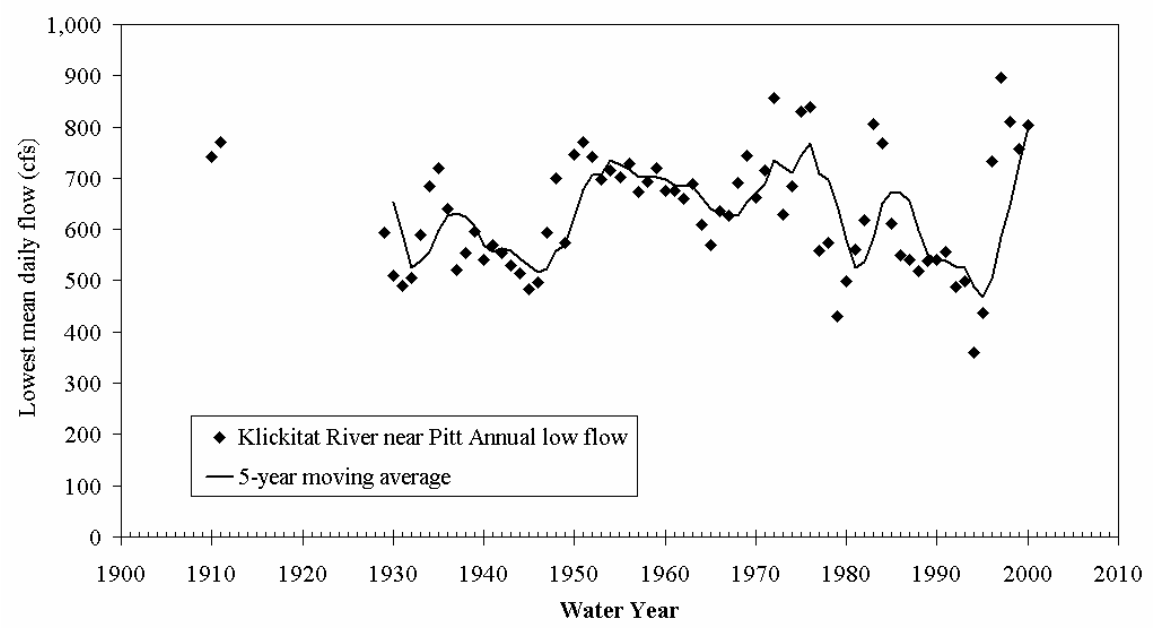


Figure 5-15. Annual low flows at the Klickitat River gage near Pitt.

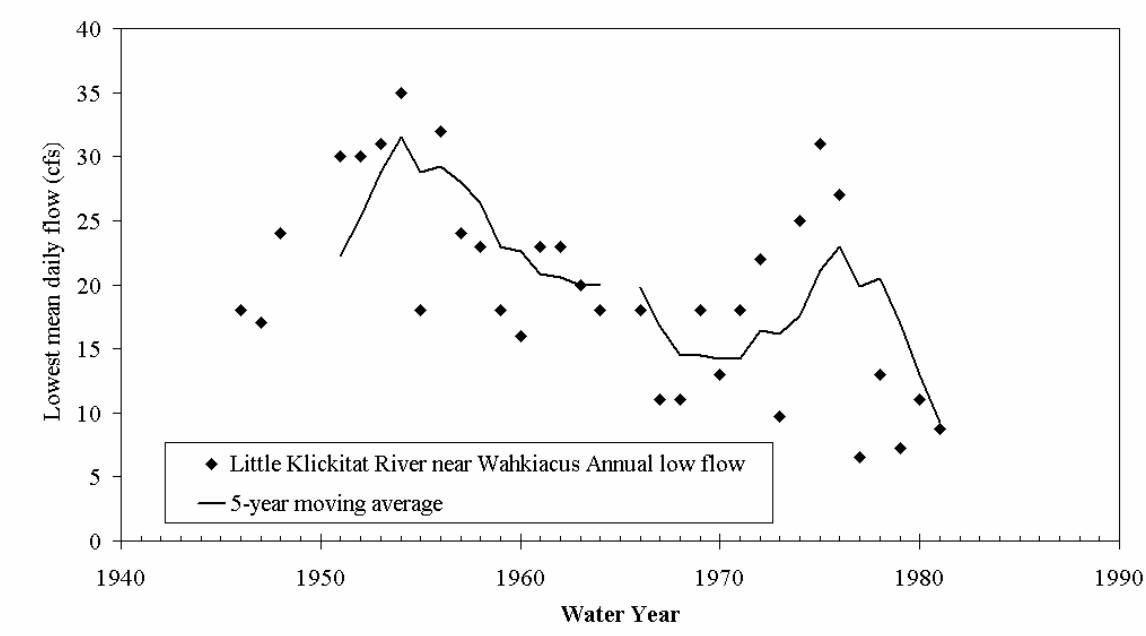


Figure 5-16. Annual low flows at the Little Klickitat River gage near Wahkiacus.

5.1.2.2 Residual Variation Trend Analysis

Regression analysis[4] was used to examine the relative significance of precipitation on stream flow, following which time trends were evaluated in the residual variation. The residual variation was plotted against time to determine if there was a time trend in the unexplained variation. Precipitation records from the Goldendale/Goldendale 2E climate stations[5] were used for this portion of the analysis. The general form of the regression equations used was:

$$\mathbf{Y = aX^{b}} \qquad \textbf{Equation 5-1}$$

Where: Y = Stream flow variable (cfs)
a and b = Regression constants
X = Precipitation variable at Goldendale/ Goldendale 2E station (in.)

As in the preceding section, the variables used to describe stream flow were mean annual flow and annual low flow at both stream gage locations. Mean annual precipitation at the Goldendale/Goldendale 2E station was the precipitation variable used to evaluate mean

---

[4] Regression analysis is a statistical evaluation of a group of identifiable characteristics which together can predict the outcome of a specific event

[5] See section 2.0 of this report for a description of climatic data available for WRIA30.

annual flow. Annual low flow was evaluated using an antecedent wetness index as the precipitation variable. The antecedent wetness index was derived using daily precipitation values from the Goldendale/Goldendale 2E climate station following the approach used by Lewis and others (2001). The underlying assumption of the antecedent wetness index is that precipitation that has occurred prior to time "t" influences the runoff efficiency at time "t", and that this influence decays over time. Put another way, the runoff associated with today's precipitation will be strongly influenced by yesterday's precipitation, slightly less by precipitation from the day before yesterday, and so on. The antecedent wetness index was calculated as follows:

$$\mathbf{W_i = CW_{i-1} + P_i} \qquad \textbf{Equation 5-2}$$

Where: C = wetness constant
W_i = wetness index on day i (in.)
W_{i-1} = wetness index on day i-1 (in.)
P_i = Precipitation on day i (in.)

The value of the wetness constant in Equation 5-2 is the value that satisfies the relationship $C^{\text{half-life}} = 0.5$, where half-life is in days. The values of C used in Equation 5-2 were derived iteratively by trying several values for half-life (in 7 day increments), solving for C, calculating W_i on the day of the annual low flows, and then solving Equation 5-1. The final value chosen for C was the value that gave the best solution (i.e., highest r^2 value) to Equation 5-1.

Little Klickitat River Gage Near Wahkiacus

Mean annual discharge at the Little Klickitat River gage near Wahkiacus and mean annual precipitation at the Goldendale/Goldendale 2E station are closely correlated (Figure 5-17). The correlation coefficient between mean annual precipitation and mean annual stream flow for this site is 0.86 (Table 5-4), which means that 86% of the variance in stream flow is explained by precipitation alone. The rest of the variability is likely related to variations in air temperature, which affects evaporation, changes in vegetation, and variations in water use. There are no significant time-related trends in the residual variation (Figure 5-18, Table 5-4) using Kendall's rank-order correlation.

The correlation between **annual low flow** discharge at the Little Klickitat River gage near Wahkiacus and the precipitation index at the Goldendale/Goldendale 2E station (Figure 5-19) was also investigated. The two variables are weakly correlated (Table 5-4, Figure 5-19). There was a weak (trend coefficient = -0.26) but significant (p=0.0351) time-related trend in the residual variation (Figure 5-20, Table 5-4).

As was discussed previously, the City of Goldendale has implemented changes in sources used to supply water to its customers. These changes are expected to increase flows in the Little Klickitat River. This time-trend analysis does not reflect those changes.

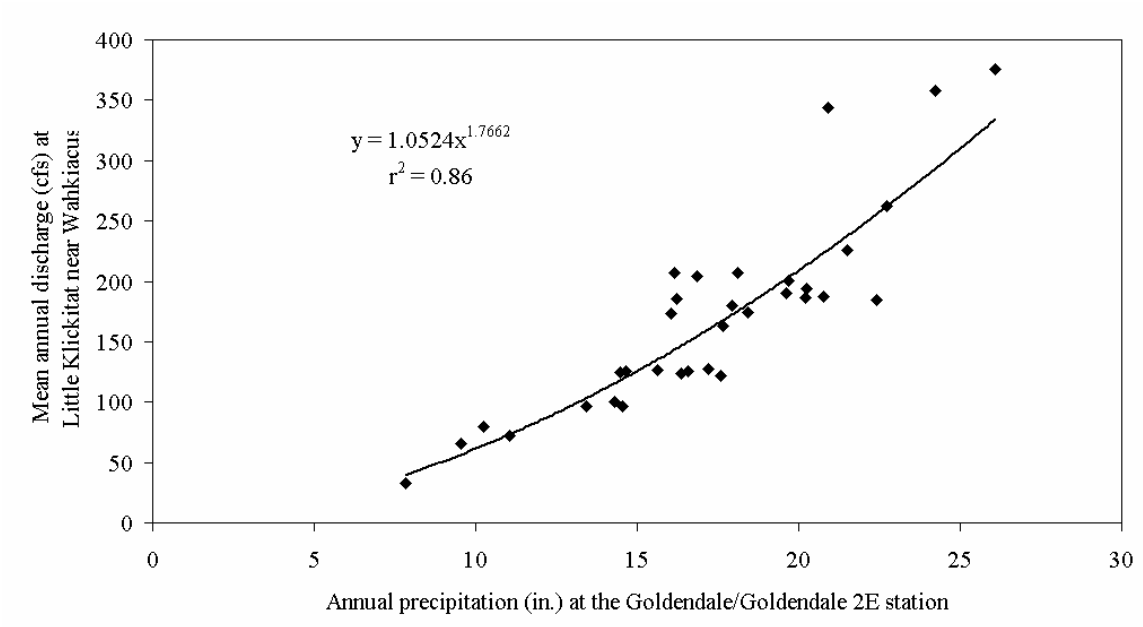


Figure 5-17. Relationship between mean annual discharge at the Little Klickitat River gage near Wahkiacus and annual precipitation at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for regression results.

Table 5-4. Regression results for equations predicting stream flow based on precipitation and residual trend analysis results.

Location	Stream flow variable	Precipitation variable	n	[1] r^2	Wetness constant	Wetness ½ life (weeks)	Trend coeffi-cient	Signi-ficance of trend
Little Klickitat River near Wahkiacus gage	Mean annual flow	Mean annual precipitation	33	0.86	n/a	n/a	0.07	0.5560
Klickitat River near Pitt gage	Mean annual flow	Mean annual precipitation	73	0.64	n/a	n/a	0.08	0.2948
Little Klickitat River near Wahkiacus gage	Annual low flow	Antecedent wetness index	33	0.51	0.99931259	144	-0.26	0.0351
Klickitat River near Pitt gage	Annual low flow	Antecedent wetness index	65	0.20	0.997645134	42	-0.05	0.5713

Notes: [1] Adjusted for degrees of freedom

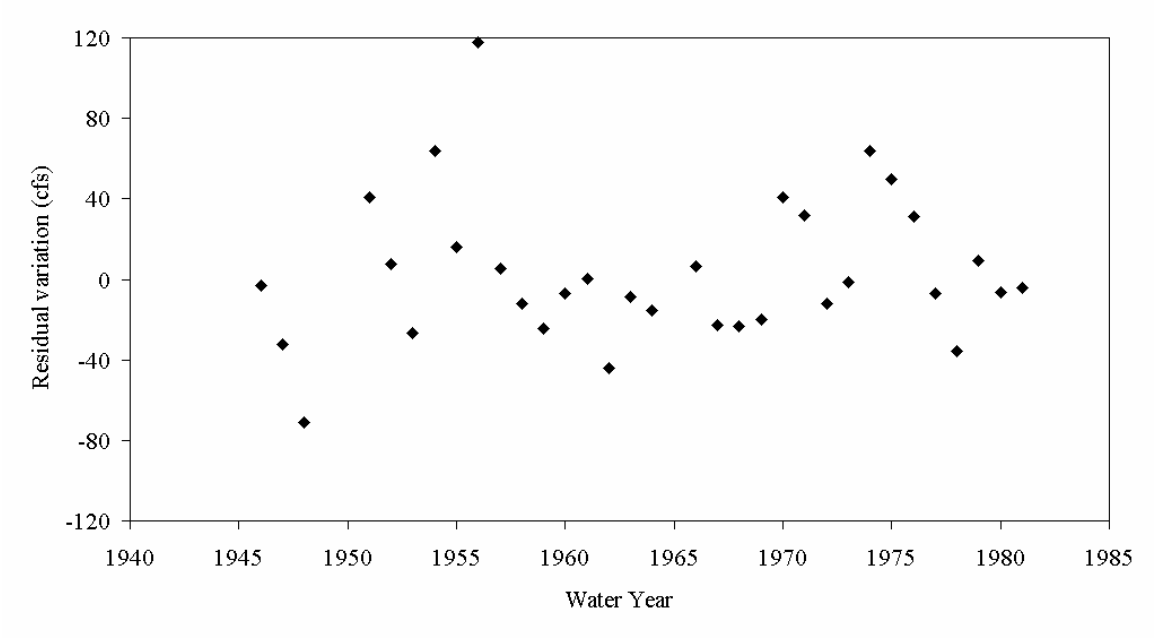


Figure 5-18. Temporal distribution of residual variation in relationship between mean annual discharge at the Little Klickitat River gage near Wahkiacus and annual precipitation at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for trend analysis results.

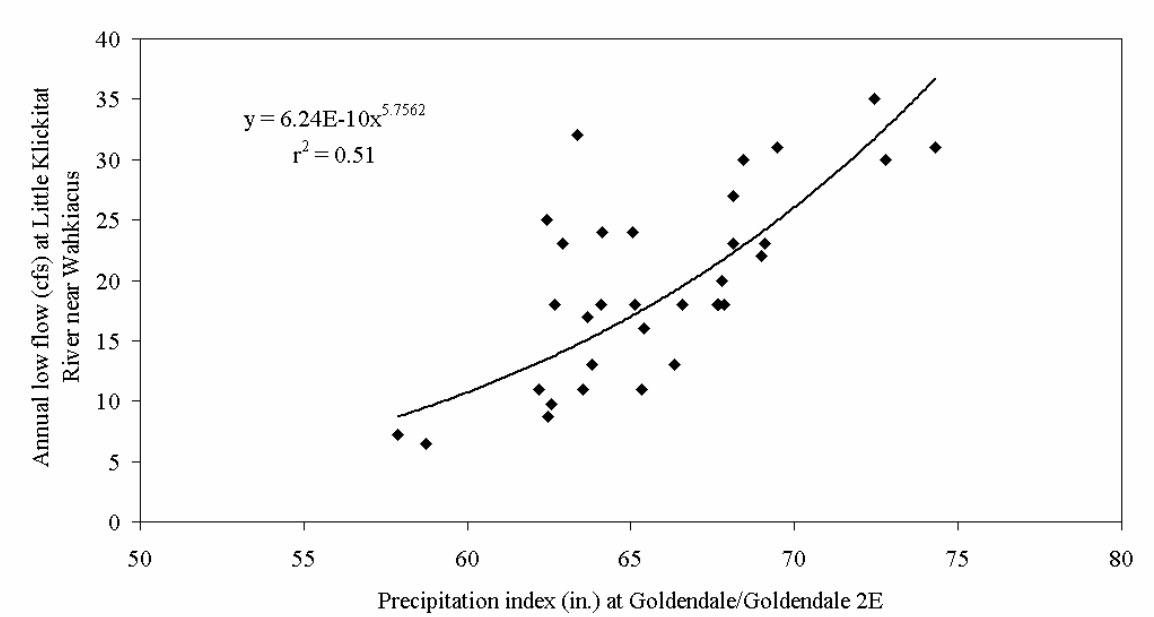


Figure 5-19. Relationship between annual low flow at the Little Klickitat River gage near Wahkiacus and the precipitation index at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for regression results.

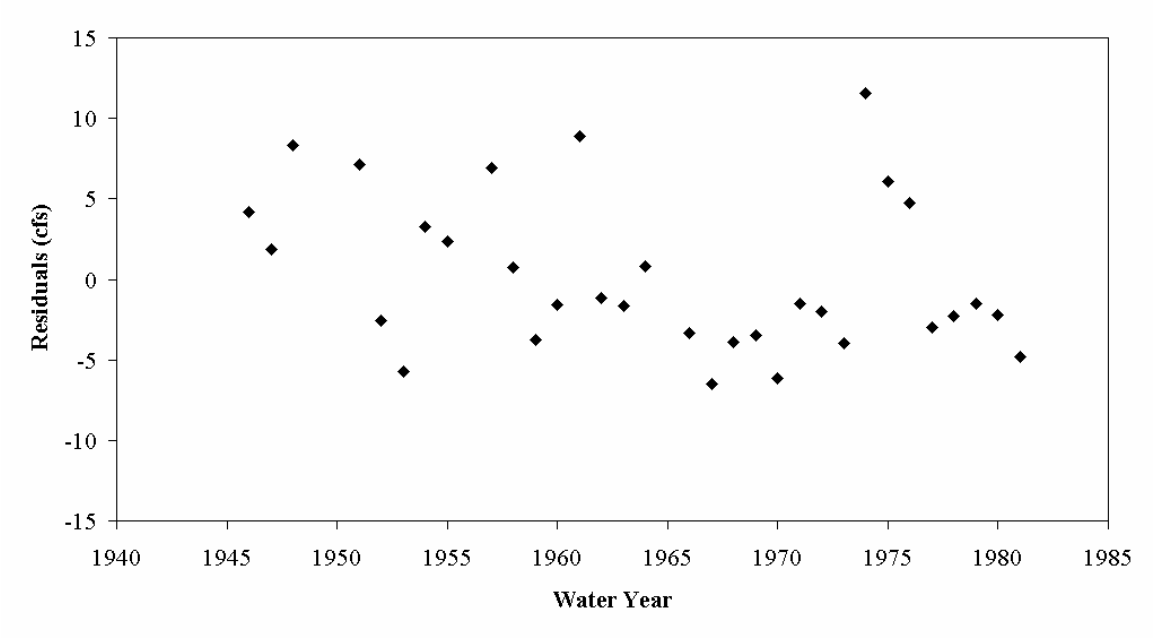


Figure 5-20. Temporal distribution of residual variation in relationship between annual low flow discharge at the Little Klickitat River near Wahkiacus gage and precipitation index at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for trend analysis results

Klickitat River Gage Near Pitt

Mean annual discharge at the Klickitat River gage near Pitt and annual precipitation at the Goldendale/Goldendale 2E station are correlated (Figure 5-21). Mean annual precipitation is a reasonably good predictor ($r^2 = 0.64$) of mean annual stream flow for this site (Table 5-4). There are no significant time-related trends in the residual variation (Figure 5-22, Table 5-4) using Kendall's rank-order correlation.

Annual low flow discharge at the Klickitat River gage near Pitt as a function of precipitation index at the Goldendale/Goldendale 2E station yielded a poor relationship (Figure 5-23, Table 5-4). There was no significant time-related trend in the residual variation (Figure 5-24, Table 5-4). The magnitude of the annual low flow at the Klickitat River gage near Pitt is probably more closely related to snow pack conditions within the drainage area than to a measure of total precipitation. An examination of the relationship between annual low flow at Pitt, and maximum snow pack at the Lost Horse SNOTEL site[6] (Figure 5-25), shows a better correlation than with precipitation index.

[6] See section 2.0 of this report for a description of climatic data available for WRIA30.

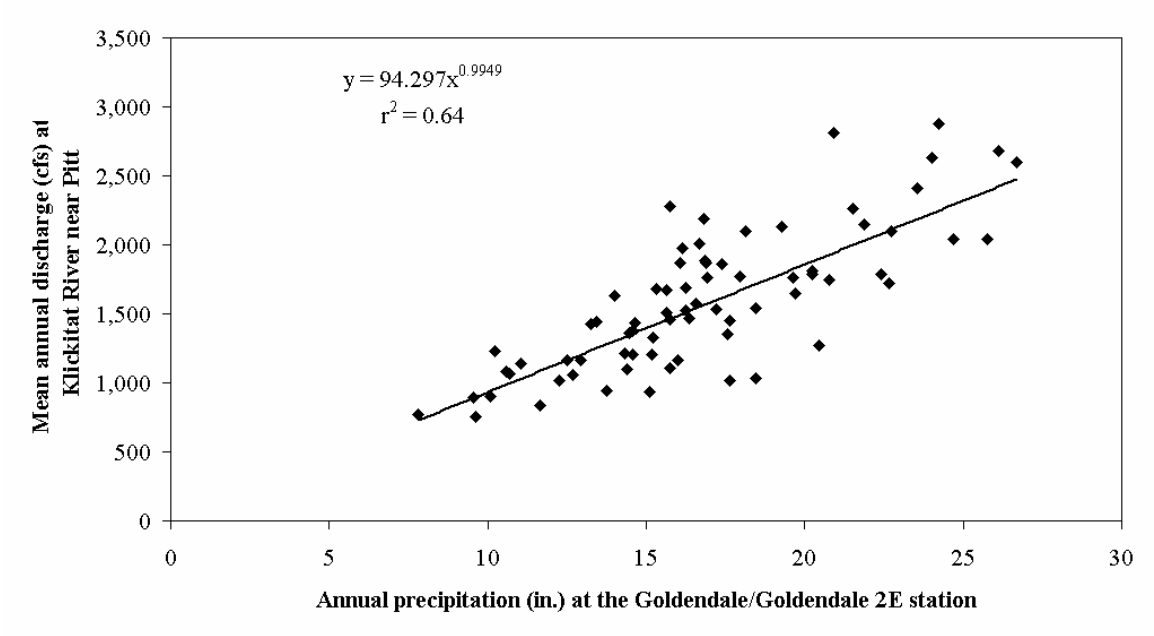


Figure 5-21. Relationship between mean annual discharge at the Klickitat River gage near Pitt and annual precipitation at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for regression results.

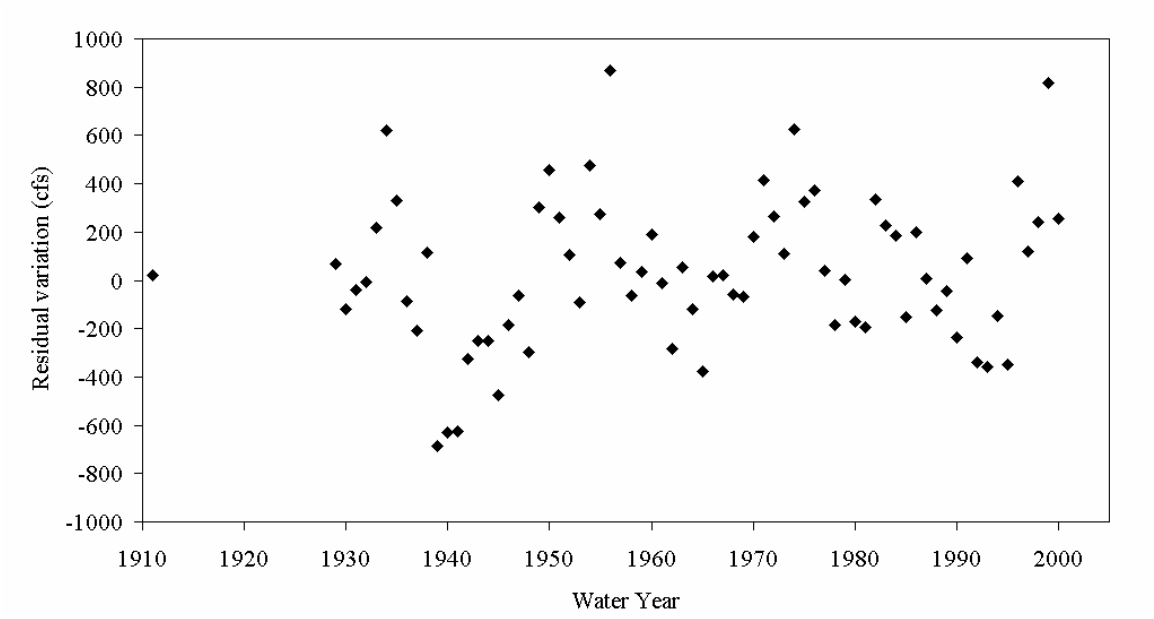


Figure 5-22. Temporal distribution of residual variation in relationship between mean annual discharge at the Klickitat River gage near Pitt and annual precipitation at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for trend analysis results.

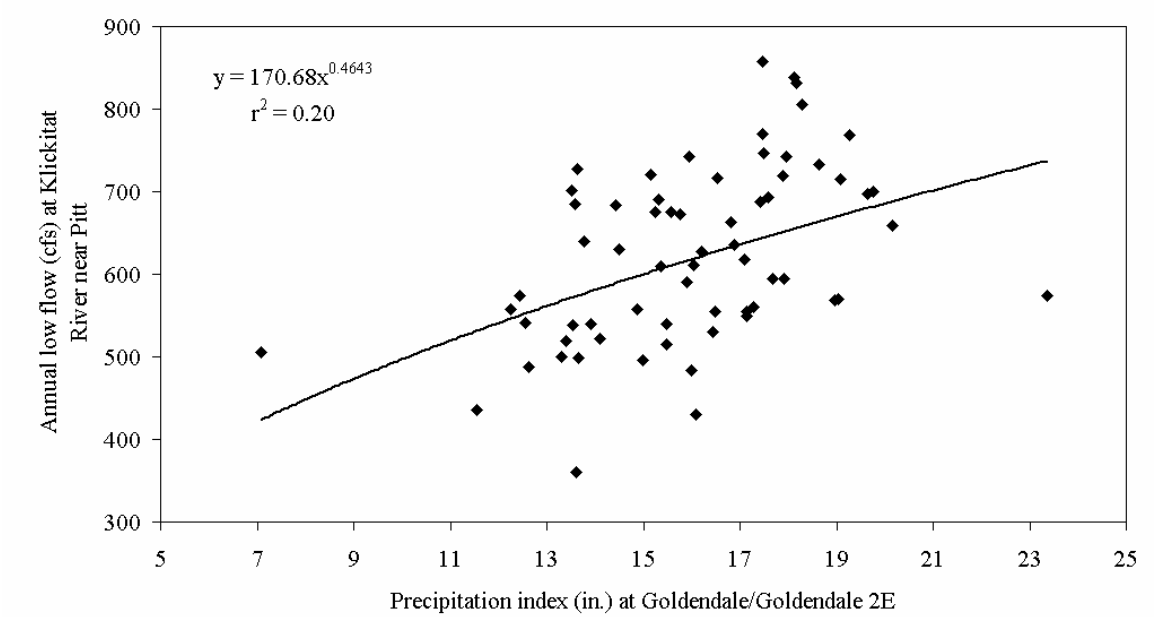


Figure 5-23. Relationship between annual low flow discharge at the Klickitat River gage near Pitt, and precipitation index at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for regression results.

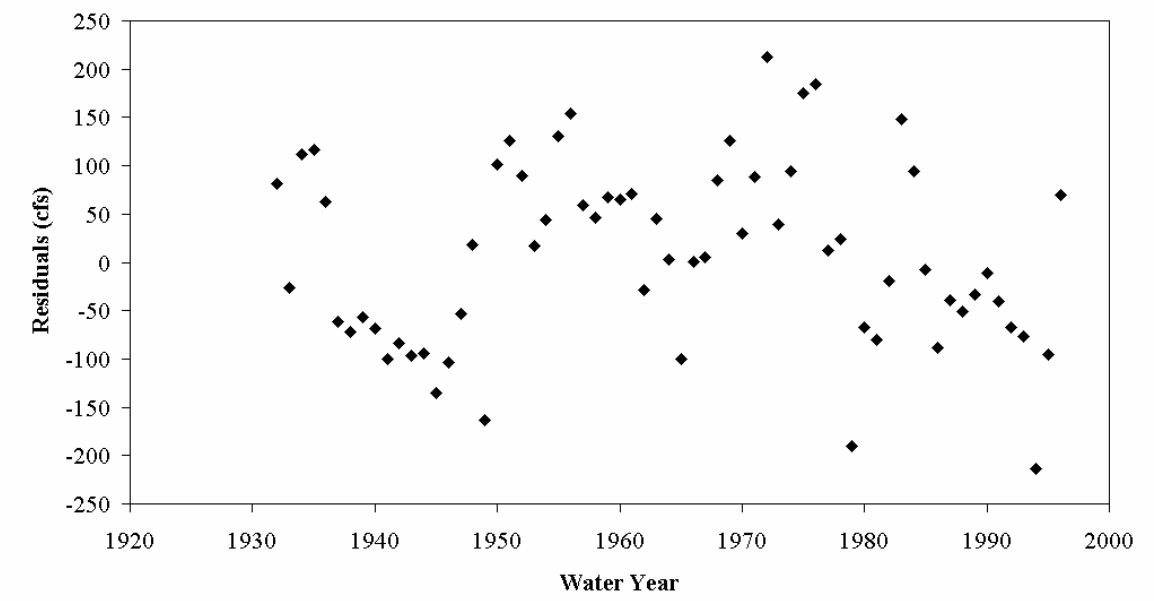


Figure 5-24. Temporal distribution of residual variation in relationship between annual low flow discharge at the Klickitat River gage near Pitt and precipitation index at the Goldendale/Goldendale 2E station. Refer to Table 5-4 for trend analysis results.

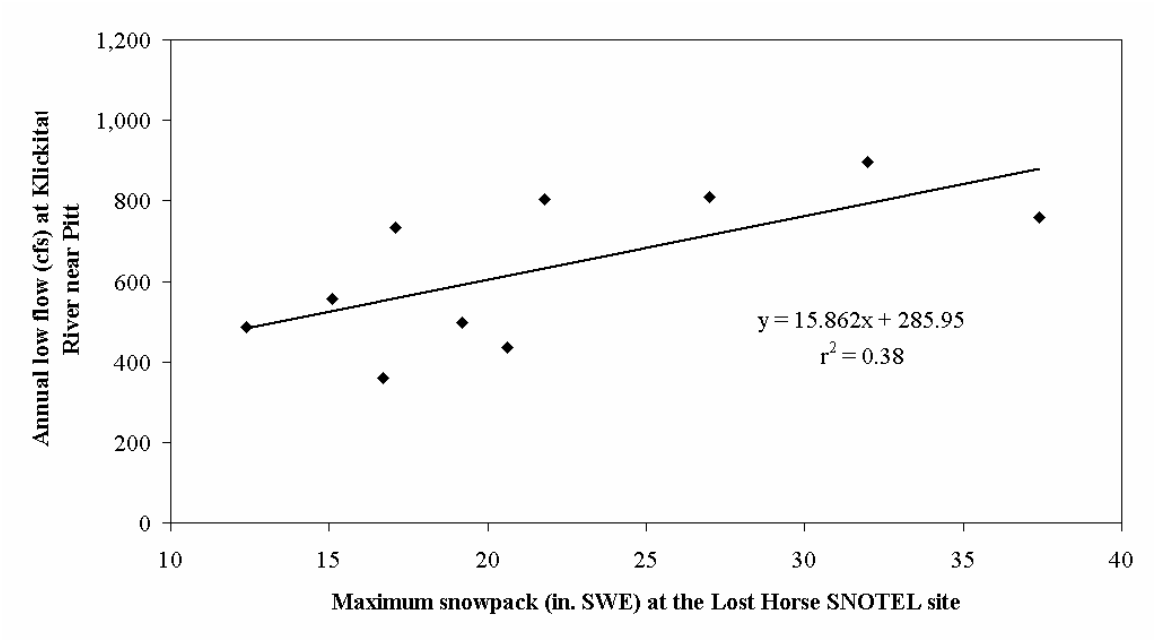


Figure 5-25. Relationship between annual low flow discharge at the Klickitat River gage near Pitt, and maximum snow pack at the Lost Horse SNOTEL site.

5.1.2.3 Summary of Trend Analyses

No significant trends over time were detected in the mean annual stream flow data at the two representative locations (i.e., the Little Klickitat River gage near Wahkiacus and Klickitat River gage near Pitt) evaluated in this assessment. In addition, when precipitation was factored out, there were also no significant time trends in mean annual stream flow at either location.

Annual low flows occur primarily in the month of August at the Little Klickitat River gage near Wahkiacus, and in the months of September and October at the Klickitat River gage near Pitt. No significant trends were found in annual low flows over the period of record at the Klickitat River near Pitt gage; however, a significant declining trend was observed in the data from the Little Klickitat River gage near Wahkiacus. When precipitation was factored out, there were no significant time trends over the period of record at the Klickitat River near Pitt gage; however, a weak but statistically significant declining trend was still observed in the Little Klickitat River near Wahkiacus data. This observed trend may be due to additional climatic variables not accounted for (e.g., air temperature, snow pack), land use effects on water yield, increases in consumptive water use, or some combination of the above. The analysis does not reflect recent changes in water withdrawal implemented by the City of Goldendale which are expected to increase flows in the Little Klickitat River.

Additional analyses at other gage locations, as well as more robust analyses at the representative sites above, is limited by the availability of long-term stream flow records at locations other than for the mainstem Klickitat River. Given the short-term nature of

the data set, and the many years that would be required to obtain adequate data for a more robust analysis, the appropriate level II recommendation may be to undertake further hydrologic modeling to assess the effects of other climatic variables and land use activities.

5.1.3 Peak Flows

Estimated peak discharges at USGS stream gages within WRIA 30 were calculated by Sumioka et al. (1997) (Table 5-5). These values are the most recent available for the area, and include the February 1996 flood values. Only two gages (14107000, Klickitat River above West Fork near Glenwood; 14113000, Klickitat River near Pitt) were active at the time of the February 1996 flood, however, the recurrence interval for the 1996 flood exceeded the magnitude of the 100-year flood at both locations.

5.2 GROUNDWATER

This section draws upon information regarding geology of the Klickitat watershed that was presented in Section 2.3. The reader is encouraged to refer to that section for additional information regarding the geologic units discussed here.

From the surface down (youngest to oldest), the geologic units of primary significance with respect to WRIA 30 groundwater are:

- Alluvium
- Quaternary Volcanics (including Simcoe Volcanics)
- Wanapum Basalt
- Grande Ronde Basalt

Groundwater within WRIA 30 occurs both within the basalt bedrock units and the surficial alluvium (overburden). Groundwater in the basalts occurs primarily at the tops of the individual flows ("flow top") that became vesicular (porous) as gas bubbles escaped the lava flows during cooling, and/or at the flow bottoms where molten lava encountered water ("pillow"). Flow tops and pillows are usually porous and permeable, and therefore transmit water more readily than the intervening massive portion of the basalt flow "interior". A flow top is normally present for each flow, while pillows range from relatively thick units to completely absent. Collectively, the flow tops and bottoms are referred to as interflow zones. In some locations, the interflows may be completely unproductive in terms of groundwater flow.

Where sediments interbedded (layered) between basalt flows are coarse grained, the interbeds may also transmit groundwater. Because the interbeds' composition, thickness, and extent are highly variable, groundwater production from these units is correspondingly variable. In many localities, the productivity of the interbeds is often low because of limited lateral extent and changes in composition.

Table 5-5. Estimated peak discharge at USGS stream gages within WRIA 30 by recurrence interval. Refer to Figure 5-1 and Table 5-1 for gage location. From: Sumioka et al., 1997.

Station number: Name	Number of peaks used in analysis	Flood discharge, in cubic feet per second for indicated recurrence interval event (95-percent confidence interval) Weighted[1] estimate of flood discharge, in cubic feet per second					Max. peak used in analysis (cfs)
		2 year	10 year	25 year	50 year	100 year	
14107000: Klickitat R Abv West Fork Nr Glenwood	39	1,840 (1,660-2,040) 1,850	3,130 (2,760-3,690) 3,170	3,880 (3,340-4,750) 3,950	4,480 (3,790-5,640) 4,580	5,110 (4,250-6,620) 5,250	5,500
14110000: Klickitat River Nr Glenwood	69	3,180 (2,930-3,450) 3,190	5,500 (4,970-6,220) 5,550	6,820 (6,050-7,930) 6,900	7,870 (6,880-9,330) 7,990	8,970 (7,740-10,800) 9,130	9,870
14111800: W Prong Little Klickitat R Nr Goldendale	15	105 (74-149) 110	302 (206-554) 321	459 (292-981) 491	605 (366-1,440) 647	781 (450-2,070) 832	569
14112000: Little Klickitat R Nr Goldendale	26	1,070 (822-1,390) 1,050	3,060 (2,250-4,670) 2,950	4,560 (3,190-7,680) 4,330	5,940 (4,000-10,700) 5,570	7,550 (4,900-14,500) 6,990	5,200
14112200: Little Klickitat River Trib Nr Goldendale	29	25 (19-33) 25	88 (63-140) 85	148 (99-263) 140	208 (132-404) 192	287 (174-603) 259	229
14112400: Mill Creek Nr Blockhouse	14	113 (84-152) 126	250 (182-415) 310	331 (230-613) 442	397 (267-791) 560	466 (304-993) 694	430
14112500: Little Klickitat R Nr Wahkiacus	36	3,260 (2,560-4,150) 3,190	9,250 (6,970-13,400) 8,860	13,200 (9,550-20,400) 12,500	16,400 (11,600-26,600) 15,400	19,900 (13,700-33,600) 18,500	17,500
14113000: Klickitat River Near Pitt	71	7,840 (6,790-9,040) 7,840	20,500 (17,200-25,400) 20,400	29,700 (24,100-38,500) 29,500	37,800 (30,000-50,700) 37,400	47,200 (36,600-65,300) 46,600	51,000

Notes: [1] Weighted estimates of flood magnitude were obtained using two different estimates of flood magnitude (from the frequency analysis and from the regression equation). The weighted estimates generally provide better estimates of the true flood discharges than those determined from either the flood-frequency analysis or the regression analysis alone.

Because a single basalt formation (e.g., Wanapum Basalt) encompasses multiple individual basalt flows, it can encompass multiple hydrogeologic units – a layered sequence of aquifer zones (interflows) separated by flow interiors serving as aquitards[7].

The alluvium can be highly variable in composition (from clay to gravel), with significant groundwater occurrence limited to the coarse-grained (sand and gravel) portions.

---

[7] An aquitard is a water-saturated sediment or rock whose permeability is so low it cannot transmit any useful amount of water.

The continuity and distribution of water-bearing zones within the basalt bedrock are affected by the geologic structures. Folds and faults can disrupt the continuity of the permeable interflow zones. For example, where the Warwick Fault crosses the southwestern edge of the Swale Creek valley, it locally appears to act as a hydraulic barrier impounding groundwater on the up gradient (northeast) side of the fault (toward Centerville). Faults also can provide conduits for vertical groundwater flow between water-bearing zones. Across most of WRIA 30, the vertical component of groundwater flow is downward, except near major surface water drainages where groundwater discharge occurs (Brown, 1979). However, upward flow along faults has also been inferred in some localities (e.g., at Lyle and near Klickitat; Newcomb, 1969). In these situations, the quality of the groundwater is often poor because groundwater from greater depths typically has high levels of dissolved solids.

Erosional canyons can also limit lateral continuity of shallower groundwater-bearing zones. This dissection of the basalt surface can restrict lateral movement of groundwater, and thus limit the productivity of shallower aquifer systems.

5.2.1 Groundwater Recharge and Discharge

5.2.1.1 Groundwater Recharge

Groundwater recharge within WRIA 30 occurs primarily through the infiltration of precipitation (both rain and snowmelt), and secondarily as seepage from surface waters and from anthropogenic affects (e.g. return flows from irrigation and septic systems).

The USGS has estimated average annual groundwater recharge rates across WRIA 30 (from Bauer and Vaccaro, 1990) (Figure 5-26). These estimates were developed using a deep percolation model for the entire Columbia Plateau regional aquifer system and represent current land use conditions. The model used precipitation, temperature, stream flow, soils, land use, and altitude data to compute transpiration, soil evaporation, snow accumulation, snowmelt, sublimation, and evaporation of intercepted moisture. The modeling made use of daily climatic data for the period from 1956 through 1977. Daily changes in soil moisture, plant interception, and snow pack were computed and accumulated. Recharge was computed when soil moisture exceeded the soil's field capacity. Irrigation return flows were considered in the modeling, based on data collected from irrigation districts throughout the Columbia Plateau. The reported results from the modeling (Figure 5-26) represent the long-term average from simulation of the 22-year period.

As is depicted on Figure 5-26, the western edge of the USGS' modeling study area occurs within WRIA 30. Lacking recharge information for the western margin of WRIA 30, the USGS' westernmost recharge estimates (generally greater than 10 inches per year) were therefore extrapolated to the western boundary of the WRIA as depicted by the lined hatch patterns. Annual groundwater recharge rates may be lower, and may approach zero, in the higher elevations of the Cascades (particularly on Mount Adams) along the

watershed's western boundary. However, more detailed evaluation of recharge rates in this area was beyond the scope of this Level 1 Assessment.

Using the USGS' estimated average annual recharge rates for current conditions, the average annual groundwater recharge rate and recharge volume can be estimated for each subbasin. Because the USGS' recharge polygons represented a range in recharge rates, the midpoint of the range was assigned as the average for each polygon. A recharge rate of 15 inches/year was assigned for the >10 inch/year polygons.

Using this methodology, an estimated 841,000 acre-feet of annual groundwater recharge occurs on average within WRIA 30. As expected, the highest recharge rates occur in those subbasins bordering the western side of WRIA 30 (Upper, Middle, and Lower Klickitat Subbasins), where precipitation is greatest. The volume of recharge by subbasin is the product of that recharge rate and the subbasin area. In order of relative contribution to the total annual recharge volume in WRIA 30, the subbasins are ranked as follows:

- Middle Klickitat (41% of WRIA 30 total)
- Upper Klickitat (33% of WRIA 30 total)
- Little Klickitat (13% of WRIA 30 total)
- Lower Klickitat (8% of WRIA 30 total)
- Swale Creek (3% of WRIA 30 total)
- Columbia Tributaries (2% of WRIA 30 total)

The USGS also estimated pre-development recharge by converting current commercial/industrial, irrigated agriculture, and dry land agriculture land uses to pre-development land uses (sage, forest, grassland, sand/barren). Based on the modeling results, recharge for the current land use is nearly 60% greater than under pre-development land uses, primarily as a result of irrigation return flows.

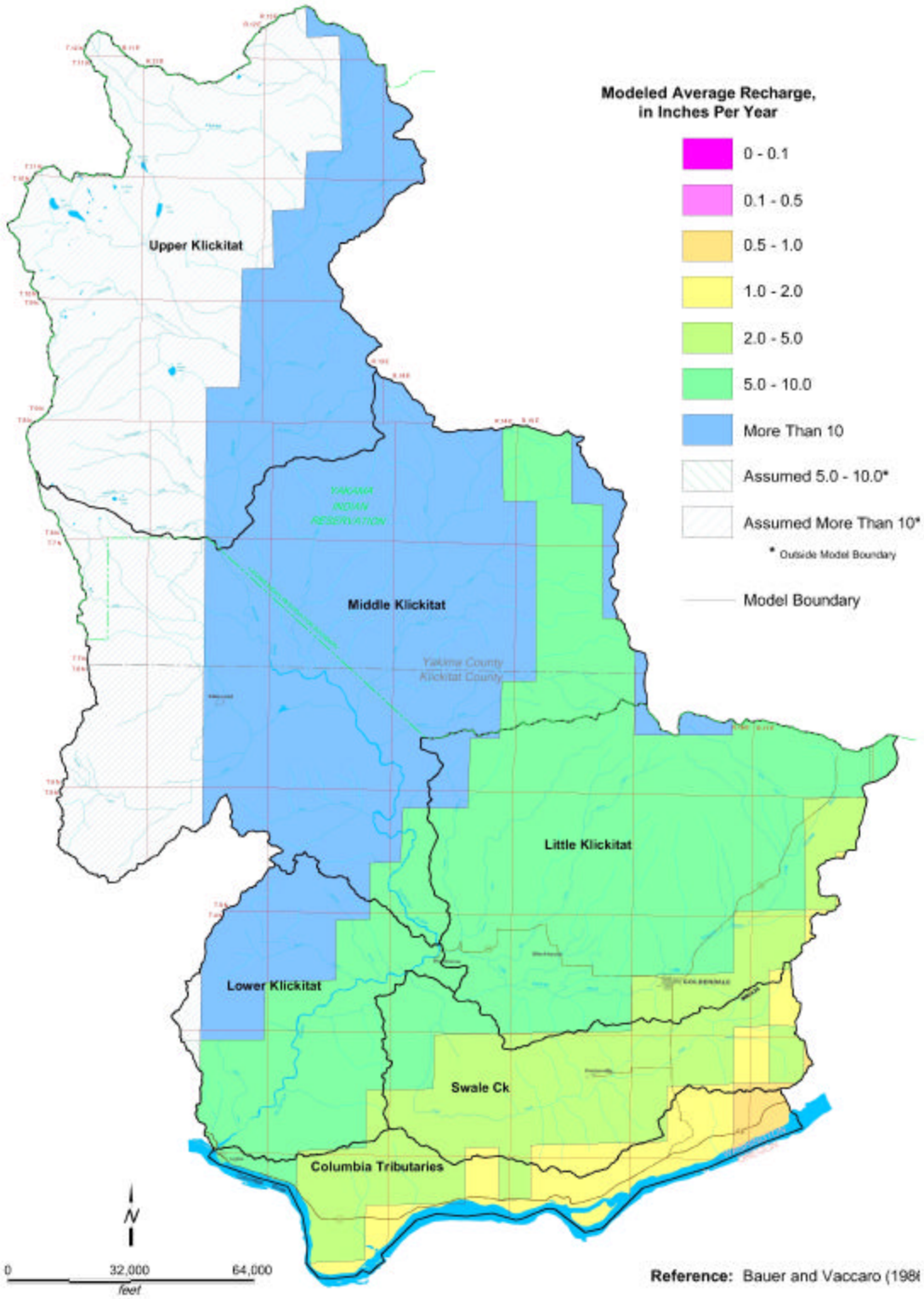


Figure 5-26. Estimated Annual Groundwater Recharge Rates (source: Bauer and Vaccaro, 1990).

		Acreage Within Each Recharge Zone[1]						
Subbasin	**Area (acres)**	**0.5-1.0 inch/yr**	**1.0-2.0 inch/yr**	**2.0-5.0 inch/yr**	**5.0-10.0 inch/yr**	**>10 inch/yr**	**Ave. Annual Recharge Rate (inch/yr)**	**Ave. Annual Recharge Volume (acre-ft/yr)**
Upper Klickitat	224,113	-	-	-	-	224,113	15	280,000
Middle Klickitat	298,831	-	-	-	45,686	253,146	14	345,000
Little Klickitat	179,195	-	829	21,137	150,190	7,041	7	109,000
Swale	80,490	845	10,048	57,360	12,236	-	4	26,000
Lower Klickitat	82,111	-	-	1,673	51,295	29,143	10	69,000
Columbia Tribs	58,155	4,872	27,727	22,473	3,082	-	3	12,000
WRIA 30 Totals	**922,915**	5,717	38,604	102,643	262,488	513,463	-	**841,000**
Value Assigned to Each Zone to Calculate Average for area		0.75	1.5	3.5	7.5	15		

[1] *Recharge zones digitized from Bauer and Vaccaro (1990).*

Table 5-6. Estimated Annual Recharge Volumes by Subbasin

The USGS estimates uncertainties of up to 25 percent in recharge estimates developed using the Deep Percolation Model, with greater errors (as a percentage of recharge) occurring in more arid areas. The USGS' modeling of recharge relied upon climate data from a time period (1956-1977) within an inferred cool/wet cycle of the Pacific Decadal Oscillation (1947-1976 cycle; see Section 2.4.2). However, the USGS also notes that the average annual precipitation from the 22-year period used for the modeling was slightly less than the 100-year average annual precipitation. Despite the uncertainties, the USGS' recharge estimates represent the most comprehensive and reliable regional estimates available.

5.2.1.2 Groundwater Discharge

Most groundwater recharge entering WRIA 30 ultimately discharges to surface waters within the watershed; however, some groundwater both enters and exits the watershed via deep flow systems. Springs are the most obvious indication of groundwater discharge locations. Figure 2-7, in Section 2.3, shows locations of springs within the Klickitat County portion of WRIA 30 (from Brown, 1979). Spring locations within the Yakima County portion of the watershed are not similarly documented.

Although the data on spring locations are somewhat coarse and do not cover the upper half of WRIA 30 (all of Upper Klickitat and part of Middle Klickitat Subbasins), some general patterns are apparent.

- A relatively large number of springs occur in and around the Camas Prairie region of the Middle Klickitat Subbasin. Several of these springs are large in magnitude, and stream flow increases of 100 cfs as a result of major spring discharges have been documented in this area (described further in Section 5.2.3).

- In the Little Klickitat Subbasin, the majority of the documented springs discharge from the Quaternary Volcanics, often feeding tributary streams to the Little Klickitat River. Much of this discharge is fed by snowmelt in the Simcoe Mountains, and as such has a short residence time in the aquifer prior to discharge. Springs of note are Simcoe Springs, within the subbasin headwaters, which serve as the City of Goldendale's principal water supply. Bloodgood Spring, lower in the subbasin, likewise served as a water supply for Goldendale until recently.

The few springs mapped in the Lower Klickitat Subbasin appear to emanate from the Wanapum Basalt. Springs are not mapped discharging from the Grande Ronde Basalt where the Klickitat River has eroded down into it.

- Relatively few springs are mapped in the Swale Creek Subbasin. Those that are occur within or near the alluvial fill within the Swale Creek syncline near Centerville. A few small springs were observed discharging from the basalts within Swale Canyon during an April 2003 field reconnaissance. None of these observed springs had significant discharge, which is consistent with their lack of mapping in Brown (1979).

- Few springs are likewise mapped within the Columbia Tributaries Subbasin; however, groundwater is known to discharge to the Columbia River.

5.2.2 Groundwater Occurrence and Flow Directions

The groundwater characteristics of the principal geologic units in WRIA 30 (described in Section 2.3) are discussed briefly below (from oldest to youngest).

Grande Ronde Basalt. Relatively few wells within WRIA 30 produce groundwater from the Grande Ronde Basalt, and those that do are typically deep wells used for irrigation in the southern watershed Figure 5-27 depicts generalized groundwater elevation contours for the Grande Ronde Basalt, as well as the locations of existing wells completed in this basalt unit (modified from Bauer et al, 1985). Inferred groundwater flow directions are also depicted.

Based on these 1983 data, groundwater in the Grande Ronde beneath the most of the watershed (Middle Klickitat Subbasin and south) regionally flows toward the south with discharge to the main stem Klickitat River and the Columbia River.

Based on regional assessment of structural controls (folds and faults) in the basalts, Newcomb (1969) concluded that the Warwick Fault, which bisects the western portion of Swale Creek valley at Warwick, forms a structural closure to the Swale Creek valley and thus should create an impoundment of groundwater to the east of the fault. Previous USGS interpretations of regional groundwater flow conditions indicate that the Warwick Fault does impound groundwater in the overlying Wanapum Basalt (discussed below), but there were no specific data to confirm the same for the Grande Ronde Basalt. However, the Yakama Nation recently drilled a 100-foot deep well into the Grande Ronde Basalt near Wahkiacus, just east (upgradient) of the Warwick Fault (new well depicted on Figure 5-27). The well is flowing artesian, with a flow of 700 gpm and a shut in pressure of 10 psi. The presence of considerable excess pressure upgradient of the fault suggests that it also impounds groundwater in the Grande Ronde.

In the Goldendale area and immediately north, deep wells completed in the Grande Ronde have had water quality unsuitable for potable use (mineralized water with high total dissolved solids). Based on limited exploration, groundwater quality in this unit appears to be moderate to good within the Swale Creek subbasin south of Goldendale.

The observed differences in Grande Ronde water quality across the watershed are likely attributable to the source and amount of recharge to the unit. Little information regarding groundwater in the Grande Ronde is available for the northwestern portion of the watershed.

Wanapum Basalt. The Wanapum Basalt is typically the largest source for groundwater supply, particularly for large irrigation withdrawals, across the southern portion of WRIA 30. Figure 5-28 depicts regional groundwater elevation contours for the Wanapum Basalt (1983 data), as well as the locations of existing wells completed in this unit (from Bauer et al, 1985). Inferred groundwater flow directions are also depicted.

Groundwater in the Wanapum regionally flows toward the southwest, but a significant east-west trending groundwater divide occurs along an unnamed anticline separating the Goldendale area (to the north) from the Centerville area (to the south). From this groundwater divide, groundwater flows in the basalt northward to the Little Klickitat River and southward to the Swale Creek valley. Groundwater in the Wanapum flows into the Swale Creek valley from the north and south. As discussed above for the Grande Ronde, the Warwick Fault creates an impoundment of groundwater in the Wanapum Basalt to the east (Figure 5-28). This groundwater flow interpretation is consistent with that presented in Luzier (1969).

Groundwater quality in the Wanapum is variable depending on location and depth, but is generally suitable for most, if not all, uses. In the central region of the basin near Goldendale, the available data suggest that total dissolved solids (TDS) increases with depth.

Cline (1976) reports that groundwater in the Quaternary Volcanics of the Camas Prairie region (Middle Klickitat Subbasin) flows toward the northeast, discharging to large springs along tributaries to the Klickitat River (e.g., Outlet Creek).

5.2.3 Groundwater Conditions and Hydraulic Continuity by Subbasin

This section provides an overview of groundwater conditions by hydrologic subbasin within WRIA 30. This includes a qualitative assessment of hydraulic continuity between groundwater and surface water, based on available geologic, groundwater flow, and spring discharge information. Hydraulic continuity refers to the hydraulic interaction between surface and groundwater within the watershed. A surface water body that loses water to the groundwater system is referred to as “losing”; conversely, surface waters that receive flow from groundwater are referred to as “gaining”.

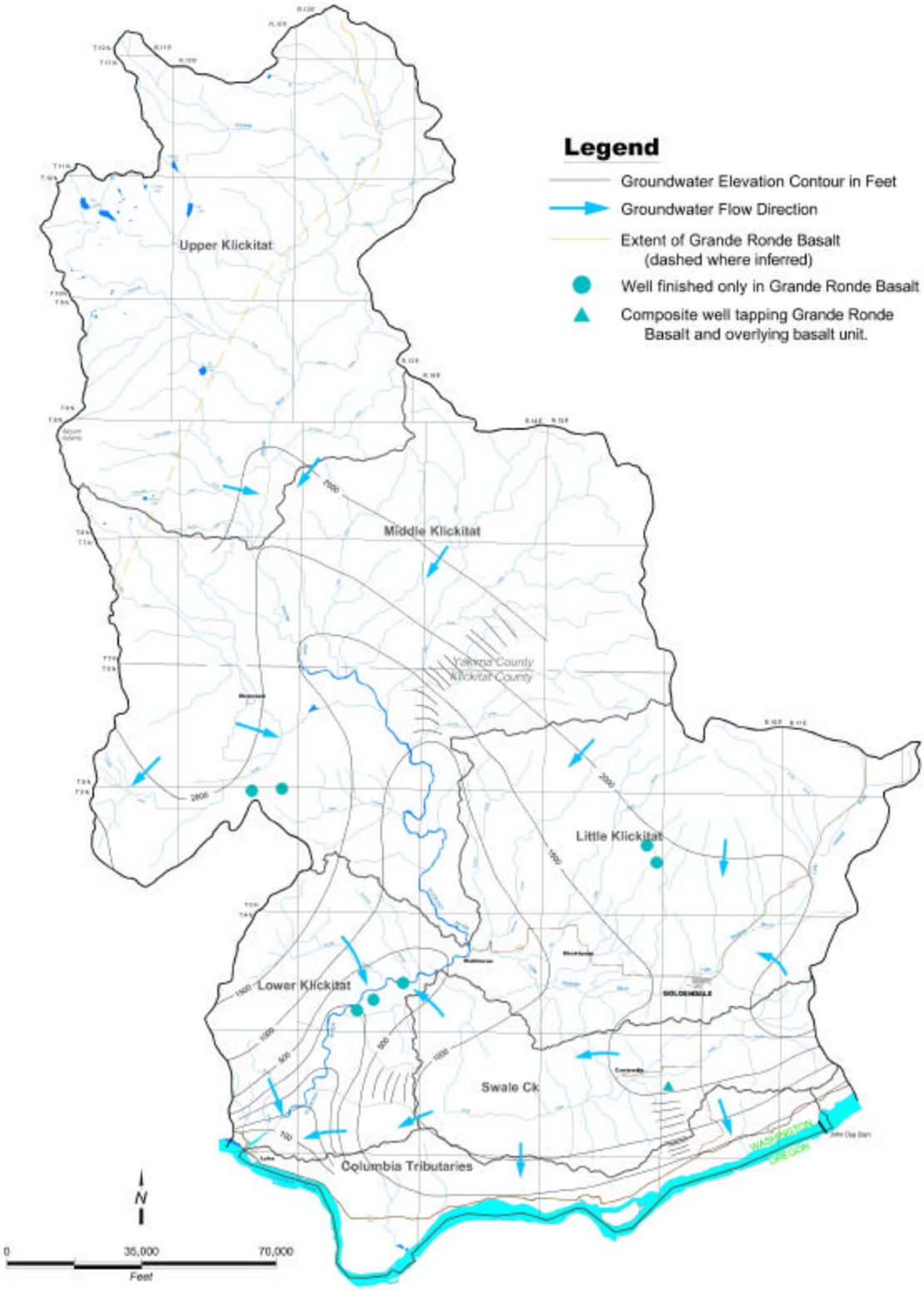


Figure 5-27. Groundwater Elevations and Inferred Flow Directions in the Grande Ronde Basalt (modified from Bauer et al., 1985).

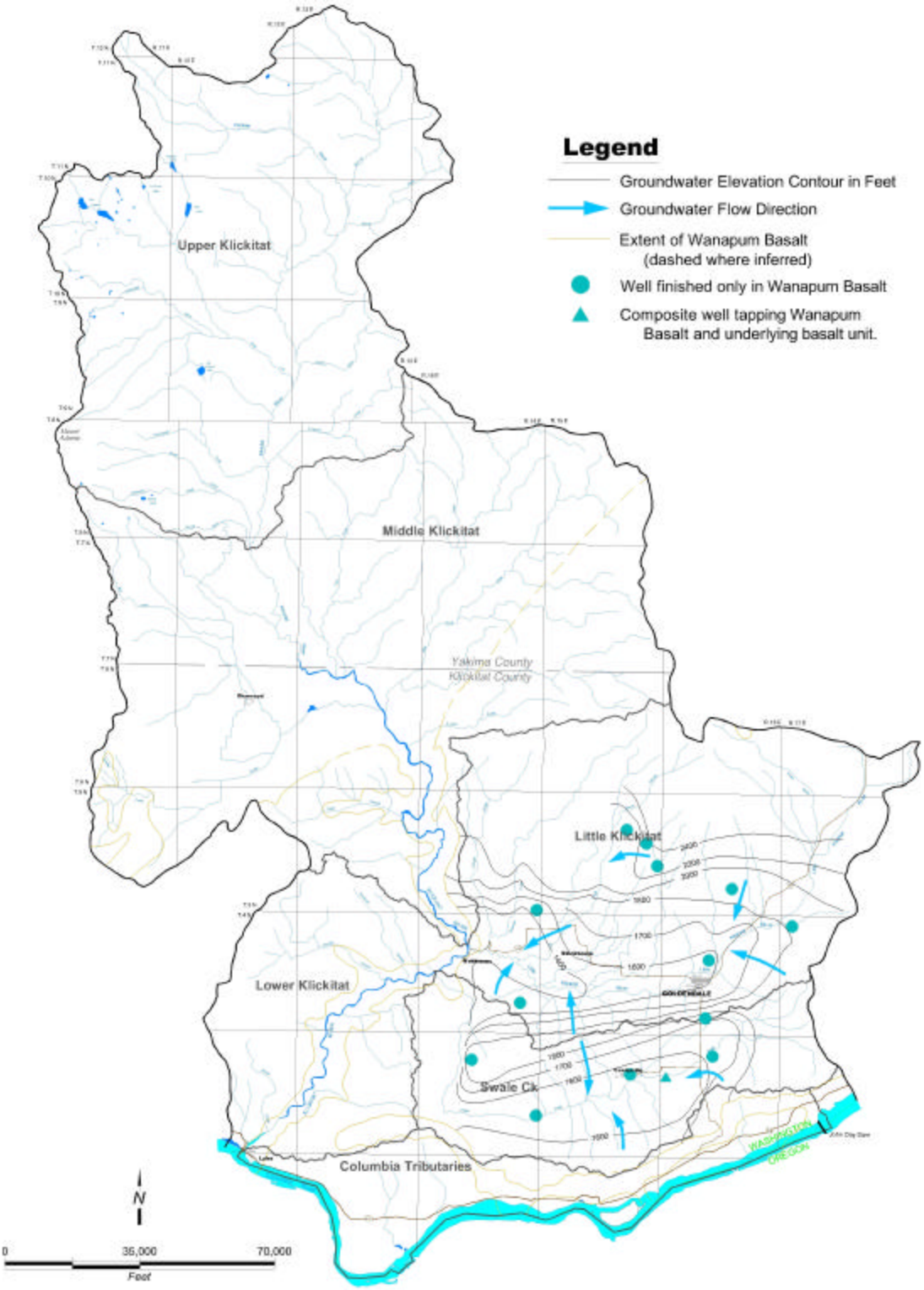


Figure 5-28. Groundwater Elevations and Inferred Flow Directions in the Wanapum Basalt (modified from Bauer et al., 1985)

There are varying degrees of hydraulic continuity between groundwater and surface water depending largely on the horizontal and vertical position of the groundwater aquifer relative to the surface water body and the presence or absence of low-permeability materials or structural controls between the two. In WRIA 30, groundwater in areas of shallow alluvial aquifers typically has significant hydraulic connection with all classes of streams as well as rivers. Conversely, groundwater in deeper basalt aquifers may have limited connection to headwater streams and principally discharges to the major, lower elevation drainages including the mainstem of the Klickitat and Columbia Rivers as well as smaller streams.

Upper Klickitat. Little information exists to document groundwater conditions in the Upper Klickitat Subbasin. The subbasin is underlain by Quaternary Volcanics and, in the eastern subbasin, the Grande Ronde. In addition, significant deposits of alluvium are mapped occur along the Klickitat River (see Figure 2-7 in Section 2.3). Groundwater in the Quaternary Volcanics west of the Klickitat River likely discharges to the Klickitat River, although no hard data are available to assess the degree of hydraulic continuity.

Middle Klickitat. The Middle Klickitat River Subbasin includes the Camas Prairie region west of the Klickitat River and, east of the river, the Summit Creek drainage. The Camas Prairie consists of a large expanse of alluvium with thickness of up to 160 feet, which was deposited in a synclinal trough of the underlying Quaternary Volcanics. Groundwater in this area is used principally for domestic and stock watering uses. Irrigation water is derived primarily from surface water (diversion from streams farther to the north, via Hellroaring Ditch). Shallow wells (including dug wells) in the alluvium are common, with small to moderate yields depending on the permeability of the alluvium. A few wells tap the deeper basalt aquifers.

As a result of the abundant shallow groundwater in the region, springs are common in the Camas Prairie (Glenwood) area. For example, springs discharging to Outlet Creek reportedly increase flows in that stream on the order of 100 cfs (Brown, 1979). Spring discharge supplies water to the state's salmon hatchery east of Glenwood, and McCumber Springs, north of Glenwood, provides water supply for the Glenwood area. Documentation of substantial spring discharge to local streams demonstrates direct hydraulic continuity between shallow groundwater (alluvium) and streams in this portion of the Middle Klickitat Subbasin.

The Summit Creek drainage, east of the Klickitat River, is incised within the Quaternary Volcanics, but there is little information (no well records) regarding groundwater resources in this area.

Little Klickitat. Groundwater production in the Little Klickitat River Subbasin occurs primarily from the Wanapum Basalt and, north and west of Goldendale, from the younger Simcoe Volcanics. A few deep wells also tap the underlying Grande Ronde at depths of 900 feet or more. The majority of Wanapum wells are completed at depths less than 500 feet, but some wells extend to depths greater than 900 feet, with the lower portion open to

the Grande Ronde Basalt. Available geologic data indicate that the Wanapum Basalt extends to depths of roughly 750 feet in the Goldendale area. Yields from this aquifer are normally less than 500 gpm, with a few of the deeper wells capable of producing greater than 1,000 gpm.

Several wells north and west of Goldendale produce groundwater of excellent quality from the Simcoe Volcanics. In addition, spring discharge from the Simcoe Volcanics, within the Simcoe Mountains, provides the City of Goldendale's primary municipal water supply. The pyroclastic zones of these volcanics typically have a coarse open texture and thus provide good lateral and vertical permeability. The Simcoe Volcanics can be highly productive in areas where a substantial thickness of these permeable pyroclastic zones occurs. For example, Goldendale's recently completed test/production well within the Simcoe Mountain Volcanics at their Chlorination Station site (north of the city) yields 1,000+ gpm from this unit.

Based on recorded water right information (Section 6.1), the greatest quantities of groundwater withdrawn from WRIA 30 occur from the Little Klickitat Subbasin (18,900 acre-feet/year). However, total estimated water use in this subbasin (groundwater and surface water) is approximately 11,400 acre-feet/year (refer to Section 6.2), indicating that actual groundwater withdrawals are considerably less than the permitted quantities.

Swale Creek. Similar to Camas Prairie, the Swale Creek subbasin is an alluvium-filled basin within an east-west trending synclinal trough of the Wanapum Basalts, in the area surrounding Centerville. Alluvial deposits have filled the depression over an area measuring approximately 3 miles wide and 8 miles long, with depths to bedrock along the axis of Swale Creek greater than 200 feet near Centerville. Groundwater in this basin occurs within both the alluvial deposits and the underlying Wanapum and Grande Ronde Basalts.

The principal use of groundwater in the Swale Creek subbasin is for irrigation and domestic supply. The irrigation wells in the Swale Creek Basin are generally deep, from 200 to 1,000 feet below ground surface, with the majority completed in the Wanapum Basalt and limited numbers penetrating the Grande Ronde Basalt. Many of the older irrigation wells are also open to the alluvial deposits. The domestic wells generally obtain water from the alluvial aquifer or a combination of the alluvial aquifer and the underlying Wanapum Basalt. Domestic wells range in depth from hand-dug wells to drilled wells with depths up to 500 feet or greater. The City of Goldendale recently constructed two new municipal supply wells (Basse wellfield) in the Wanapum Basalts east of Centerville. Irrigation water rights were transferred to the new Basse wellfield for municipal supply, thus the older irrigation wells associated with the transferred rights are no longer operating.

The presence of surface water flow in the central portion of Swale Creek, between Highway 97 on the east and the Warwick area on the west, is ephemeral or of a seasonal nature directly related to the groundwater level in the surrounding alluvium. In early spring groundwater levels in the alluvium are generally high (shallow depth below the ground surface). Localized flooding of the low-lying areas around Swale Creek has

reportedly occurred during particularly wet periods in the late winter and early spring. This portion of the creek is generally dry by late spring/early summer and for the balance of the year as groundwater levels in the alluvium decline.

The presence of the Warwick fault on the western margin of Swale Creek valley, which impedes westerly groundwater flow within the basalts, together with reportedly low surface water flows within Swale Creek Canyon (west of Warwick), suggest limited baseflow contribution of groundwater from the basalts. A field reconnaissance of the entire Swale Creek Canyon in early April 2003 (prior to start of irrigation pumping in the region) confirmed very low quantities of spring discharge from the basalts. Flows in Swale Creek appear to be supported primarily by runoff from numerous small tributaries draining the surrounding uplands (e.g., Columbia Hills and High Prairie). Once these tributaries dry up by late spring, flows in Swale Creek correspondingly diminish. Anecdotal information from a 40-year resident (Mr. Tony Sareson) of the upper Swale Canyon indicates the creek dries up every year, except at Warwick and in scattered pools throughout the canyon.

The similar water quality conditions and water level elevations within both the Wanapum and underlying Grande Ronde Basalt aquifers near Centerville suggests good hydraulic communication between these units. The limited available water level data for the deep basalts, based on observations during drilling of the City of Goldendale's Basse Well Field, indicates the absence of downward vertical gradients between these basalt units.

Lower Klickitat. The Lower Klickitat River Subbasin encompasses the area between Wahkiacus and the river's discharge to the Columbia River at Lyle. Groundwater in this region is produced primarily from the Wanapum Basalt. In the highlands west of the Klickitat River, groundwater is typically produced from shallow wells tapping the Wanapum Basalt, but yields are generally low.

In areas where the Klickitat River valley is wider, some shallow wells produce from recent alluvial gravels. Groundwater in the alluvium is expected to have direct hydraulic continuity with the river. Springs commonly discharge from the basalts along the walls of the Klickitat River valley in this subbasin (see Figure 2-7 in Section 2.3). Notably, Klickitat Springs, between Wahkiacus and Klickitat, contains water with high mineral content and is charged with carbon dioxide ("soda water"). Wells drilled to depths of 200 to 300 feet in this area have historically flowed at the surface, and have produced water of similar quality. It is hypothesized that this groundwater has migrated upward from deeper basalt zones via faults. The locations of springs adjacent to some streams in the subbasin indicate hydraulic continuity between groundwater in the Wanapum Basalt and surface waters of the subbasin.

Columbia Tributaries. Within this subbasin, groundwater is used primarily for municipal, domestic, and limited industrial supplies; the bulk of the irrigation and industrial water supply is obtained from the Columbia River. In the western half of the gorge, springs discharging from the basalt provide small water quantities for domestic or stock watering purposes. However, most of the groundwater in this area is obtained from wells. Wells completed in close proximity to the Columbia River can be highly

productive, owing largely to their direct hydraulic connection with the river. Substantial groundwater withdrawals are reported in the Dallesport area, whereas marginal productivity has generally been reported in the areas of the John Day dam. Groundwater is known to discharge to the Columbia River, but the magnitude of the contribution is uncertain.

APPENDIX A

Chapter 6: Water Rights and Water Use

Table of Contents

6.1 Water Rights ***1***
6.1.1 Water Rights Analysis Methods *2*
6.1.2 Results of Water Rights Analysis *3*

6.2 Estimated Water Use ***19***
6.2.1 Estimated Irrigation Water Use *20*
6.2.2 Residential Water Use *24*
6.2.3 Non-Residential Water Use *29*
6.2.4 Estimated Water Use by Subbasin *30*

6.3 Water Available for Allocation ***31***
6.3.1 Methods *32*
6.3.2 Upper Klickitat *32*
6.3.3 Middle Klickitat *33*
6.3.4 Little Klickitat Subbasin *34*
6.3.5 Lower Klickitat *35*
6.3.6 Swale Subbasin *37*
6.3.7 Columbia Tributaries *39*
6.3.8 Confidence Regarding Estimated Water Budgets *39*

List of Tables

Table 6-1. Waterbody Segments on 1998 303(d) List Based on Instream Flows. *1*

Table 6-2. Recorded Water Rights, Claims, and Applications by Primary Beneficial Use for Each Subbasin. *4*

Table 6-3. Allocated Annual Water Rights (Certificates + Permits) in WRIA 30 by Primary Beneficial Use. *5*

Table 6-4. Cumulative Recorded Water Rights and Claims by Source, Middle Klickitat. *11*

Table 6-5. Cumulative Recorded Water Rights and Claims by Source, Little Klickitat Subbasin. *14*

Table 6-6. Cumulative Recorded Water Rights and Claims by Source, Swale Creek. *15*

Table 6-7. Cumulative Recorded Water Rights and Claims by Source, Lower Klickitat Subbasin. *17*

Table 6-8. Cumulative Recorded Water Rights and Claims by Source, Columbia Tributaries. 19

Table 6-9. Comparison of Irrigated Acre Estimates _____ 21

Table 6-10. Estimated Irrigation Water Use by Subbasin _____ 23

Table 6-11. Estimated Public Water System Water Use._____ 25

Table 6-12. 2000 Population Data by Subbasin _____ 28

Table 6-13. Estimated Self-Supplied Residential Annual Water Use _____ 28

Table 6- 14. Estimate of Maximum Self-Supplied Residential Annual Water Use. _____ 29

Table 6-15. Estimated Total Water Use for WRIA 30 by Subbasin _____ 31

List of Figures

Figure 6-1. Distribution of Water Right Certificates and Permits.----------7

Figure 6-2. Distribution of Water Claims. ----------8

Figure 6-3. Distribution of Water Right Applications. ----------9

Figure 6-4. Recorded Annual Water Rights by Use in Middle Klickitat Subbasin. ---------- 10

Figure 6-5. Recorded Annual Water Rights by Use in Little Klickitat Subbasin.---------- 12

Figure 6-6. Recorded Annual Water Rights by Use in Swale Creek Subbasin. ---------- 13

Figure 6-7. Recorded Annual Water Rights by Use in Lower Klickitat Subbasin. ---------- 16

Figure 6-8. Recorded Annual Water Rights by Use in Columbia Tributaries Subbasin. --------- 18

Figure 6-9. Irrigated Acres in Klickitat County, 1920-1997---------- 22

Figure 6-10. Total surface water use and water appropriation in the Middle Klickitat Subbasin relative to the 50% and 90% exceedance flows.---------- 34

Figure 6-11. Current estimated surface water appropriation and use relative to the 50% and 90% exceedance flows in the Little Klickitat subbasin. Note that the confidence in actual water use in this subbasin is low. ---------- 36

Figure 6-12. Exceedance flows, water appropriation and use within the lower Klickitat subbasin (values are very small and do not show on plot) and total cumulative water appropriation and use reflecting water use in the Lower Klickitat subbasin and upstream subbasins. ---------- 37

Chapter 6: Water Rights and Water Use

The current status of water appropriations in the watershed is determined through existing state issued certificates and permits, claims submitted to the state by the water user, and applications for future water use. However, actual water use is often very different from the amount of water allocated in a basin. Therefore estimates of actual water use are also needed to assess the current water demand. Total depletion, factoring in actual water use and return flows, is needed to evaluate the net effect of water use on the volume of water present in water bodies. This chapter addresses water rights in Section 6.1, water use in Section 6.2, and water available for allocation in Section 6.3.

6.1 WATER RIGHTS

To help develop a preliminary understanding of the water quantity picture in WRIA 30, this section summarizes the quantity of water allocated for use through existing water rights in each subbasin, based on available information. A discussion of pending applications for water rights on record with Ecology is also included to provide a general understanding of existing requests for additional future water use in each subbasin.

Water rights represent the major portion of the allocated water, but exempt groundwater withdrawals (or exempt wells) are also legal entitlements to the use of water in the state. Accounting for these exempt wells is difficult since no tabulation of these wells is available. A rough estimate of water use by exempt wells is provided in Section 6.2.

Statutory minimum instream flows also represent a legal allocation of water, but there are no instream flow minimums for WRIA 30 defined in Washington State statute. However, Ecology has included six WRIA 30 waterbody segments on its 1998 Section 303(d) list for impaired water quality, based on instream flows (Table 6-1). In addition, EPA has established a total maximum daily load (TMDL) based on dilution requirements for the City of Goldendale's wastewater treatment plant discharge to address dissolved oxygen and chlorine in the Little Klickitat River (T4N, R16E, sec. 19) (ID no. AY21LB).

Table 6-1. Waterbody Segments on 1998 303(d) List Based on Instream Flows.

Waterbody	Location (Township, Range, Section)	ID No.
Blockhouse Creek	T4N, R15E, sec. 17	ID95ML
Bloodgood Creek	T4N, R16E, sec. 17	XU61D0
Bowman Creek	T5N, R14E, sec. 35	TN94DB
Little Klickitat River	T4N, R14E, sec. 9	AY21LB
Little Klickitat River	T4N, R15E, sec. 28	AY21LB
Mill Creek	T4N, R15E, sec. 5	FF43IZ
Swale Creek	T4N, R14E, sec. 19	XN32NH

6.1.1 Water Rights Analysis Methods

The water rights analysis for this Level I Assessment summarizes recorded water rights (certificates and permits), water claims, and applications for new water rights by size and type of use in WRIA 30. For clarification, the terms water right permit, certificate, claim, and application are defined as follow:

- A *Permit* is permission given to water right applicants by the state to develop a water right. Water rights are perfected when water right applicants follow the provisions outlined in their permit, using water for the purposes and up to the limits (instantaneous rate and annual volume) stated in the permit. Water right permits remain in effect until the water right certificate is issued, if all terms of the permit are met, or the permit has been canceled.

- A *Certificate* is issued by Ecology to certify that water users have the authority to use a specific amount of water under certain conditions. These conditions are based on beneficial use of water as defined by the water right permit. The water right certificate is a legal document recorded at the county auditor's office. The certificate completes the process of obtaining a water right. Once a certificate is issued, no expansion (enlargement) is allowed under the water right.

- A *Claim* is a statement of claim to a water use that is not covered by a permit or certificate. A claim may represent a valid water right if it describes a surface water use that began before 1917 or a groundwater use that began before 1945, a water right claim that was filed with the state during an open filing period designated under RCW 90.14 (the Water Rights Claim Registration Act), or is covered by the groundwater exemption. The validity of a claim can only be determined through a general adjudication.

- An *Application* is a request submitted to obtain a new water right or transfer/change an existing water right from the Department of Ecology. There are separate applications for these two processes.

Water rights include authorization for both instantaneous quantities (Qi; maximum rate in gallons per minute (gpm) for groundwater or cubic feet per second (cfs) for surface water) and annual volume (Qa; acre-feet/year for both groundwater and surface water). Water right control numbers beginning with G are groundwater; those beginning with S are surface water; those beginning with R are storage rights for reservoirs.

The water rights information used in this analysis was obtained in August 2002 from Department of Ecology's Water Rights Application Tracking System (WRATS). The WRATS includes the location of the point of diversion/withdrawal for each water right record to the nearest quarter-quarter section (1/16 square mile) within the township/range/section (TRS) system. However, many records have locations that are only reported to the nearest section (1 square mile) and, in some cases, no location is recorded. For this analysis, the individual water rights, claims, and applications were assigned within specific subbasins based on the location of the center of the recorded section (for point of diversion/withdrawal). Place of use for the water rights is not recorded in the WRATS.

The WRATS includes numerous water right entries that identify multiple points of diversion/withdrawal for a single water right. For these cases, the first listed point of diversion/withdrawal is used for locating the water right in this analysis.

Only rights/claims/applications reported to be active are considered in this analysis. Rejected, relinquished, or cancelled rights/claims/applications are deleted from the analysis. Water right applications are discussed here to provide information on potential future water demand within the watershed; however, Ecology's approval or denial of the applications is unknown at this time. In addition, only instantaneous quantities requested by the applications for new appropriations are recorded in the WRATS. Annual quantities are not recorded since they are determined as part of the permitting process and thus not assigned until the permit is issued.

For many records, certain fields in the WRATS are blank, such as allocated amounts and locations. In particular, information regarding claims (some dating to the late 1800s) is sparse. Because of the missing data and the inexact nature of identifying the location of water right diversions/withdrawals based on the quarter-quarter section, the information provided in this section is considered preliminary and is intended to provide a general understanding of water allocation within WRIA 30. More detailed assessment of individual water rights would require obtaining the water right file from Ecology. Furthermore, water rights allocated "on paper" are not equivalent to actual water use. The water right statutes include specific provisions resulting in relinquishment of all or a portion of the authorized water right due to lack of continued beneficial use. As a result of these provisions and lapses or curtailment of water use by holders of water rights, the total actual water use is typically notably less than the total allocated quantities within a watershed (estimated water use is discussed in Section 5.4).

A water right can have more than one recorded beneficial use, but the amount allocated for each of these uses is not listed in the WRATS. For the purposes of this assessment, the first beneficial use listed was assumed to be the primary beneficial use unless irrigation was one of the listed uses, in which case irrigation was assumed to be the primary beneficial use. This assumption was based on the fact that WRIA 30 rights for irrigation use are typically combined with stock watering and/or domestic uses – uses that typically require much smaller water quantities than irrigation in WRIA 30. Although this assumption introduces some degree of uncertainty in quantifying water use by type, it is considered the most reasonable approach for this Level I Assessment, based on knowledge of water use in WRIA 30.

Although there are more than 1,500 claims recorded in the WRATS for WRIA 30, only a couple hundred have information recorded regarding water quantity. Furthermore, the validity of the claims in not certain; therefore, the water right certificates/permits, rather than the claims, are of primary interest in this initial analysis. An adjudication of surface water rights within the Little Klickitat River drainage in the late 1980s determined the legal standing and level of water use appropriation of surface water claims within that subbasin.

6.1.2 Results of Water Rights Analysis

Table 6-2 summarizes the existing information for water rights permits and certificates (separated by groundwater and surface water), water claims, and water right applications, by the primary beneficial use category. Note that springs are recorded as surface water in the WRATS.

Table 6-2. Recorded Water Rights, Claims, and Applications by Primary Beneficial Use for Each Subbasin.

Groundwater Certificates & Permits			Surface Water Certificates & Permits			Claims			Applications		
Primary Listed Beneficial Use	**Number of Records**	**Sum of Listed Qa (ac-ft/yr)**	**Primary Listed Beneficial Use**	**Number of Records**	**Sum of Listed Qa (ac-ft/yr)**	**Primary Listed Beneficial Use**	**Number of Records**	**Sum of Listed Qa (ac-ft/yr)**	**Primary Listed Beneficial Use**	**Number of Records**	**Sum of Listed Qi (cfs)**
Upper Klickitat											
			Irrigation	2	6	Domestic General	3				
			Stock Watering	8	4	Irrigation	3	43,300			
						Not Indicated	1				
						Stock Watering	21				
Subbasin Totals:	0	0	Subbasin Totals:	10	10	Subbasin Totals:	28	43,300	Subbasin Totals:	0	0
Middle Klickitat											
Domestic Multiple	1	80	Commercial/Industrial	1		Domestic General	37		Commercial/Industrial	1	1.0
Domestic Single	1	2	Domestic Multiple	2	135	Irrigation	44	44,555	Irrigation	2	201
Irrigation	4	405	Fire Protection	1	10	Not Indicated	1		Stock Watering	2	0.02
			Fish Propagation	7	6	Stock Watering	196	35			
			Irrigation	139	502						
			Stock Watering	38	46						
Subbasin Totals:	6	487	Subbasin Totals:	188	699	Subbasin Totals:	278	44,590	Subbasin Totals:	5	202
Little Klickitat											
Commercial/Industrial	5	823	Domestic Multiple	5	18	Domestic General	101	1	Domestic Multiple	4	0.90
Domestic Multiple	11	231	Domestic Single	31	38	Irrigation	59	1,525	Domestic Single	3	0.08
Domestic Single	39	52	Fire Protection	2	17	Not Indicated	5		Fire Protection	1	1.3
Fire Protection	1	30	Fish Propagation	2		Other	1	0.07	Highway	1	0.04
Irrigation	113	16,168	Irrigation	128	11,928	Stock Watering	16	10	Irrigation	18	5.0
Municipal	2	1,568	Municipal	4	3,072				Municipal	3	11
Stock Watering	10	37	Not Indicated	1					Stock Watering	1	0.045
			Power	1							
			Stock Watering	83	57						
			Wildlife Propagation	2	7						
Subbasin Totals:	181	18,910	Subbasin Totals:	259	15,136	Subbasin Totals:	182	1,536	Subbasin Totals:	31	19
Swale Creek											
Domestic Single	1	1	Irrigation	3	22	Domestic General	110		Domestic Multiple	1	0.02
Irrigation	45	11,629	Stock Watering	4	5	Irrigation	51		Fire Protection	1	0.05
Not Indicated	11					Not Indicated	5		Irrigation	12	5.7
Stock Watering	1	2				Stock Watering	107	15	Stock Watering	8	0.03
Subbasin Totals:	58	11,632	Subbasin Totals:	7	27	Subbasin Totals:	273	15	Subbasin Totals:	22	5.8
Lower Klickitat											
Domestic Single	5	10	Commercial/Industrial	1	1,203	Domestic General	100		Environmental Quality	1	100
Irrigation	9	204	Domestic Multiple	6	950	Irrigation	40	11	Fish Propagation	2	20
Stock Watering	1	3	Domestic Single	15	17	Not Indicated	7		Irrigation	11	0.90
			Fire Protection	2	30	Stock Watering	93	3	Municipal	1	0.45
			Fish Propagation	1					Stock Watering	1	0.45
			Irrigation	32	794						
			Not Indicated	1							
			Stock Watering	9	9						
Subbasin Totals:	15	217	Subbasin Totals:	67	3,002	Subbasin Totals:	240	13	Subbasin Totals:	16	122
Columbia Tributaries											
Commercial/Industrial	2	967	Domestic Single	2	2	Domestic General	35		Domestic Multiple	3	0.72
Domestic Multiple	17	1,524	Irrigation	18	1,441	Irrigation	52	1,321	Domestic Single	1	0.04
Domestic Single	3	5	Power	2		Not Indicated	8		Irrigation	10	18
Heat Exchange	2	1,928	Stock Watering	7	25	Other	1	15	Mining	1	1.3
Irrigation	33	2,936				Stock Watering	81	272	Municipal	2	1.1
Not Indicated	1								Power	1	800
Railway	3	637									
Subbasin Totals:	61	7,997	Subbasin Totals:	29	1,468	Subbasin Totals:	177	1,608	Subbasin Totals:	18	821
WRIA 30 Totals:	**321**	**39,242**	**WRIA 30 Totals:**	**560**	**20,341**	**WRIA 30 Totals:**	**1,178**	**91,062**	**WRIA 30 Totals:**	**92**	**1,169**

Based on the WRATS database for WRIA 30, a total of 59,577 acre-feet/year of water is allocated by 881 water right certificates and permits. Of this total quantity, the vast majority (77%) of water allocated within the watershed is for irrigation use. Water rights allocated for municipal, domestic, commercial/industrial, heat exchange, and railway uses collectively make up an additional 22% of the total. Water rights allocated for stock watering, fire protection, fish propagation, and wildlife propagation collectively make up less than 1% of the total (Table 6-3). There are numerous water right records with no purpose of use recorded in the WRATS ("not indicated" in this report); none of these had annual allocations recorded. There were three surface water rights designated for use in power generating facilities, none of which had annual allocations recorded.

Table 6-3. Allocated Annual Water Rights (Certificates + Permits) in WRIA 30 by Primary Beneficial Use.

Primary Beneficial Use	Allocated Annual Water Rights in Acre-Feet/Year	Percentage of Total Allocated Rights
Irrigation	46,029	77%
Municipal	4,640	8%
Domestic	3,064	5%
Commercial/Industrial	2,993	5%
Heat Exchange	1,928	3%
Railway	637	1%
Stock Watering	186	0.3%
Fire Protection	87	0.1%
Wildlife Propagation	7	0.01%
Fish Propagation	6	0.01%
Not Indicated	0	0%
Power	0	0%
	59,577	**100%**

According to the WRATS, there are a total of 1,178 claims in WRIA 30 for a total of 91,062 acre-feet of water per year. The overwhelming majority of water claimed is for irrigation use (see Table 6-2).

The WRATS database includes a total of 92 water right applications for new appropriations (groundwater and surface water) pending in WRIA 30. The cumulative rate of diversion/withdrawal encompassed by these applications is approximately 1,170 cfs (Table 6-2). The largest number of applications, but not necessarily the largest quantities requested, is for irrigation use. Again, annual quantities are determined during the permitting process and thus not recorded for applications.

Figure 6-1 depicts the spatial distribution of the existing annual water right certificates plus permits, by section, recorded within WRIA 30. Figure 6-2 provides the same information for water claims. On these figures, the displayed number within each section is the number of recorded rights or claims in that section, and the color depicts the cumulative annual volume for all rights or claims (acre-feet/year) recorded for that section. That is, the colors represent the total annual volume of water allocated ("on paper") for diversion/withdrawal from each section. The colors are ramped, from lighter to darker, based on the following categories for allocated annual diversion/withdrawal (see Figures 6-1 and 6-2):

- 0 to 20 acre-feet/year
- 20.01 to 50 acre-feet/year
- 50.01 to 100 acre-feet/year
- 100.01 to 500 acre-feet/year
- 500.01 to 1,000 acre-feet/year
- greater than 1,000 acre-feet/year

Figure 6-3 provides analogous information for applications, except that the cumulative instantaneous rates of diversion/withdrawal (Qi in gpm), not annual quantities, applied for are displayed. Progressively darker colors represent progressively greater cumulative instantaneous rates of diversion/withdrawal applied for (categories listed on Figure 6-3).

The distribution and nature of water rights certificates/permits, claims, and applications by subbasin, based on the WRATS records, are summarized briefly below.

6.1.2.1 Upper Klickitat

The Upper Klickitat Subbasin lies entirely within the Yakama Indian Reservation boundary. This analysis of water rights is limited to State-of-Washington-issued appropriations and does not address Federal Reserve rights. There are only ten water right certificates issued by the State of Washington, with a cumulative allocation of only 4 acre-feet/year, recorded within the Upper Klickitat Subbasin (Table 6-2). However, this is misleading since there are no annual quantities recorded in the WRATS for the two irrigation diversions. These two diversions have recorded instantaneous rates of 100 and 10 cfs (from Big Muddy and Cougar Creeks in Sections 20 and 33, respectively, of T8N, R12E; Figure 6-1) to irrigate 5,000 and 500 acres, respectively.

There are 28 claims in this subbasin, but only one has a quantity recorded in the WRATS – a diversion of 43,300 acre-feet/year from Hellroaring Creek (T8N, R12E, Section 20; Figure 6-2) to irrigate 8,600 acres. There are no water right applications recorded in the WRATS for the Upper Klickitat Subbasin.

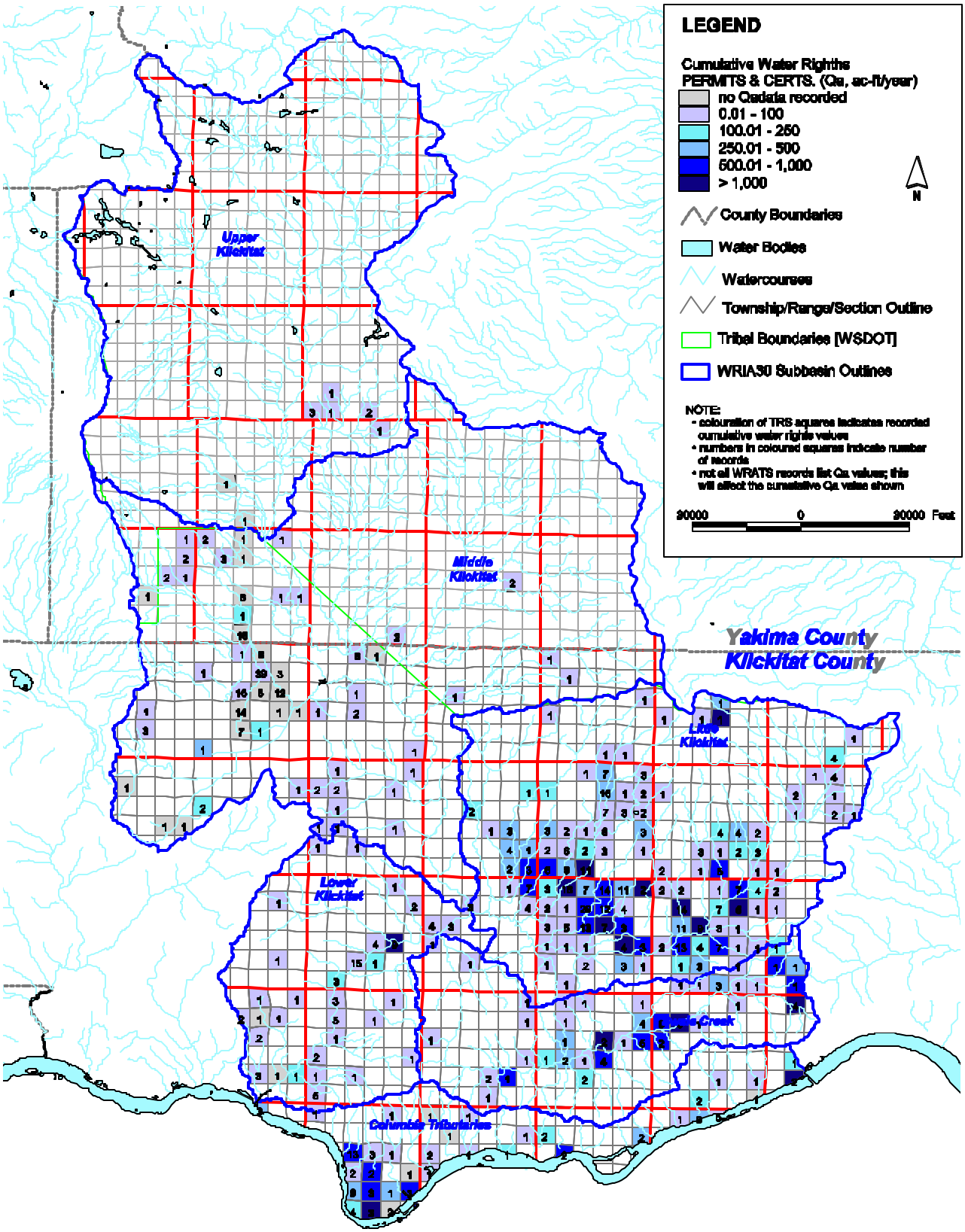


Figure 6-1. Distribution of Water Right Certificates and Permits.

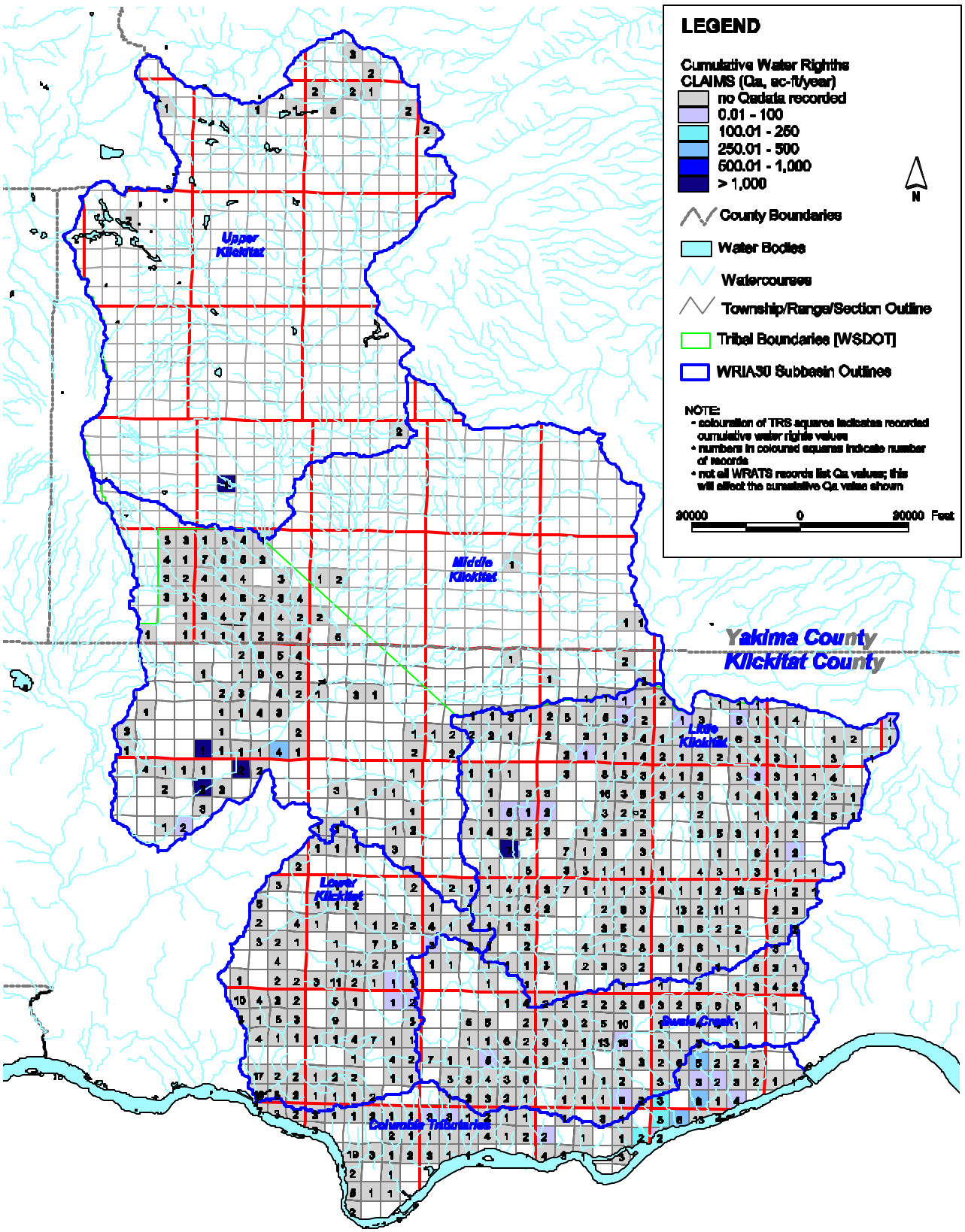


Figure 6-2. Distribution of Water Claims.

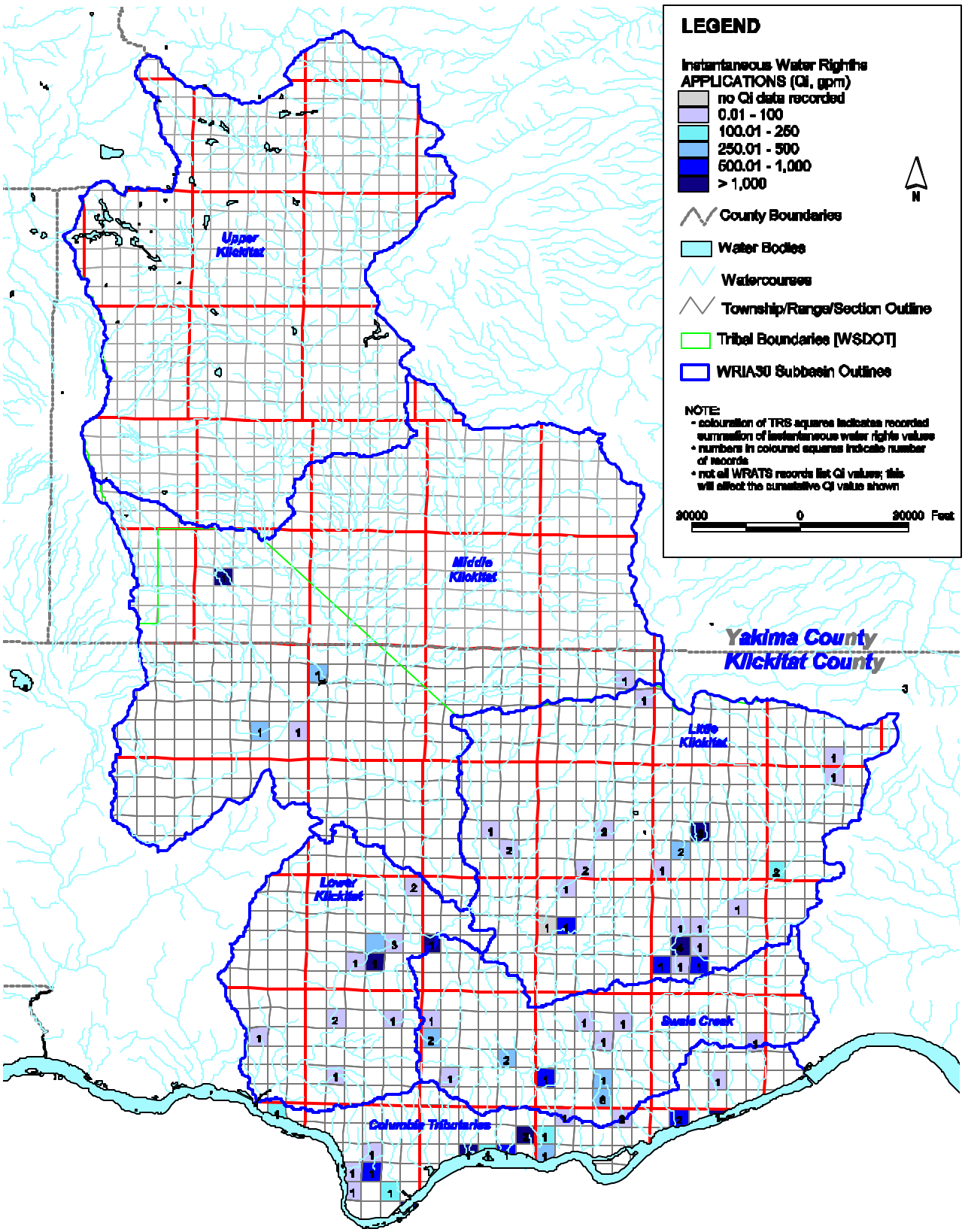


Figure 6-3. Distribution of Water Right Applications.

6.1.2.2 Middle Klickitat

There are 194 water rights recorded within the Middle Klickitat Subbasin, with a total annual allocation of 1,186 acre-feet/year. The majority of the recorded annual rights (77% or 907 acre-feet/year) are for irrigating approximately 9,900 acres (Figure 6-4). The remaining rights are allocated mostly for domestic and stock watering uses. The largest individual annual right recorded is a 405 acre-feet/year irrigation right from an unnamed spring in T6N, R12E, Section 31 (Figure 6-1).

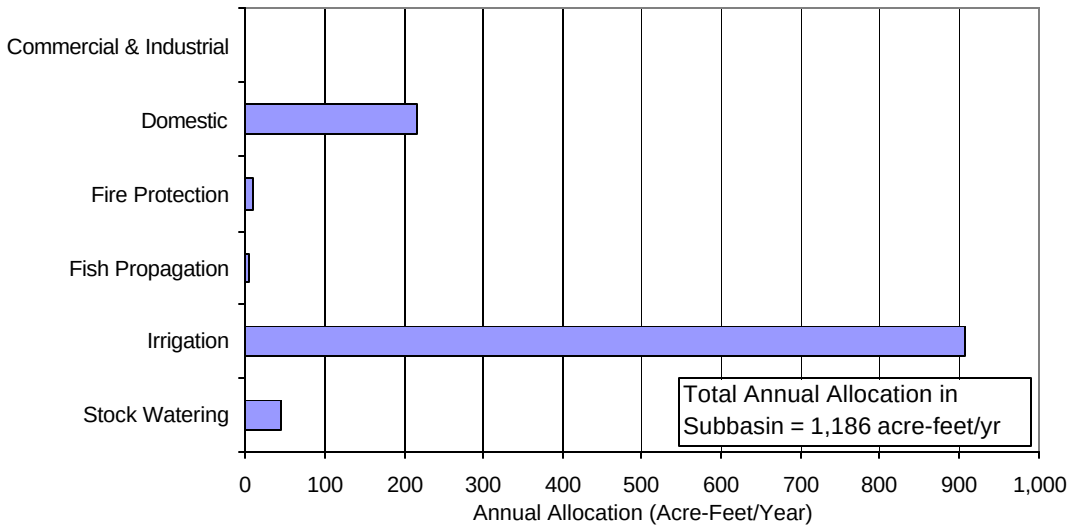


Figure 6-4. Recorded Annual Water Rights by Use in Middle Klickitat Subbasin.

In addition, there are 278 claims recorded in this subbasin, only six of which have quantities recorded. Of note are two very large surface water claims for diversions from Outlet and Holmes Creeks (T6N, R12E, Sections 4 and 7, respectively; Figure 6-2) that reportedly total 41,500 acre-feet/year combined (one is for 34,000 acre-feet/year).

Table 6-4 presents the recorded cumulative groundwater and surface water rights and cumulative water claims (cfs and acre-feet/year) by water source in the Middle Klickitat Subbasin. For this table, instantaneous rights for both groundwater withdrawals and surface water diversions are expressed in cfs. Note that the source names are taken verbatim from those listed in WRATS.

Table 6-4. Cumulative Recorded Water Rights and Claims by Source, Middle Klickitat.

	Cumulative Instantaneous in cfs	Cumulative Annual in AFY
Groundwater Certificates+Permits		
INFILTRATION TREN	0.5	98
WELL	1.6	389
Totals:	*2.2*	*487*
Surface Water Certificates+Permits		
601 WATERHOLE *	0.01	0.5
BACON CREEK	11	0.0
BEEKS CNYN CR	0.01	1.0
BIRD CREEK	69	0.0
BORDE CAMP SPR	0.01	0.5
COTTONWOOD SPRING	0.01	0.5
DAIRY CREEK	2.0	0.0
DEER CREEK	0.4	67
DRAPER SPRINGS	0.5	21
DRY CREEK	1.0	0.0
FRASIER CREEK	38	0.0
HATHAWAY SPRING	0.01	1.0
INDIAN FORD SPRIN	27	6.0
KLICKITAT RIVER	30	0.0
KUHNHAUSEN SPRING	0.01	2.0
MAPLE SPR *	0.01	0.5
MASONDALE SPRING	0.01	1.0
MCCUMBER SPRING	1.1	135
MUD SPRING	0.01	0.5
NORTH FORK DAIRY	2.0	0.0
OUTLET CREEK	0.5	0.0
PARADISE SPRING	0.02	1.0
PENNINGTON SPRING	0.01	1.0
PRAHL SPRS	0.01	0.5
SINK CR *	2.9	0.0
UNNAMED SPRING	6.2	460
WELLENBROCK SPRIN	0.01	0.5
WONDER SPRINGS CR	12	0.0
Totals:	*204*	*699*
Claims		
CHAPMAN CREEK	0	30
COLD SPRING	0.0	2630
HOLMES CREEK	0.0	7500
OUTLET CREEK	0.0	34,425
UNNAMED SPRING	0	5
Totals:	*0.0*	*44,590*

There are five water right applications (four surface water and one groundwater) recorded in the Middle Klickitat, with a cumulative instantaneous diversion/withdrawal of 202 cfs. Almost that entire quantity (200 cfs) is for an application to divert water for irrigation use from an unnamed stream in T7N, R12E, Section 17 (Figure 6-3).

6.1.2.3 Little Klickitat

Within WRIA 30, the greatest number of recorded water rights and the greatest cumulative volume of allocated rights (34,000 acre-feet/year) occur within the Little Klickitat Subbasin (Table 6-2; Figure 6-1). There are 181 groundwater and 259 surface water rights. Most of the larger rights are from groundwater wells and springs. Eighty-three percent (83%) of the water (28,000 acre-feet/year) allocated in the Little Klickitat Subbasin is for irrigation use (on 9,670 acres), with lesser volumes allocated for municipal (City of Goldendale), commercial/industrial, and domestic uses (Figure 6-5).

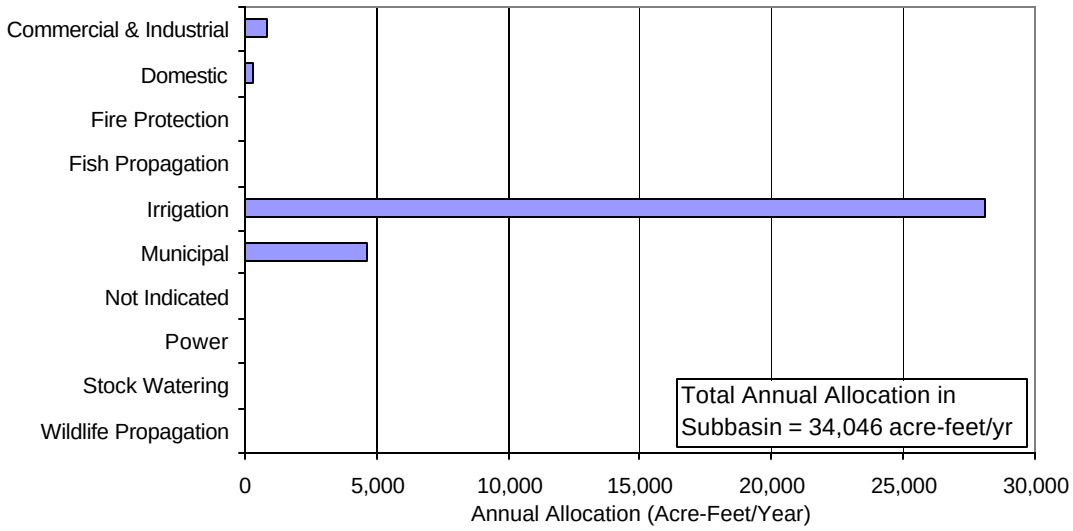


Figure 6-5. Recorded Annual Water Rights by Use in Little Klickitat Subbasin.

There are also 182 claims recorded in the Little Klickitat Subbasin (Table 6-2) for stock watering, irrigation, and domestic uses (few have quantities recorded). The vast majority of the claims are for groundwater; however, the claim with the highest recorded annual quantity (1,500 acre-feet/year) is for a surface water diversion from Bowman Creek (T5N, R14E, Section 26; Figure 6-2) for irrigation use. The 18 surface water claims presumably have been filed subsequent to the 1987 surface water adjudication in this subbasin. The recorded cumulative groundwater and surface water rights and cumulative water claims by water source in the Little Klickitat Subbasin are presented in Table 6-5.

There are 31 water right applications pending in the subbasin, with a cumulative instantaneous diversion/withdrawal of 19 cfs. All but five of the applications are for groundwater wells or springs. Of the other five applications, one is for a diversion from

the Little Klickitat River and two each are from Mill Creek and Bowman Creek. Of the 19 cfs total applied for, 18 applications request a total of 5 cfs for irrigation, three request a total of 11 cfs for municipal supply, and one requests 1.3 cfs for fire protection.

6.1.2.4 Swale Creek

There are 65 recorded water rights (58 groundwater, 7 surface water) within the Swale Creek Subbasin with a cumulative annual allocation of 11,659 acre-feet/year. Of this quantity, groundwater withdrawals for irrigation use represent 99.8% of the total allocation (Figure 6-6). The larger irrigation water rights are distributed within the Swale Creek valley around Centerville (Figure 6-1).

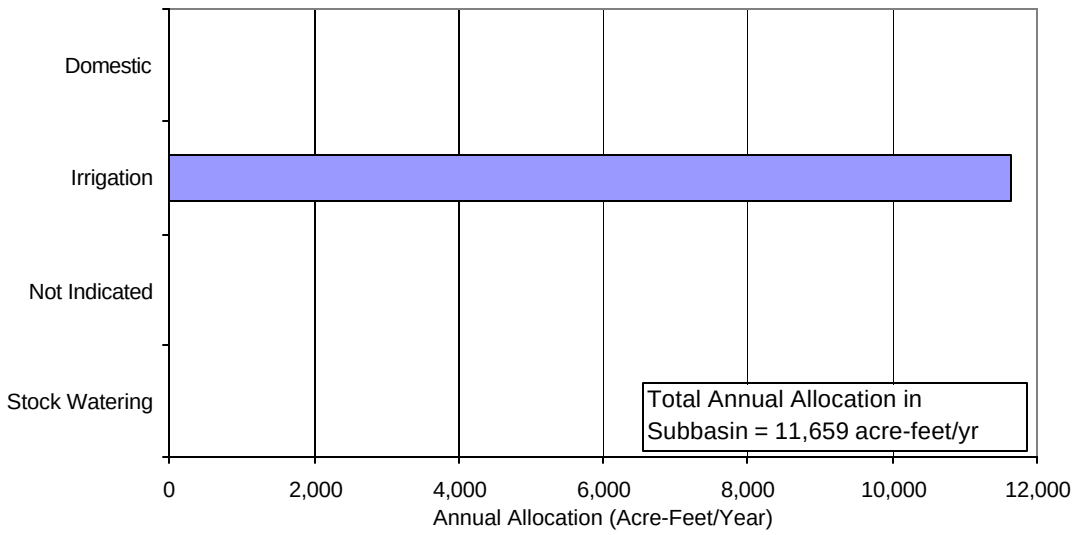


Figure 6-6. Recorded Annual Water Rights by Use in Swale Creek Subbasin.

Table 6-5. Cumulative Recorded Water Rights and Claims by Source, Little Klickitat Subbasin.

	Cumulative Instantaneous in cfs	Cumulative Annual in AFY
Groundwater Certificates+Permits		
INFILTRATION TREN	0.8	269
SUMP	0.4	68
WELL	68	18,572
Totals:	*69*	*18,910*
Surface Water Certificates+Permits		
BLOCKHOUSE CREEK	14	1601
BLOODGOOD SPRS	2	1338
BOWMAN CREEK	4.3	954
CARROLLS CREEK	1.8	311
COZY NOOK CREEK	3.1	486
DEVILS CANYON CRE	2.2	529
DRY CREEK	0.3	75
EMERSON SPRS	0.4	1363
KLICKITAT RIVER	0.2	32
LITTLE KLICKITAT	8.2	2074
MCCLINTOCK SPRING	0.01	2.0
MILL CREEK	6.3	1250
ROCKWELL SPR	0.5	371
SMITH-WARREN CREE	0.1	11
SPRING BRANCH	0.2	0.0
SPRING CREEK	18	2382
STUMP CREEK	2.5	400
UNN (MCCLINTOCK)	0.4	150
UNNAMED POND	0.02	25
UNNAMED SOURCE	0.0	10
UNNAMED SPRING	6.4	1040
UNNAMED STREAM	4.0	732
Totals:	*75*	*15,136*
Claims		
BOWMAN CREEK	0.0	1528
DEVILS CANYON CRE	0.0	1.3
DRY CREEK	0.0	1.3
IDLEWILD CREEK	0.0	1.3
MIDDLE PRONG CREE	0.0	1.3
MILL CREEK	0.0	1.3
UNNAMED POND	0.0	1.1
UNNAMED SPRING	0.0	0.6
WEST PRONG CREEK	0.0	1.3
Totals:	*0*	*1537*

There are 269 claims in this subbasin, primarily for domestic, stock watering, and irrigation uses. Very few claims have quantities recorded, and the total annual quantity recorded for the subbasin is only 15 acre-feet/year (Table 6-2). The recorded cumulative groundwater and surface water rights and cumulative water claims by water source in the Swale Creek Subbasin are presented in Table 6-6.

There are 22 water right applications pending for the Swale Creek Subbasin, with a cumulative instantaneous diversion/withdrawal of 5.8 cfs. Consistent with the permitted rights, the quantity of water applied for is nearly all for irrigation use (Table 6-2).

Table 6-6. Cumulative Recorded Water Rights and Claims by Source, Swale Creek.

	Cumulative Instantaneous in cfs	Cumulative Annual in AFY
Groundwater Certificates+Permits		
WELL	41	11,632
Totals:	*41*	*11,632*
Surface Water Certificates+Permits		
SWALE CREEK	0.01	11
UNNAMED POND	0.007	1.0
UNNAMED SPRING	0.1	4.5
UNNAMED STREAM	0.06	10
Totals:	*0.2*	*27*
Claims		
#1 SPRING	0.0	1.0
#2 SPRING	0.0	0.5
#3 POND	0.0	1.7
#4 POND	0.0	1.7
SWALE CREEK	0.0	3.1
UNNAMED CREEK	0.0	6.4
UNNAMED SPRING	0.0	0.9
Totals:	*0.0*	*15*

6.1.2.5 Lower Klickitat

There are 82 water rights recorded within the Lower Klickitat Subbasin, with a combined annual allocation of 3,219 acre-feet/year (Table 6-2). Water rights in this subbasin are allocated relatively evenly between commercial/industrial (37%), irrigation (31%), and domestic (30%) uses (Figure 6-7). The two largest annual rights (combined 2,144 acre-feet/year, 67% of total subbasin allocation), located near the Town of Klickitat (T4N, R13E, Section 23; Figure 6-1), are diversions from the Klickitat River for industrial use.

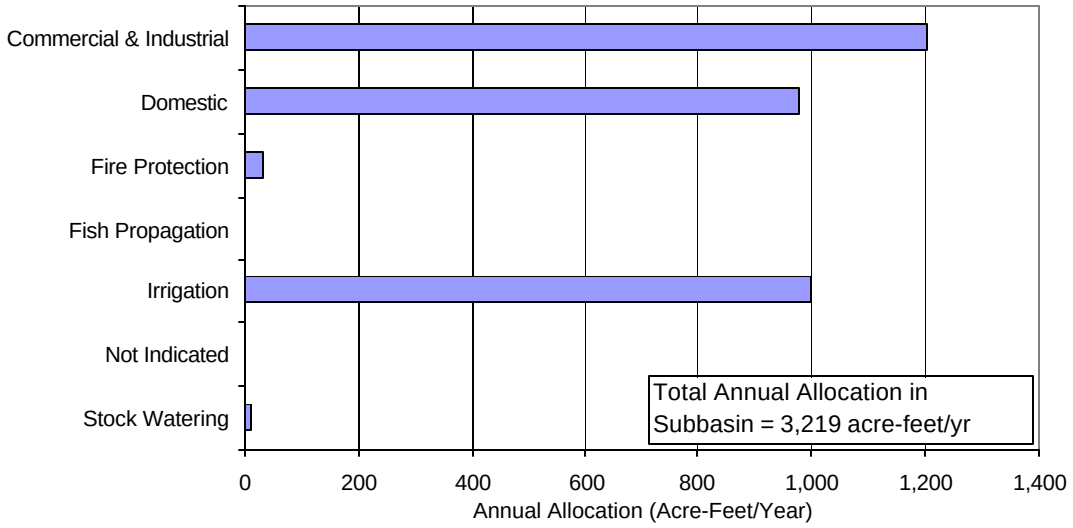


Figure 6-7. Recorded Annual Water Rights by Use in Lower Klickitat Subbasin.

There are also more than 240 claims recorded in this subbasin (domestic, irrigation, and stock watering uses). Very few claims have quantities recorded in the WRATS and the total annual quantity recorded is only 13 acre-feet/year (Table 6-2). The recorded cumulative groundwater and surface water rights and cumulative water claims by water source in the Lower Klickitat Subbasin are presented in Table 6-7.

There are 16 water right applications (10 surface water and 6 groundwater) recorded in the Lower Klickitat Subbasin, with a cumulative instantaneous diversion/withdrawal of approximately 122 cfs. Two applications cover 120 cfs of the total 122 cfs applied for. One of these applications, in the amount of 100 cfs, is for environmental quality (T4, R13, Section 27) and the other, in the amount of 20 cfs (non-consumptive), is for fish propagation (T4, R14, Section 19) (Figure 6-3).

Table 6-7. Cumulative Recorded Water Rights and Claims by Source, Lower Klickitat Subbasin.

	Cumulative Instantaneous in cfs	Cumulative Annual in AFY
Groundwater Certificates+Permits		
INFILTRATION TREN	0.09	27
WELL	0.94	190
Totals:	*1.0*	*217*
Surface Water Certificates+Permits		
DEAD HORSE SPR	0.03	4.0
KLICKITAT RIVER	259	2834
LEGALL SPRING	0.01	1.0
MURRAY SPRING	0.01	1.0
MYTING SPRING	0.01	1.0
SILVAS CREEK	0.05	4.0
SNYDER CREEK	4.3	30
UNNAMED SPRING	0.8	112
UNNAMED STREAM	0.1	15
Totals:	*265*	*3002*
Claims		
KLICKITAT RIVER	0.0	10.5
UNNAMED CREEK	0.0	0.7
UNNAMED POND	0.0	2.1
Totals:	*0.0*	*13*

6.1.2.6 Columbia Tributaries

Within this subbasin, there are 90 recorded water rights (Table 6-2). The largest number and magnitude (annual quantity) of rights in this subbasin are for irrigation use (Figure 6-8). There are 33 groundwater and 18 surface water rights for irrigation use totaling nearly 4,400 acre-feet/year (46% of subbasin total allocation). The Army Corps of Engineers holds the subbasin's two largest recorded annual rights (1,928 acre-feet/year combined) to pump groundwater for heat exchange at the John Day Dam. Water rights for domestic use total 1,531 acre-feet/year. There are two recorded water rights in the Dallesport area designated for industrial use, totaling 967 acre-feet/year.

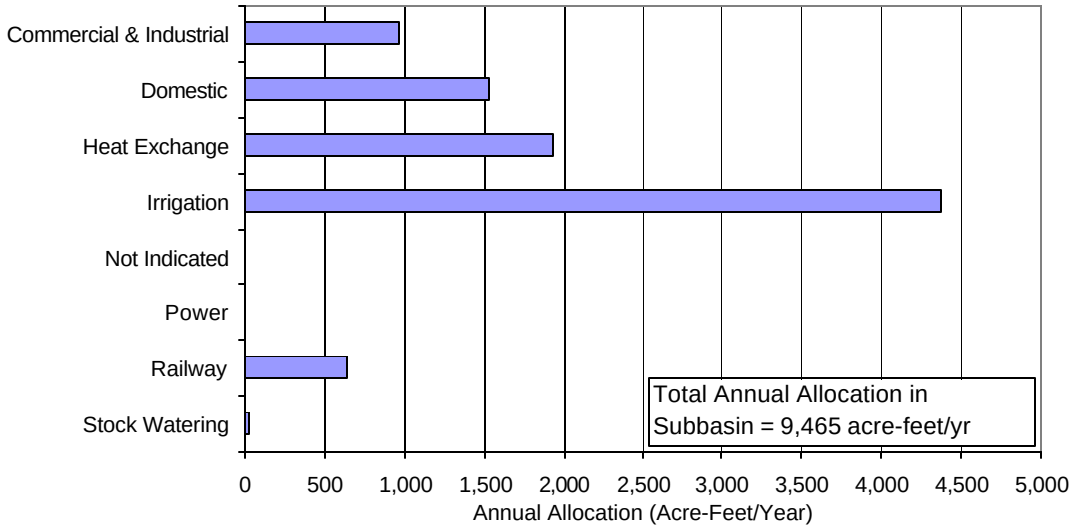


Figure 6-8. Recorded Annual Water Rights by Use in Columbia Tributaries Subbasin.

In addition, there are 177 claims in this subbasin, with a recorded annual quantity claimed of approximately 1,608 acre-feet/year (Table 6-2). Of this quantity, 82% is recorded for irrigation use and 17% is for stock watering. Several of these claims in the Columbia Hills area south of Swale Creek have recorded annual quantities of between 100 and 350 acre-feet/year for irrigation uses (Figure 6-2). The recorded cumulative groundwater and surface water rights and cumulative water claims by water source in the Columbia Tributaries Subbasin are presented in Table 6-8.

Finally, there are 18 water right applications in the Columbia Tributaries Subbasin, with a cumulative instantaneous diversion/withdrawal of 821 cfs. The largest number (10) of these applications are for irrigation use, but the single application for power use encompasses most of the 821 cfs applied for (Klickitat County PUD's application to divert 800 cfs from the Columbia River near Dallesport (T2N, R13E, Section 36; Figure 6-3).

Table 6-8. Cumulative Recorded Water Rights and Claims by Source, Columbia Tributaries.

	Cumulative Instantaneous in cfs	Cumulative Annual in AFY
Groundwater Certificates+Permits		
WELL	58	7997
Totals:	*58*	*7,997*
Surface Water Certificates+Permits		
COLUMBIA RIVER	816	264
EIGHTMILE CREEK	0.5	0.0
HARTLEY CNYN CR	0.1	0.0
LAKE CELILO	2.5	397
SPEARFISH LAKE	2.5	550
STANLEY CANYON SP	0.02	2.0
UNNAMED SPRING	2.2	255
Totals:	*824*	*1468*
Claims		
STREAM	0.0	3.0
UNNAMED SPRING	0.0	1605
Totals:	*0*	*1608*

6.2 ESTIMATED WATER USE

Estimates of actual water use are important for comparison against allocated ("paper") water rights and for constructing a preliminary water budget for WRIA 30. Typically, actual water use will be lower than water right allocations because water rights recorded in the WRATS may be inactive or development of the allocated resources may be constrained by a variety of factors. With the exception of the larger purveyors, water use is typically not metered. As such, preliminary estimates of actual water use are developed for this Level 1 Assessment based on available information and numerous assumptions.

The following sections present the estimates (methods and results) for irrigation, residential, and non-residential (including commercial/industrial) water uses within WRIA 30. Estimating water use within the Upper Klickitat Subbasin has not been attempted in this Level 1 Assessment since little if any information is available for that subbasin.

6.2.1 Estimated Irrigation Water Use

As discussed in Section 6.1, the beneficial use with the largest volume of allocated water in WRIA 30 is irrigation use (comprising 77% of annual total rights). In an attempt to estimate current irrigation water use by subbasin, records were obtained from the local Farm Service Agency (FSA) documenting numbers of current irrigated acres by subbasin (Ms. Noreen Bartkowski, personal communication, September 2002). The 2002 irrigated acre estimates from FSA are presented in Table 6-9. Note that only those acres owned or operated by farmers participating in federal crop programs through FSA are included in the FSA estimates. According to Ms. Bartkowski, most farmers who irrigate in the watershed participate in an FSA program and should thus be accounted for in the FSA acreages, with the exception of farmers in the Glenwood/Camas Prairie region (Middle Klickitat Subbasin) who use flood irrigation. Personal communication with Mr. Dan Hathaway of Hathaway Farms in Glenwood (December 2002) confirmed that most farmers in the Glenwood/Camas Prairie region do not participate in FSA programs, therefore the FSA's irrigated acreage values would be underestimated for the Middle Klickitat Subbasin.

As a point of comparison, Table 6-1 provides the 2002 irrigated acreage from FSA records and the 1967 estimates from the Soil Conservation Service (SCS), by subbasin. The number of irrigated acres recorded for water right certificates and permits (not including claims) in Ecology's WRATS is also provided for comparison. The current number of WRIA 30 irrigated acres (4,914 acres) for farms participating in FSA programs is less than half of the 1967 estimate for all farms (11,360 acres) based on data from the SCS available at that time as reported by Mix (1976). Both data sources report zero irrigated acres within the Lower Klickitat Subbasin. The SCS also reports 0 irrigated acres for the Upper Klickitat Subbasin in 1967.

The SCS estimate for 1967 appears to be generally consistent with the USDA's irrigated acre estimates for Klickitat County for that time (published in the USDA Census of Agriculture). Because there is considerable irrigation in eastern Klickitat County (outside WRIA 30), the number of irrigated acres for the county will be greater than that for WRIA 30 (excluding the Upper Klickitat Subbasin). According to the Census of Agriculture, there were 15,192 and 19,363 irrigated acres in Klickitat County in 1965 and 1969, respectively. This suggests that 11,360 acres for WRIA 30 in 1967 is reasonable (60 to 75% of the county totals).

Table 6-9. Comparison of Irrigated Acre Estimates

Subbasin*	Irrigated Acres		
	1967 Irrigated Acres[a]	2002 Irrigated Acres for Farms in FSA Programs[b]	Irrigated Acres Allocated in Water Rights[c]
Middle Klickitat	4,060	366	9,912
Little Klickitat	4,000	2,860	9,669
Swale Creek	800	1,674	5,334
Lower Klickitat	0	0	324
Columbia Tributaries	2,500	14	1,962
WRIA 30 Totals*	**11,360**	**4,914**	**27,201**

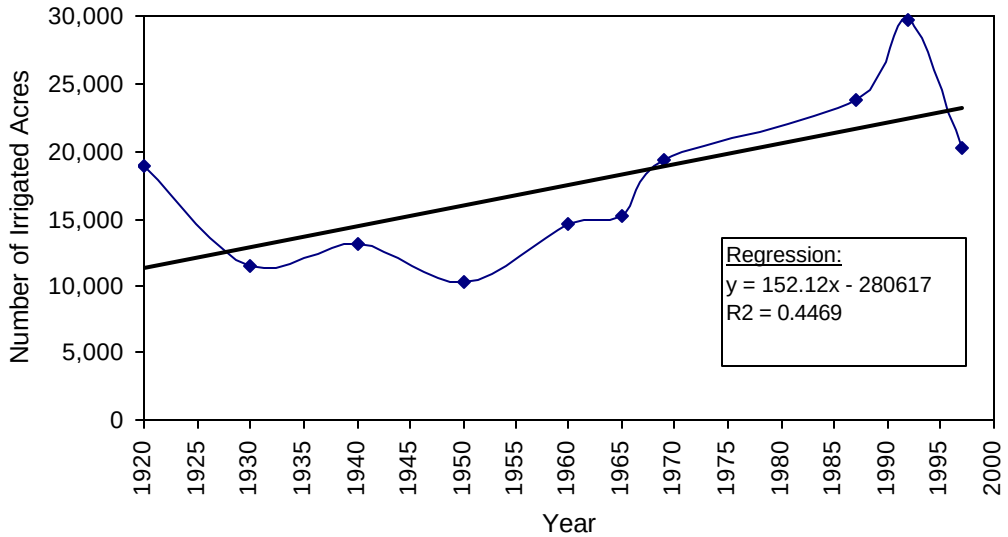
Notes:
*: Upper Klickitat Subbasin not included.
[a] From Soil Conservation Service, reported in Mix (1976).
[b] From Farm Service Agency Records (September 2002).
[c] Data for water right certificates + permits, recorded in WRATS.

The greatest discrepancies between the acreages estimated by the SCS and those currently in FSA programs occur in the Middle Klickitat and Columbia Tributaries Subbasins (Table 6-9). According to Mr. Dan Hathaway, the number of irrigated acres in the Glenwood/Camas Prairie region (Middle Klickitat) has likely not changed appreciably from 1967, and roughly 4,000 irrigated acres likely remains a reasonable estimate for current conditions. Based on this, the major reason for the discrepancies between the 1967 SCS and 2002 FSA estimates appears to be that not all farmers are participating in FSA programs and are therefore not accounted for in the FSA estimates. The FSA documents current irrigated acreage in the Swale Creek Subbasin that is approximately twice that estimated by SCS for 1967; this appears reasonable given the increase in irrigation known to have occurred during the 1970s in that region. However, in more recent years there has generally been a decline in the number of irrigated acres in the Swale Creek subbasin due to energy costs, land use changes, and water right transfers.

Figure 6-9 shows the change in irrigated acreage within Klickitat County (not WRIA 30) between 1920 and 1997 based on the USDA Census of Agriculture (reported in Mix, 1976). The data show a long-term increase in irrigated acreage over time, but with a sharp increase in 1992 (29,739 acres) followed by a sharp decline in 1997 (20,239 acres). It is uncertain if the county-wide decline in irrigated acreage observed between 1992 and 1997 is continuing at present (the 2002 Census of Agriculture is scheduled for publication in 2004).

Assuming the generalized rate of long-term change in irrigated acres observed for Klickitat County as a whole (represented by linear regression line on Figure 6-1) can be generally applied to WRIA 30 as a whole, the 11,360 irrigated acres in WRIA 30 in 1967

would be expected to be roughly 14,000 acres in 1997 (25 percent increase over that 30-year period). It is anticipated that with the changes in land use in WRIA 30 and economic conditions including high energy costs in the 1990s, that the actual number of irrigated acres is somewhat lower and potentially on the decline in parts of the WRIA. This is particularly true for the Little Klickitat subbasin.



Data from USDA Census of Agriculture.

Figure 6-9. Irrigated Acres in Klickitat County, 1920-1997

Although there is considerable uncertainty in irrigated acreages for each subbasin, the FSA estimates are used for all subbasins except for the Middle Klickitat. Based on personal communication with Mr. Dan Hathaway, we assume for this assessment that the current number of irrigated acres in the Middle Klickitat is the same as the 1967 Soil Conservation Service estimates (4,060 acres).

With these assumptions, the estimated total number of irrigated acres in WRIA 30 is approximately 8,600, which is considerably less than the estimate of 14,000 acres based on long-term trends for Klickitat County as a whole (discussed above).

Using those irrigated acreage estimates by subbasin, the proportion of acres of irrigated cropland vs. irrigated pasture was then assumed to estimate acreages for both land uses. For this assessment, the simplified assumption was made that the proportion for Klickitat County – 79% cropland and 21% pasture (USDA, 1997) – was the same across the entire watershed.

An annual water duty (acre-feet/year per acre, or feet of water/year) was then assumed for both cropland and pasture. Again, the simplified assumption was made that water duties for cropland and pasture were the same across the watershed. For cropland, a water duty of 3.4 feet was assumed, which is the water duty for alfalfa used in the 1980s adjudication of surface water rights for the Little Klickitat River Basin (Little Klickitat

River Adjudication, Report of Referee, 1983, p.22). For pasture, a water duty of 3.5 feet was assumed, based on the alfalfa water duty and the ratio of water duties for pasture/alfalfa for Bickleton published by WSU (1982).

Using these assumptions, the average annual irrigation water use estimates were calculated (irrigated acres times annual water duty). The estimates by subbasin are presented in Table 6-10.

Based on this assessment, roughly 29,500 acre-feet/year of water are used for irrigation in WRIA 30. The largest quantity (approximately 14,000 acre-feet/year) is used in the Middle Klickitat Subbasin. The estimated annual volume used is substantially less than the cumulative volume of irrigation water allocated through water right certificates and permits in the watershed as a whole. There are some very large claims for irrigation use in the watershed. Notably, Kreps Ranch reportedly holds claims totaling greater than 44,000 acre-feet/year in the Middle Klickitat Subbasin (refer to Section 6.1.2). Based on communication with Kreps Ranch, these large claims are used principally to flood fields for frost protection; however, much of this water makes its way as return flow to Conboy Wildlife Refuge and adjacent surface waters. Therefore, it is assumed for this assessment that the actual water use associated with these large claims is accounted for by using the current best estimate of irrigated acres in the subbasin (based on local knowledge) and the assumed water duties.

Table 6-10. Estimated Irrigation Water Use by Subbasin

Subbasin*	Irrigated Acres	Acres of Irrigated Cropland[c]	Cropland Water Duty in Feet/Year[e]	Cropland Irrigation in Acre-Feet/Year	Acres of Irrigated Pasture[d]	Pasture Water Duty in Feet/Year[f]	Pasture Irrigation in Acre-Feet/Year	Estimated Current Irrigation Use in Acre-Feet/Year	Recorded Irrigation Water Rights in Acre-Feet/Year[g]	Recorded Irrigation Claims in Acre-Feet/Year[h]
Middle Klickitat	4,060 [a]	3,207	3.4	10,905	853	3.5	2,989	13,895	907	44,555
Little Klickitat	2,860 [b]	2,259	3.4	7,682	601	3.5	2,106	9,788	28,096	1,525
Swale Creek	1,674 [b]	1,322	3.4	4,496	352	3.5	1,233	5,729	11,651	0
Lower Klickitat	0 [b]	0	3.4	0	0	3.5	0	0	997	11
Columbia Tributaries	14 [b]	11	3.4	38	3	3.5	10	48	4,377	1,321
WRIA 30 Totals*	8,608	6,800		23,121	1,808		6,338	**29,459**	46,028	47,412

Notes:
*: Irrigated acreage data not available for Upper Klickitat Subbasin.
[a] Assumes no change from 1967 SCS irrigated acreage estimates (from personal comm. with Dan Hathaway of Glenwood).
[b] From FSA records (2002).
[c] Assumes 79% of irrigated acres are irrigated cropland (from 1997 USDA Census of Agriculture for Klickitat County).
[d] Assumes 21% of irrigated acres are irrigated pasture (from 1997 USDA Census of Agriculture for Klickitat County).
[e] Assumes alfalfa water duty from Little Klickitat River Water Rights Adjudication (1987).
[f] Based on alfalfa water duty estimate and ratio of pasture/alfalfa water duties for Bickleton from WSU (1982).
[g] Data for water right certificates + permits, recorded in WRATS.
[h] Data for water claims recorded in WRATS.

As discussed above, there is considerable uncertainty in multiple assumptions used to develop these preliminary irrigation water use estimates. Given that irrigation comprises

the largest water use in WRIA 30, refinement of the irrigation water use estimates would be warranted as part of a Level 2 Assessment.

6.2.2 Residential Water Use

Residential (domestic) water use includes water supplied both by public water systems (PWS) and by exempt wells (self-supplied). The estimated annual water use by PWS-supplied and self-supplied populations is discussed below.

6.2.2.1 Public Water System Residential Usage

The PWS located within WRIA 30 were determined from GIS coverages provided by the state Department of Health (DOH). Using the coverages, the PWS were divided into subbasins based on source location. No PWS were identified in the Upper Klickitat Subbasin. The PWS numbers were then cross-referenced to the DOH PWS databases (Group A and Group B systems) to obtain the numbers of residential and non-residential connections and the residential population served for each PWS. Group B water systems include systems with 2 to 14 connections. Group A water systems include systems with 15 or more connections. Summary information for the 74 PWS identified in DOH databases is presented in Table 6-11 by subbasin. According to these data, 6,846 persons in WRIA 30 are served by a PWS (58% of the total population in the watershed, as discussed below).

The Klickitat Public Utilities District (PUD), City of Goldendale, Dallesport Water Association, and Dallesport Mobile Homes Park – operators of the largest PWS in the watershed based on resident population served (Table 6-11) - were contacted to request available information on actual annual water uses. The City of Goldendale (Little Klickitat Subbasin) operates the single largest PWS in the watershed and the PUD operates six PWS within three different subbasins. Of these purveyors, actual water use data were obtained from the City of Goldendale and the PUD.

Klickitat PUD operates six Group A water systems within WRIA 30: Glenwood Water System in the Middle Klickitat Subbasin; Ponderosa Park Water System and Rimrock Water Association in the Little Klickitat Subbasin; Klickitat Water System in the Lower Klickitat Subbasin; and the Lyle Water System and Wishram Water System in the Columbia Tributaries Subbasin (Table 6-11). The PUD provided residential, non-residential, and unaccounted-for water use for 2001. Of the accounted water use, residential use ranged from 88 to 100%, with an average of 90% for the six water systems. Therefore, 90% of the unaccounted use was apportioned to residential use with the remaining 10% to non-residential use. The residential per capita water use for the six PWS range from 111 to 224 gallons per capita day (gpcd), with an average of 160 gpcd. Because the PUD's six PWS are located throughout the watershed, this 160 gpcd average was assumed for this assessment as the residential per capita water use throughout the watershed.

Table 6-11. Estimated Public Water System Water Use.

PWS ID	PWS Name	Group	Resid. Population Served	No. Resid. Connects	No. Total Connects	No. Non-resid. Connects	Estimated Annual Resid. Water Use (Acre-Feet/Year)	Estimated Annual Non-Resid. Water Use (Acre-Feet/Year)
Middle Klickitat								
28220	GLENWOOD WATER SYSTEM*	A	447	204	204	0	150.4	10.0
8933	KLICKITAT SALMON HATCHERY	B	15	3	4	1	2.7	0.04
25981	CAMP DRAPER WATER SYSTEM	B	5	3	4	1	0.9	0.04
26171	CHAMPION TRUCK SHOP	B	0	0	2	2	0.0	0.1
	Subbasin Totals:		467	210	214	4	**154**	**10**
Little Klickitat								
15571	PONDEROSA PARK WATER SYSTEM*	A	115	82	82	0	37.6	0.0
21140	ROADHOUSE 97	A	1	1	3	2	0.2	0.1
23251	THREE CREEKS RESORT	A	2	1	22	21	0.4	0.8
28450	GOLDENDALE, CITY OF	A	3,760	1,072	1,428	356	673.9	397.1
72472	RIMROCK WATER ASSOCIATION*	A	56	21	21	0	11.4	0.0
SP016	BROOKS MEMORIAL CG STATE PARK	A	0	0	31	31	0.0	1.2
SP120	BROOKS MEM STATE PARK ELC & ADMIN	A	2	2	27	25	0.4	1.0
2087	OLSON, LEO WATER SYSTEM	B	7	3	3	0	1.3	0.0
2089	OLSON, WILLIAM WTR SYSTEM	B	6	2	2	0	1.1	0.0
2090	MATULA, FLOYD H. WTR SYSTEM	B	5	2	2	0	0.9	0.0
2091	WEDGWOOD WATER SYSTEM	B	6	2	2	0	1.1	0.0
3568	LINK, JAMES H. WATER SYSTEM	B	7	2	2	0	1.3	0.0
3635	ESHELMAN WATER SYSTEM	B	4	2	2	0	0.7	0.0
3707	RED CEDAR WATER SYSTEM	B	5	3	3	0	0.9	0.0
4122	HODGES & JUNG-HODGES	B	4	2	2	0	0.7	0.0
5869	CLARK, DONALD & IDA	B	5	2	2	0	0.9	0.0
5877	STORKEL WATER SYSTEM	B	4	2	2	0	0.7	0.0
5880	LOUGHBOROUGH WATER SYSTEM	B	3	2	2	0	0.5	0.0
6400	MT VIEW ACRES	B	20	4	4	0	3.6	0.0
7708	WEST MEADOW WATER SYSTEM	B	6	2	2	0	1.1	0.0
11611	OLD AMERICAN WAY	B	2	1	1	0	0.4	0.0
20096	BRONG'S COMMUNITY WATER ASSN.	B	5	2	2	0	0.9	0.0
26720	CASE, RICHARD G	B	8	3	3	0	1.4	0.0
26866	PINE SPRINGS RESORT	B	2	1	4	3	0.4	0.1
27311	HILMAN	B	4	2	2	0	0.7	0.0
29479	FOSTER ROAD WATER ASSOCIATION	B	20	8	8	0	3.6	0.0
34701	SCHRODER, LAURENCE E.	B	4	2	2	0	0.7	0.0
38636	GOLDENDALE S.D.A. SCHOOL	B	0	0	2	2	0.0	0.1
39203	MILL CREEK PLAT WATER SYSTEM	B	5	3	3	0	0.9	0.0
40964	CANYON BREAKS	B	8	4	4	0	1.4	0.0
FW012	GOLDENDALE FISH HATCHERY	B	8	2	3	1	1.4	0.04
FW018	KLICKITAT WILDLIFE AREA	B	0	0	2	2	0.0	0.1
HD006	SATUS PASS MAINTENANCE SITE	B	0	0	2	2	0.0	0.1
	Subbasin Totals:		4,084	1,237	1,682	445	**750**	**400**
Swale Creek								
21127	CENTERVILLE GRADE SCHOOL	A	0	0	1	1	0.0	0.04
5881	BARTLETT WATER SYSTEM	B	10	2	2	0	1.8	0.0
8403	HARVEST GOLD BOTTLED WATER	B	5	1	2	1	0.9	0.04
	Subbasin Totals:		15	3	5	2	**3**	**0.1**

PWS ID	PWS Name	Group	Resid. Population Served	No. Resid. Connects	No. Total Connects	No. Non-resid. Connects	Estimated Annual Resid. Water Use (Acre-Feet/Year)	Estimated Annual Non-Resid. Water Use (Acre-Feet/Year)
Lower Klickitat								
07842	WISHBONE WELL	A	1	1	2	1	0.2	0.04
42800	KLICKITAT WATER SYSTEM*	A	422	181	181	0	105.3	25.7
4120	RIPPLINGER WATER SYSTEM	B	2	2	2	0	0.4	0.0
5878	MILLER, GEORGE WATER SYSTEM	B	4	2	2	0	0.7	0.0
6192	SILVA RIDGE WATER SYSTEM A	B	6	2	2	0	1.1	0.0
7150	SILVA RIDGE WATER SYSTEM B	B	6	2	3	1	1.1	0.04
22397	KLICKITAT CO. F.P.D. #13	B	3	1	2	1	0.5	0.04
26161	WOODRUFF WATER SYSTEM	B	5	2	2	0	0.9	0.0
34711	PARADISE FLAT	B	5	2	2	0	0.9	0.0
	Subbasin Totals:		454	195	198	3	**111**	**26**
Columbia Tributaries								
00238	DALLESPORT INDUSTRIAL PARK	A	0	0	8	8	0.0	0.3
00682	MURDOCK WATER	A	62	33	33	0	11.1	0.0
01500	PEACH BEACH RV PARK	A	0	0	69	69	0.0	2.6
01842	PROSPECT WATER ASSN INC	A	95	39	39	0	17.0	0.0
08136	DALLESPORT MOBILE HOME PARK	A	135	42	44	2	24.2	0.1
08138	MARYHILL VINTNERS	A	0	0	1	1	0.0	0.04
15077	DALLESPORT DOMESTIC WATER SHARERS	A	32	14	15	1	5.7	0.04
17715	DALLESPORT WATER ASSOCIATION	A	375	167	171	4	67.2	0.2
20327	MINOR ADDITION WATER SUPPLY	A	30	13	14	1	5.4	0.04
20527	MOUNTAIN VIEW ASSOCIATION	A	42	21	21	0	7.5	0.0
25041	MARYHILL MUSEUM OF ART	A	2	1	2	1	0.4	0.04
40951	PAT'S RANCHMART INC	A	6	2	3	1	1.1	0.04
49000	LYLE WATER SYSTEM*	A	491	287	287	0	117.5	16.0
97950	WISHRAM WATER SYSTEM*	A	459	199	199	0	83.6	10.1
SP325	HORSETHIEF LAKE STATE PARK	A	3	1	16	15	0.5	0.6
SP510	MARYHILL STATE PARK	A	4	3	104	101	0.7	3.9
2679	NEWCASTLE WATER SYSTEM	B	12	3	4	1	2.2	0.04
2768	SEXTON, GISELA WATER SYSTEM	B	2	2	2	0	0.4	0.0
4518	ELLIS WATER SYSTEM	B	16	4	4	0	2.9	0.0
15804	NORTHDALLES FRUIT & GARDEN TRACTS	B	14	9	9	0	2.5	0.0
19536	RIVERVIEW	B	24	9	9	0	4.3	0.0
22401	SMITH RANCH	B	5	2	3	1	0.9	0.04
32589	MARYHILL GARDENS	B	8	2	2	0	1.4	0.0
32821	ODOM'S WELL	B	9	4	4	0	1.6	0.0
41901	SAM HILL'S COUNTRY STORE	B	0	0	1	1	0.0	0.04
	Subbasin Totals:		1,825	857	1,064	207	**358**	**34**
	WRIA 30 Totals:		6,846	2,502	3,163	661	1,376	471

*: Operated by Klickitat PUD.

An average annual water use of 1,071 acre-feet/year for the City of Goldendale was estimated using water usage data provided by the City for their three water sources, Simcoe Springs, Bloodgood Spring, and Basse Wellfield, during the period 1999 through October 2002. Note that the City's largest water source, the Simcoe Mountains Springs, includes an overflow to the Little Klickitat River. The meter for this overflow was inoperable for the last few months of 2001, resulting in higher apparent water usage for these months (i.e., water entering the river is not subtracted from the Simcoe Springs water totals). To account for this, monthly averages were calculated for the 4-year period excluding those months when the overflow meter was inoperable. The averages for each month were then summed to obtain an estimated annual water usage. This adjustment does not change the assumed 160 gpd per capita water use, since that value was based on the average of the per capita uses obtained from the Klickitat PUD's six PWS, as described above.

The City of Goldendale reportedly serves a resident population of 3,760 persons through 1,072 residential connections. The City also supplies 356 non-residential connections. Information regarding the distribution of residential versus non-residential water use is not available, therefore the residential use was estimated assuming 160 gpcd multiplied by 3,760 persons served (674 acre-feet/year). Non-residential use assumed to make up the remaining 397 acre-feet/year (Table 6-11). Residential water use for the other PWSs was likewise estimated by multiplying the reported resident population served by the assumed 160 gpcd (Table 6-11).

6.2.2.2 Self-Supplied Residential Usage

The self-supplied population was estimated by subtracting the resident population served by PWS from the total population for each subbasin. Total population by subbasin (excluding Upper Klickitat) was estimated using information obtained from the 2000 U.S. Census. Census data were obtained by county subdivision and place (cities) (http://factfinder.census.gov). These data were assigned to subbasin based on geographic location. The e population estimates for each subbasin are presented in Table 6-12. The total population estimate for WRIA 30 (11,705 persons) agrees reasonably well with the estimate of 11,267 developed independently by Ecology (WRIA 30 Demographics; http://www.ecy.wa.gov/programs/wq/wria_summaries/wria30.pdf). Based on these estimates, 58% of the watershed's population resides within the Little Klickitat Subbasin, with roughly one-third of the total population within the City of Goldendale (3,760 persons). Subtracting the estimated 6,846 persons supplied by PWS from the total watershed population leaves an estimated 4,859 persons who are assumed to be self-supplied in WRIA 30.

Consistent with water use estimates for PWS-supplied residents, self-supplied residents were assumed to use 160 gpcd of water. The self-supplied population of WRIA 30 is therefore estimated to use 871 acre-feet/year of water (Table 6-13).

Table 6-12. 2000 Population Data by Subbasin

County Subdivision and Place	Population	Housing units
Middle Klickitat		
Yakama Reservation CCD	538	249
Subbasin Totals:	538	249
Little Klickitat		
Goldendale city	3,760	1,690
Remainder of Goldendale CCD	2,984	1,327
Subbasin Totals:	6,744	3,017
Lower Klickitat		
Klickitat CDP	417	173
Remainder of Wahkiakus CCD	1,749	766
Subbasin Totals:	2,166	939
Swale Creek		
Centerville CDP	120	49
Subbasin Totals:	120	49
Columbia Tributaries		
Dallesport CDP	1,185	525
Lyle CDP	530	260
Maryhill CDP (part)	6	4
Maryhill CDP (part)	92	45
Wishram CDP	324	194
Subbasin Totals:	2,137	1,028
WRIA 30 Totals	**11,705**	**5,282**

Data from http://factfinder.census.gov

Table 6-13. Estimated Self-Supplied Residential Annual Water Use

Subbasin	Total Population	PWS-Supplied Population	Self-Supplied Population	Estimated Self-Supplied Annual Residential Water Use (Acre-Feet/Year)
Middle Klickitat	538	467	71	13
Little Klickitat	6,744	4,084	2,660	477
Lower Klickitat	2,166	454	1,712	307
Swale Creek	120	15	105	19
Columbia Tributaries	2,137	1,825	312	56
WRIA 30 Totals:	11,705	6,846	4,859	**871**

While 871 acre-feet/year is the best estimate of self-supplied water use based on available information, a maximum self-supplied water use can also be estimated assuming that

each household of the self-supplied population fully uses the 5,000 gpd volume of water allowed without a water right from the state ("exempt well"). To estimate this water use, the self-supplied population was converted to number of households, and each household was assumed to use 5,000 gpd. It is assumed that each household contains an average of 2.54 persons, based on Klickitat County census figures (http://quickfacts.census.gov/qfd/states/53/53039.html). Therefore, 1,913 self-supplied households are assumed to each be using 5,000 gpd, which equates to approximately 10,700 acre-feet/year across WRIA 30 (Table 6-14).

Table 6- 14. Estimate of Maximum Self-Supplied Residential Annual Water Use.

Subbasin	Self-Supplied Population	Self-Supplied Households[a]	Estimated Maximum Self-Supplied Annual Residential Water Use (Acre-Feet/Year)
Middle Klickitat	71	28	156
Little Klickitat	2,660	1,047	5,866
Lower Klickitat	1,712	674	3,775
Swale Creek	105	41	232
Columbia Tributaries	312	123	687
WRIA 30 Totals:	4,859	1,913	**10,716**

[a] Assumes average of 2.54 persons/household.

This estimated annual volume equates to a per capita water use of approximately 1,970 gpd, which is an order of magnitude above estimates typically used in water use planning anywhere in the state. This maximum value could be considered as a 'worst-case scenario' in watershed planning, but it is considered a less realistic use estimate than the 871 acre-feet/year estimate presented in Table 6-13.

6.2.3 Non-Residential Water Use

The state DOH's PWS database reports the number of residential and non-residential connections. PWS non-residential use could include commercial/industrial, power, recreation (parks), stock watering, etc. The eight PWS that have more than five recorded non-residential connections (Table 6-11) were contacted for this assessment in an attempt to obtain their estimates of annual water use. Of the eight contacted, water use information was obtained from the City of Goldendale, Klickitat PUD, and Maryhill State Park.

As discussed above, City of Goldendale's non-residential water use is estimated to be approximately 397 acre-feet/year (Table 6-11). This water is primarily for commercial/industrial use. Goldendale Energy Inc. is currently constructing a gas-fired turbine power plant in Goldendale. When completed, this power plant will substantially increase the quantity of water the City of Goldendale supplies for non-residential use.

Klickitat PUD supplies water for non-residential use from its Glenwood, Klickitat, Lyle, and Wishram PWS (Table 6-11), but the non-residential quantities comprise only 12% of these four PWS' combined total supply. Although there is industrial property in Wishram that may increase the non-residential water demand for future industrial uses, there currently is no significant industrial use. In fact, industrial water use in WRIA 30 is limited overall. Current known industrial water uses include lumber (log deck) operations and rock quarry (processing) in Dallesport. There are numerous commercial operations throughout the basin; however the cumulative water use is generally small relative to irrigation and residential uses.

Maryhill State Park, with 101 non-residential connections, provided annual water use numbers for 2000 and 2001 (4.6 acre-feet/year average). Of the park's average annual usage, the quantity for residential use was estimated assuming 160 gpcd times the reported number of residents served (4), or 0.7 acre-feet/year. The non-residential use was assumed to be the remainder (3.9 acre-feet/year) and the average use per non-residential connection was calculated at 0.038 acre-feet/year (34 gpd year-round). Lacking other data, this estimated water use per non-residential connection was also applied to the non-residential PWS connections for other parks and resorts. Reportedly, there are no metering systems for measuring water use at either Brooks Memorial or Horsethief Lake State Parks (71 non-residential connections combined) and, excluding Goldendale and the PUD, water use data were not obtained from the other PWS with greater than five non-residential connections.

An additional category of non-residential water use in WRIA 30 is stock watering supplied by exempt wells. Groundwater withdrawal in any quantity for stock watering is exempt from water rights permitting (exempt wells). There is no readily available information from which to estimate such usage in WRIA 30. Regardless, stock watering using exempt wells is considered to be a small component of total water use in the watershed, particularly relative to irrigation use.

6.2.4 Estimated Water Use by Subbasin

Table 6-15 presents the compilation of water use estimates, by subbasin, for the various categories of use (irrigation, residential, and non-residential). Based on the results of this Level 1 Assessment, irrigation represents the overwhelming majority (approximately 92%) of the total water use in WRIA 30, which is consistent with the results of the water rights analysis (Section 6.1). Residential and non-residential uses comprise roughly 7 and 1 percent of the total water use, respectively.

Table 6-15. Estimated Total Water Use for WRIA 30 by Subbasin

Subbasin	Estimated Water Use (Acre-Feet/Year) by Category				Subbasin Totals
	Irrigation	PWS-Supplied Residential	Self-Supplied Residential	PWS Non-Residential	
Middle Klickitat	13,895	154	13	10	14,071
Little Klickitat	9,788	750	477	400	11,415
Swale Creek	5,729	3	19	0.1	5,751
Lower Klickitat	0	111	307	26	444
Columbia Tributaries	48	358	56	34	496
WRIA 30 Totals:	29,459	1,376	871	471	**32,177**
% of Total WRIA 30 Use:	92%	4%	3%	1%	100%

6.3 WATER AVAILABLE FOR ALLOCATION

One of the key issues to be addressed in this assessment is the physical and legal availability of water. This concept brings together the components of water balance, water allocation, water use, hydraulic continuity, and stream flow. This section provides, for each subbasin, a gross water balance quantifying the major components of the hydrologic cycle - precipitation, evapotranspiration, runoff (as streamflow), and groundwater recharge. Water available for allocation can not reliably be determined solely from a water balance approach, due largely to uncertainties in actual water use. In determining water available for allocation in each subbasin, comparison of instream flows to water allocation and actual water use, and the timing of each across the year, are important considerations. Therefore, comparative assessments of stream flows and estimated water uses, by month, are also presented for those subbasins with stream flow data.

The reader should note that current stream flow reflects current water use. All plots that contain both flow and water use data should be interpreted with care, recognizing that the flow as it is affected by water use. In the absence of surface water use, flows would be expected to be higher than the current levels.

Groundwater use can also have a range of effects on surface flows. The interactions between groundwater and surface water can be complex. Withdrawals from groundwater can lower water tables and subsequently affect the volume of surface water available. Conversely, use of groundwater can increase surface flows if the water used in hydrologically disconnected from the stream and a portion of the used water subsequently flows into surface water bodies through sheet flow, subsurface flow, or flow through shallower aquifers. No effort was made here to link groundwater withdrawals to surface water volumes. The information needed to quantify those linkages with confidence is not available at this time.

6.3.1 Methods

The conventional water balance approach for a subbasin accounts for partitioning of precipitation into evapotranspiration, runoff becoming stream flow, and groundwater recharge on an annual basis, as expressed by:

Precipitation = Evapotranspiration + Stream Flow + Groundwater Recharge

The water balance represents average annual conditions based on available information, with all quantities expressed in acre-feet/year for comparison against annual water allocations and use estimates.

For each subbasin, precipitation was calculated as the mean annual precipitation multiplied by subbasin area (provided in Section 2). For subbasins with reliable stream flow data (all except Swale Creek and Columbia Tributaries), stream flow was represented as the 50% exceedance flows, representing average conditions. These monthly flows are depicted graphically by subbasin in Section 5.1. Annual groundwater recharge volume estimates, based on USGS data, are presented for each subbasin in Section 5.2. Annual evapotranspiration was then calculated as precipitation minus stream flow minus groundwater recharge. Evapotranspiration was included in the USGS' estimation of groundwater recharge (deep percolation model), but the spatial distribution of evapotranspiration was not presented by itself. Note that, depending on the time periods for which stream flow data are available for each subbasin (Chapter 5.1), the stream flow data used in this assessment include the effects of existing water uses during that period of record.

Estimates of water use in each subbasin were allocated by month over the year; however, water use estimates were not developed for the Upper Klickitat (refer to Section 6.2). Irrigation was assumed to occur from April 15 through September 15 and was assumed to be constant over that time. Actual irrigation use may not start until as late as the early part of June, depending upon the quantity of spring and early summer precipitation. The majority of the other uses are residential uses.

Residential demand and water use typically increases in summer when lawns and gardens are watered. Outside watering can increase summer time demand by more than 50% (WDOH, 1999). Hence, water use was allocated over the year assuming the water use in the months of July, August, and September was 50% greater than in other months.

Except where otherwise noted, the proportion of surface to groundwater rights was assumed to be representative of the proportion of actual use from surface and groundwater sources. Note that actual consumptive water use will be less than total water use because of return flows (see discussion in Section 6.3.8).

6.3.2 Upper Klickitat

No estimates of water use were available for the Upper Klickitat. Recorded water right allocations are very small in the subbasin relative to stream flows. The recorded rights,

however, do not include Federal Reserve rights. Hence, the total use of water in the subbasin is highly uncertain. Table 6-16 provides the water balance for the Upper Klickitat Subbasin, along with the available recorded information on water allocation.

Table 6-16. Upper Klickitat Subbasin Annual Water Balance with Allocated and Actual Annual Water Uses

	All values in acre-feet/year			
Water Balance Component	**Water Balance Value (Average)**	**Allocated Water Right Certificates + Permits**	**Water Claims**	**Actual Water Use**
Precipitation	1,250,667	10 (surface water)	43,300 (all surface water)	NA
Evapotranspiration	418,280			
Streamflow	552,387	0 (groundwater)		
Groundwater Recharge	280,000			

NA: Not estimated (refer to Section 6.2).

6.3.3 Middle Klickitat

The Middle Klickitat has the highest estimated water use of any subbasin in WRIA 30. While there are relatively small water rights certificate quantities in this subbasin, there are very large surface water claims applied primarily to flood irrigation use. These claims are reportedly being put to use, and have been included in estimating the proportion of actual surface water versus. groundwater use for this subbasin (Table 6-17). As a point of comparison, total annual surface water use is approximately 2 percent of the average annual 50% exceedance flow, whereas annual groundwater use is slightly less than 0.1 percent of the total annual groundwater recharge volume. Total annual surface water allocations (including claims) are roughly 6 percent of the 50% exceedance flows, and groundwater allocations are approximately 0.1 percent of the annual groundwater recharge. However, water use is concentrated in the summer months when stream flows are naturally lowest. Figure 6-10 depicts the estimated monthly water appropriation and water use in comparison to 50% and 90% exceedance flows.

Table 6-17. Middle Klickitat Subbasin Annual Water Balance with Allocated and Actual Annual Water Uses

	All values in acre-feet/year			
Water Balance Component	**Water Balance Value (Average)**	**Allocated Water Right Certificates + Permits**	**Water Claims**	**Actual Water Use**
Precipitation	1,270,240	699 (surface water)	44,590 (all surface water)	13,920 (surface water)
Evapotranspiration	208,513			
Streamflow	716,727	487 (groundwater)		151 (groundwater)
Groundwater Recharge	345,000			

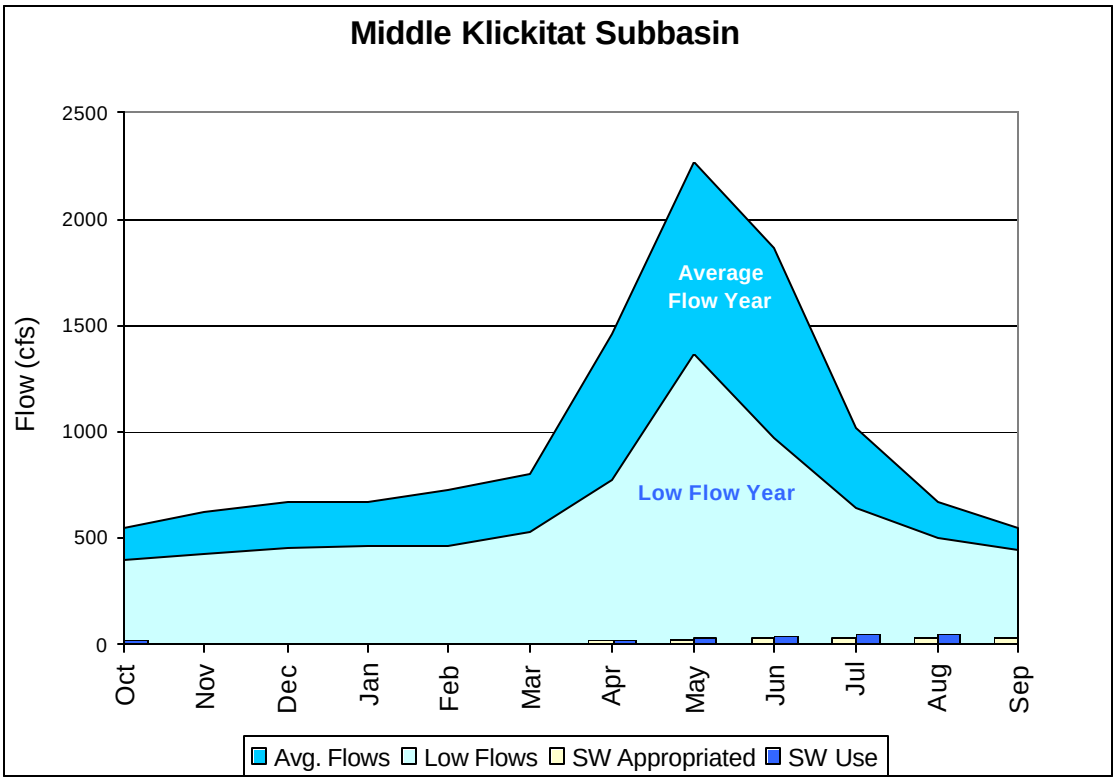


Figure 6-10. Total surface water use and water appropriation in the Middle Klickitat Subbasin relative to the 50% and 90% exceedance flows.

6.3.4 Little Klickitat Subbasin

The Little Klickitat has the second highest total water use in WRIA 30, and has the highest non-irrigation usage (combined residential and non-residential). The estimated annual surface water use is approximately 6 percent of the average annual 50%

exceedance flow, and annual groundwater use is approximately 6 percent of the annual groundwater recharge. Annual surface water and groundwater allocations (excluding claims) are 17 percent of the 50% exceedance flows and annual groundwater recharge, respectively. The water balance for the Little Klickitat Subbasin is summarized in Table 6-18. As was discussed in previous sections, there is uncertainty regarding the estimated irrigation water use in this subbasin.

Table 6-18. Little Klickitat Subbasin Annual Water Balance with Allocated and Actual Annual Water Uses

	All values in acre-feet/year			
Water Balance Component	**Water Balance Value (Average)**	**Allocated Water Right Certificates + Permits**	**Water Claims**	**Actual Water Use**
Precipitation	388,267	15,136 (surface water)	1,536 (surface water + groundwater)	5,075 (surface water)
Evapotranspiration	191,667			
Streamflow	87,600	18,910 (groundwater)		6,340 (groundwater)
Groundwater Recharge	109,000			

Figure 6-11 depicts the estimated monthly water appropriation and water use relative to the 50% and 90% exceedance flows. Uncertainty regarding actual irrigation water use has been identified as a data gap. Additionally, the estimated water budget does not reflect recent increases in flow associated with changes in the City of Goldendale's water supply system. Improvements in estimates of irrigation use and incorporation of the changes implemented by the City of Goldendale may effectively change the situation depicted in Figure 6-11.

6.3.5 Lower Klickitat

There is relatively little water use in the Lower Klickitat Subbasin, corresponding to the lack of irrigation there. Accordingly, estimated annual surface water and groundwater uses comprise less than 0.5 percent of average annual stream flow and groundwater recharge volumes, respectively. Annual surface water and groundwater allocations comprise approximately 3 and 0.3 percent of the annual stream flow and recharge volumes, respectively. The water balance for the Little Klickitat Subbasin is presented in Table 6-19.

Surface flows in the Lower Klickitat Subbasin are affected not only by water uses within the subbasin, but also by the cumulative changes in flow from upstream sources, including the Upper Klickitat, Middle Klickitat, Little Klickitat Subbasins, and Swale Subbasins. Water withdrawals in the Swale Creek subbasin are negligible during the months that Swale Creek is flowing (Section 6.3.6). Swale Creek subbasin withdrawals in the summer months deplete only the available groundwater and do not directly affect surface water flows except through possible and unknown effects of changes in groundwater levels on discharge to surface waters through seeps and springs and possible recharge of the shallower alluvial aquifer through use of water from deeper aquifers.

Therefore, the Swale Creek subbasin withdrawals were not included in the estimates of the cumulative effects of water use on surface flows in the Lower Klickitat subbasin.

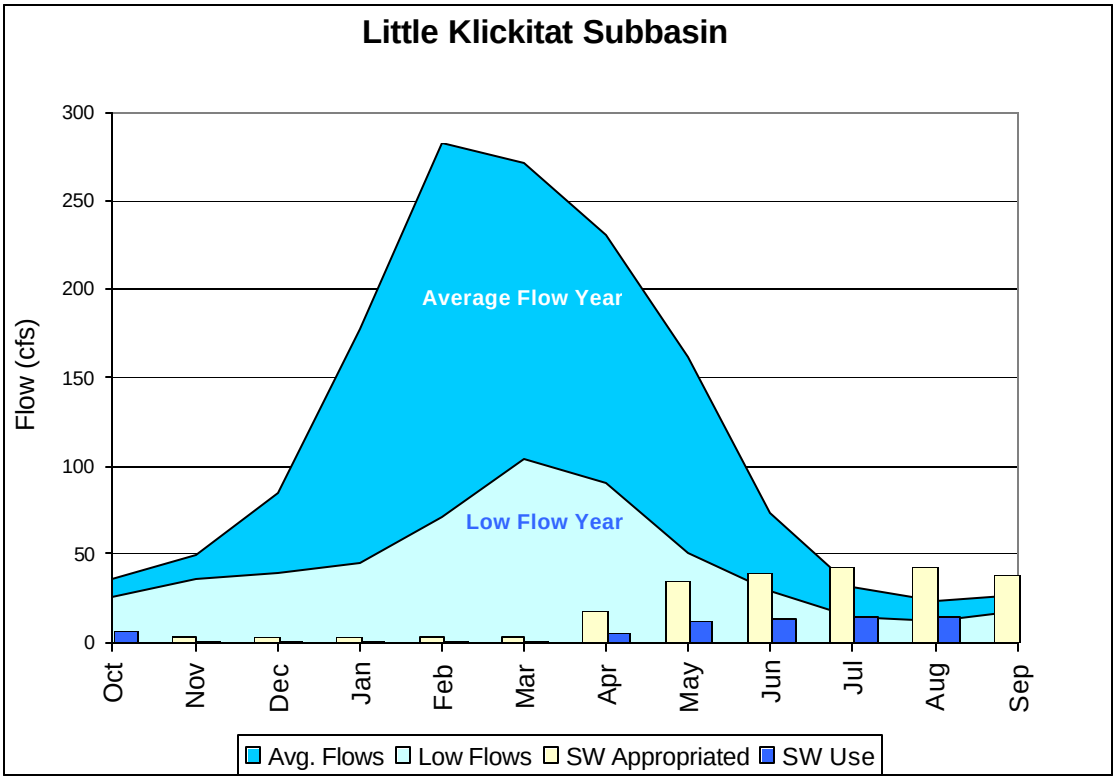


Figure 6-11. Current estimated surface water appropriation and use relative to the 50% and 90% exceedance flows in the Little Klickitat subbasin. Note that the confidence in actual water use in this subbasin is low.

Table 6-19. Lower Klickitat Subbasin Annual Water Balance with Allocated and Actual Annual Water Uses

	All values in acre-feet/year			
Water Balance Component	**Water Balance Value (Average)**	**Allocated Water Right Certificates + Permits**	**Water Claims**	**Actual Water Use**
Precipitation	177,493	3,002 (surface water)	13 (surface water + groundwater)	414 (surface water)
Evapotranspiration	9,310			
Streamflow	99,183	217 (groundwater)		30 (groundwater)
Groundwater Recharge	69,000			

No estimates of water use are available for the Upper Klickitat Subbasin (Section 6.3.2); hence, these could not be included in any estimates of cumulative effects on surface flow. Estimates of surface water use presented here reflect only the effects of water use within the Lower Klickitat subbasin plus the cumulative effects of upstream uses in the Middle and Little Klickitat subbasins.

Total water use within the Lower Klickitat subbasin is negligible (Figure 6-12). The cumulative water use from within the subbasin and upstream water uses are negligible in winter. In summer, estimated use is 7.3 percent of the 50 percent exceedance flow. The majority of the cumulative water withdrawals are associated with up river surface water irrigation uses.

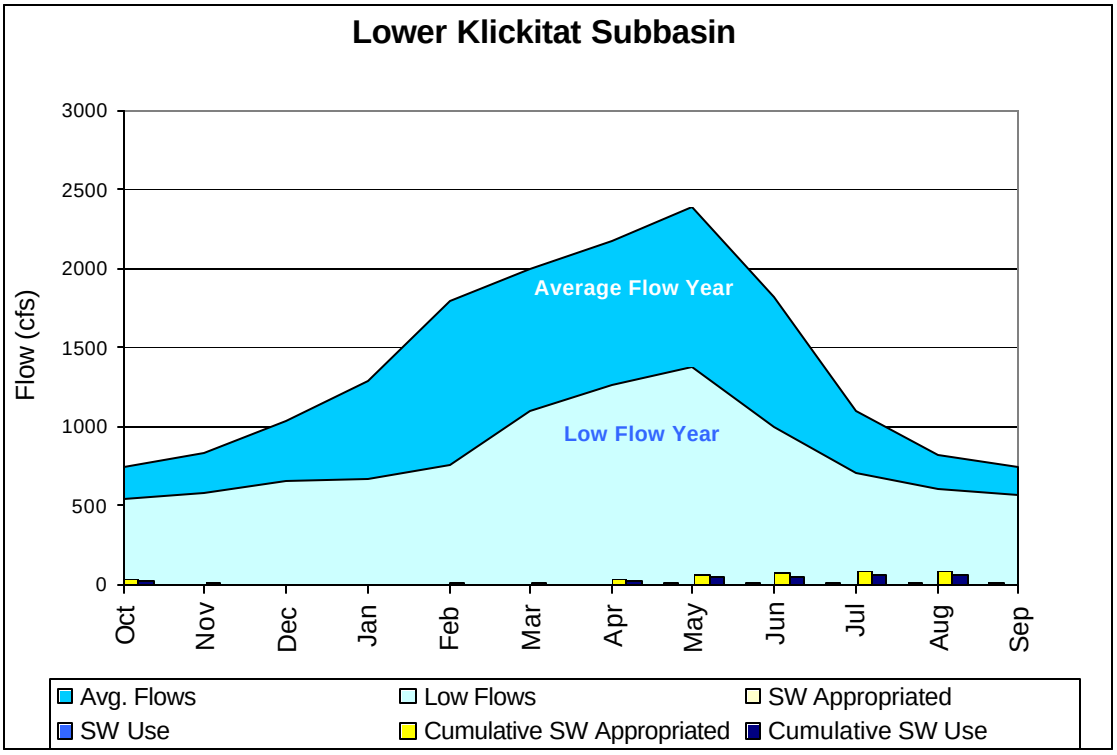


Figure 6-12. Exceedance flows, water appropriation and use within the lower Klickitat subbasin (values are very small and do not show on plot) and total cumulative water appropriation and use reflecting water use in the Lower Klickitat subbasin and upstream subbasins.

6.3.6 Swale Subbasin

Table 6-20 presents the Swale Creek Subbasin water balance components that can be determined with the available information. Reliable stream gage data are not available for this subbasin (Section 5.1) preventing determination of the stream flow component. Because evapotranspiration is calculated from the other water balance components in this assessment, it also can not be determined.

Table 6-20. Swale Creek Subbasin Annual Water Balance with Allocated and Actual Annual Water Uses

	All values in acre-feet/year			
Water Balance Component	**Water Balance Value (Average)**	**Allocated Water Right Certificates + Permits**	**Water Claims**	**Actual Water Use**
Precipitation	154,560	27 (surface water)	15 (surface water + groundwater)	13 (surface water)
Evapotranspiration	???			
Streamflow	???	11,632 (groundwater)		5,738 (groundwater)
Groundwater Recharge	26,000			

???: Not determined since reliable streamflow data are not available for this subbasin.

Surface water allocations and actual use are negligible in this subbasin; essentially all of the water use is from groundwater sources. Annual groundwater allocations and use account for approximately 45 and 22 percent, respectively, of annual groundwater in the recharge occurring across the subbasin.

The Swale Creek subbasin has two aquifers. The aquifer within the Wanapum basalts underlies an alluvial aquifer (Chapter 5.2). The alluvial aquifer is largely contained within the surrounding geology. The Warwick Fault located at the southwestern edge of the Swale Creek valley appears to act locally as a hydraulic barrier impounding groundwater within the alluvium. Some interchange of water between the two aquifers is possible; however, the volume of water that moves between the two aquifers is unknown. (See Appendices B and C for further discussion on this subject.)

Stream flow estimates are not available for the Swale Creek subbasin (Chapter 5.1). Discussions with long-term residents of the subbasin indicate that the creek does not have measurable flow in summer although there are perennial pools found in summer in the lower canyon and in other areas of the basin. Generally, the creek ceases to flow when the water level in the alluvial aquifer drops below the depth of the streambed. Therefore, summer water use in the basin is limited to withdrawals from groundwater. Likewise, return flows in summer augment the volume of water in the alluvial aquifer rather than the magnitude of stream flow.

The total water use in Swale Creek was estimated at 5,751 acre-feet per year. In the past, a significant amount of the irrigation water came from wells that drew from the alluvium aquifer. In recent years, however, many of the irrigators in the subbasin have stopped using their alluvial wells and are now pumping from wells that draw from the Wanapum basalt underlying the alluvium. No good estimates are available regarding the portion of the irrigation water that currently comes from the alluvium.

Residential and non-residential use is estimated at 22 acre-feet per year. Most (19 cfs) of this water is drawn from residential wells. Over 97 percent of these wells are drilled through the alluvium and into the Wanapum basalts; however a large portion of these wells are not cased into the basalt. As a result, much of the residential water is drawn

from a combination of the alluvial and Wanapum aquifers. The total volume drawn from the alluvium for residential and non-residential use cannot be estimated because that volume is influenced by the relative water pressure of the two aquifers, the depth and construction of the well, local variations in material in the vicinity of the well hole, and several other factors.

6.3.7 Columbia Tributaries

Stream gage data are not available for this subbasin; hence many aspects of the water budget cannot be estimated. The water balance components that can be determined with the available information is provided in Table 6-21.

Similar to the Lower Klickitat Subbasin, irrigation water use in this subbasin is limited, resulting in relatively small total water use. Estimated annual groundwater use is less than 4 percent of annual groundwater recharge in the subbasin. Allocated groundwater rights are considerably larger; equivalent to roughly 67 percent of the annual recharge volume. Nearly one quarter of the allocated groundwater in the subbasin is held by the Army Corps of Engineers for heat exchange at John Day Dam (1,928 acre-feet/year; Section 6.1.2.6).

Table 6-21. Columbia Tributaries Subbasin Annual Water Balance with Allocated and Actual Annual Water Uses

	All values in acre-feet/year			
Water Balance Component	**Water Balance Value (Average)**	**Allocated Water Right Certificates + Permits**	**Water Claims**	**Actual Water Use**
Precipitation	97,067	1,468 (surface water)	1,608 (surface water + groundwater)	77 (surface water)
Evapotranspiration	???			
Streamflow	???	7,997 (groundwater)		419 (groundwater)
Groundwater Recharge	12,000			

???: Not determined since reliable streamflow data are not available for this subbasin.

6.3.8 Confidence Regarding Estimated Water Budgets

The estimated water budgets presented above are highly dependent upon the estimates of water use in each subbasin. Irrigation is the primarily surface water use in the WRIA. Estimates of actual use are uncertain and additional effort to refine these estimates has been recommended (Section 8).

Some return flows were not addressed in this discussion of water budgets. Return flows are the water that returns to a stream after use. This includes irrigation water that runs off fields or percolates into the ground and ultimately reaches a stream. This also includes

septic water that filters through the drain field and reaches a stream as subsurface or groundwater flow, water used to irrigate lawns and other landscape vegetation, and other sources of water that are not actually consumed but are returned to the environment and ultimately reach a stream. The return flow from irrigation was at least partially accounted for in the USGS information used to support the water use discussion (Section 6.2). The return flow information from irrigation use was based on general information and could be improved.

Return flow from domestic, urban, and industrial uses has not been addressed. Actual water consumption is likely less than portrayed above due to return flows from these sources. The volume of return flow from non-irrigation uses is expected to be relatively small since these uses generally represent a small portion of the total water allocated and estimated to be used in each subbasin. Therefore, incorporation of estimates of return flow from these sources is unlikely to substantially affect the overall trends depicted in the water budget discussion.

APPENDIX A

Chapter 7: Land Use Effects

Table of Contents

7.1 Outfall From Road Drainage ***7-1***

7.2 Increased Impervious Area and Compaction ***7-3***

7.3 Decreased Floodplain Storage ***7-4***

7.4 Decreased Wetland Function ***7-5***

7.5 Altered Channel Capacity ***7-6***

7.6 Altered Channel Complexity ***7-7***

7.6.1 Channel Confinement by Structures *7-8*
7.6.2 Modification of Stream Adjacent Vegetation *7-9*
7.6.3 Clearing Channels of Rocks and/or Wood *7-10*
7.6.4 Sediment Inputs *7-10*
7.6.5 Cumulative Effects of Land Uses on Channel Incision *7-10*

7.7 Vegetation Removal Effects on Hydrology ***7-11***

7.8 Summary ***7-12***

List of Tables

Table 7- 1. Road density by subbasin. ***7-4***
Table 7- 2. Percent subbasin area within the 100- and 500-year floodplains. ***7-5***

List of Figures

Figure 7- 1. Generalized diagram of the primary interactions between land uses found in WRIA 30 and changes in peak, annual, and low stream flows. ***7-2***

Chapter 7: Land Use Effects

There are several pathways through which stream flows can be affected by land use in addition to the direct consumption of water (Figure 7.1). The primary agents of effect on hydrology (besides direct consumptive use) are:

- The interception of flow as a result of road construction and other land grading activities,
- Increases in impervious area,
- Changes in floodplain storage capacity,
- Change in wetland function,
- Alterations of channel capacity, and
- Modification of vegetative cover.

These potential effects are discussed in the sections below. Note that the effects from water use and regulation are not included in this section as they are covered elsewhere.

7.1 OUTFALL FROM ROAD DRAINAGE

Road networks have the potential to affect watershed hydrology by changing the pathways by which water moves through the watershed (WFPB, 1997). 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 drains primarily to the stream channel network.

Connectivity of the road drainage and stream channel networks was qualitatively assessed in the upper portions of the Little Klickitat subbasin[1] as part of the Upper Little Klickitat Watershed Analysis (Raines et al, 1999). Roads were found to be responsible for a 6% to 45% extension in the drainage network among 15 smaller subbasins within the analysis area, and increased the drainage network by 16% overall. These increases in the effective drainage network may potentially increase peak flows by routing stormflow more quickly to the stream system, and potentially reducing summer low flows, however, no estimates were made on the magnitude of these effects on either peak or low streamflows.

[1] The Upper Little Klickitat Watershed Analysis covered the portion of the Little Klickitat subbasin upstream of the City of Goldendale, and is approximately 94 mi^2 in size.

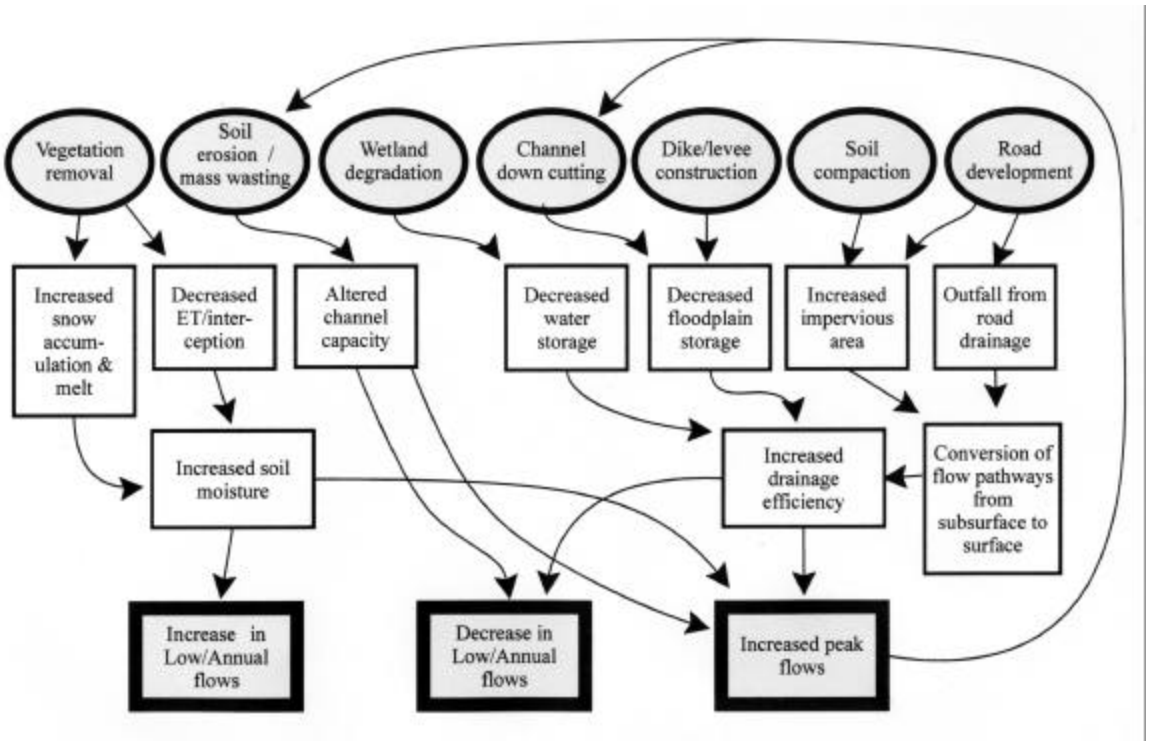


Figure 7-1. Generalized diagram of the primary interactions between land uses found in WRIA 30 and changes in peak, annual, and low stream flows (after Ziemer, 1998).

It is difficult to determine at what point increases in the drainage network may have significant impacts on peak flows, however, guidelines published by the National Marine Fisheries Service (1995), based on the work of Wemple (1994) and USDA Forest Service (1995), suggest that a significant increase may occur with a 20-25% increase or more in the drainage network due to roads. Using this criterion, drainage extension due to roads may represent a significant problem in the vicinity of the West Prong Little Klickitat River, in the vicinity of Jenkins Creek, and in the Morehead Springs area.

Currently, the road systems on forested lands are being upgraded. These upgrades are required under the State of Washington's new Forest Practices rules and regulations (Chapters 76.09 RCW and 222-24 WAC). Forest landowners are given up to 15 years to complete the road upgrades. Within WRIA 30, upgrades were initiated in 1999, following the completion of the Little Klickitat Watershed Analysis and are ongoing (Jim VanderPloeg, personal communication). No estimate for when they will be completed is available. Road upgrades will significantly reduce drainage of water off forest roads and into streams.

Other road systems in the basin could potentially have the same effect as the forest roads. No assessment of the potential effects of these roads is currently available. Spatially distributed, physically based models have been used to simulate the effects of road

drainage networks on streamflows. In two studies located in western Washington, Bowling and Lettenmaier (1997) and La Marche and Lettenmaier (1998) used a distributed hydrology-soils-vegetation model (DHSVM) to evaluate the effects of forest road systems on peak streamflows. In the event that the Planning Unit wished to further evaluate the effects of road drainage networks on stream flows in the WRIA 30, a similar approach could be used.

7.2 INCREASED IMPERVIOUS AREA AND COMPACTION

Increases in the amount of impervious area in a watershed reduces infiltration of precipitation, thereby increasing the magnitude of peak flows (Dunne and Leopold, 1978). In addition to the effects on peak flows, increases in impervious area also reduce summer low flows by reducing groundwater recharge (Dunne and Leopold, 1978). May, et al (1997) suggest that impairment begins when percent total impervious area (%TIA) in a watershed reaches 10%. Compaction can also significantly affect the amount of water that percolates into soils (Satterland and Adams 1992). Water that does not percolate into the soils is available for runoff across the land surface and can increase the magnitude of peak flows.

No specific assessments of the effects of watershed imperviousness are available within WRIA 30. Consequently, the effects of watershed imperviousness were evaluated using a relationship developed by May et al (1997) 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 subbasin in WRIA 30 using road data available from the Washington Department of Natural Resources (WDNR, 1996).

Road densities among the subwatersheds range from 1.5 miles/mi^2 in the Upper Klickitat subwatershed to 3.1 miles/mi^2 in the Middle and Little Klickitat subbasins (Table 7-1). It appears that the impervious area in the various subbasins is low. This reflects the low level of development in the WRIA. Hence, potential impact to peak and low flows does not appear to be a significant concern in WRIA 30. This simplistic analysis assumes that the DNR road coverage was correct and did not address the effects of compaction on peak flows. The analysis was completed to provide a quick index of potential effects on peak flows to help guide decisions regarding future investigations. Although this simplified analysis did not suggest any potential for a significant problem given the current level of development, the analysis could turn out to be in error if the DNR coverage significantly underestimates the road miles in the basin and/or compaction is severe enough to have a significant effect on runoff.

Table 7-1. Road density by subbasin. Data Source: WDNR (1996).

Subwatershed	Road length (miles)	Subbasin area (mi^2)	Road density ($miles/mi^2$)
Upper Klickitat	511	350	1.5
Middle Klickitat	1,451	467	3.1
Little Klickitat	861	280	3.1
Swale Ck	232	126	1.8
Lower Klickitat	365	128	2.9
Columbia Tributaries	239	91	2.6
Entire WRIA 30	3,660	1,442	2.5

7.3 DECREASED FLOODPLAIN STORAGE

Dikes and levees have been constructed in several locations within WRIA 30 for flood control purposes. 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. Digital data on locations of the 100- and 500-year[2] floodplains within WRIA 30 are available from the Federal Emergency Management Agency (FEMA, 1996; 1998), and are summarized in Table 7-2.

Floodplain locations have not been identified by FEMA for the Yakima County portion of the WRIA 30 (the entire Upper Klickitat subbasin, and half of the Middle Klickitat subbasin; Table 7-2). The largest area of floodplain in the subbasins is in the Columbia tributaries. Flooding of these areas is controlled by the Columbia River dams, which lie outside of the assessment area. Significant floodplain areas have also been identified by FEMA along Swale Creek. The total area of floodplain within WRIA 30 that is affected by dikes and levees has not been quantified. Consequently, it is not known to what extent floodplain storage has been lost within WRIA 30.

[2] FEMA's Q3 flood data specifications indicates that areas mapped as the 500-year floodplain include areas inundated by 500-year floods, areas inundated by 100-year floods with average depths of less than 1 foot or with drainage areas less than 1 square mile, or areas protected by levees from 100-year flooding.

Table 7-2. Percent subbasin area within the 100- and 500-year floodplains. Data source: FEMA (1996, 1998).

Subbasin	% subbasin area		
	100-year floodplain	Additional area within the 500-year floodplain(1)	Unknown(2)
Upper Klickitat	-	-	99.9%
Middle Klickitat	0.4%	-	55.4%
Little Klickitat	0.8%	0.02%	-
Swale Ck	3.6%	-	-
Lower Klickitat	1.3%	0.1%	-
Columbia Tributaries(3)	***7.3%***	-	-
Total for WRIA 30	1.2%	0.01%	42.3%

(1) The values shown for the 500-year flood plain are the additional areas beyond the 100-year floodplain. The 500-year also includes the 100-year floodplain shown in the preceding column.
(2) Areas identified as "Unknown" are located within an area that is not mapped, or have an undetermined flood hazard.
(3) Floodplain areas lie outside of the WRIA 30 assessment area.

7.4 DECREASED WETLAND FUNCTION

Most wetlands have bottoms of lower permeability than the surrounding landscape. They tend to form over clay soils but may also form in areas where local geology prohibits percolation of water or in areas where groundwater is intercepted. The critical factors that determine the character and persistence of wetlands are a presence of excess water. Presence of excess water occurs either when precipitation exceeds evaporation and evapotranspiration or when wetlands are fed by surface or groundwater sources (Mitsch and Gosselink, 1986). Wetlands may be present year round or may be seasonal. Seasonal wetlands occur where the volume of water feeding the wetland is less than the water loss due to runoff, evaporation, and evapotranspiration.

Hydrologically, wetlands function to buffer peak flows by providing an area where flood waters and runoff can accumulate (Mitsch and Gosselink, 1986). Within the wetlands, some of the floodwater may be stored and excess water may runoff over a longer period of time, reducing the magnitude of the peak flow in a flood event. Stored water is released over time and may be important to augment summertime low flows Wetlands can also function by enhancing groundwater recharge over an extended period of time. Where seepage into ground has been calculated, less than 20% of the impounded volume enters the groundwater supply (Millar 1971). Percolation of water into the groundwater tends to occur mostly at the margins of the wetland where soils are more permeable.

Wetlands can also reduce the sediment loads delivered to streams. Flow of surface water is slowed in wetlands and sediment tends to deposit in these areas, particularly in well vegetated wetlands (Bathurst 1993). Water flowing out of the wetland, hence carries less sediment.

The nutrient chemistry of wetlands is complex, but in wetlands where perennial vegetation forms, the nutrient uptake of plants reduces nutrient content of water (Mitsch and Gosselink, 1986). Annual plants also uptake nutrients, but tend to return them when the plant material dies and decomposes. Hence annual plants have little effect on the net nutrient balance, but can change the seasonal availability of nutrients.

Wetlands can also provide important habitat for birds and animals and often serve as nursery areas for many reptile species. The influence of wetlands on terrestrial wildlife is outside the scope of this analysis.

Land uses in the area that are likely to have the greatest impact on wetland presence and function include a) draining, and dredging, b) reduction of the water table level, and c) construction of dikes and levees. Ditching and draining are modifications that are specifically designed to dry out wetlands (Mitsch and Gosselink, 1986). Ditches and drains are hydrologically efficient, allowing more rapid runoff of water. The result can be both increased peak flows downstream of the wetlands and decreased water tables in the wetlands themselves. Drainage of wetlands may also reduce summer base flows. Water drawn from aquifers with hydrologic connectivity to the surface in the vicinity of wetlands can reduce the groundwater available to recharge wetlands, reducing their persistence through rain free periods. Dikes and levees decrease the normal area of a wetland. The smaller wetland area is able to retain less water. Hence, more water is available for runoff during peak flow events and less water is stored.

No studies are available for WRIA 30 quantifying the role of wetlands in ameliorating flood peaks and/or augmenting low flows, or identifying land use impacts to these functions. Ditches, drains, and dikes are most commonly present in agricultural areas. The extent of such features is unknown. The degree that this water use affects the persistence of wetlands is also unknown.

7.5 ALTERED CHANNEL CAPACITY

Deposition of both coarse and fine sediments in stream channels can result in a decrease in channel conveyance capacity, leading to increased frequency of overbank 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.

Occasional small sediment inputs will have local effects. Sudden pulses of sediment entering a stream will tend to be deposited, but are cleaned away within a few months to years (Hartman et al. 1987). The time required to clean the sediment away is dependent upon the volume of sediment that was delivered to the stream, stream flow, and stream gradient. Large inputs, such as major landslides, will have longer effects, but also will eventually be reworked by the stream. The more damaging sediment inputs are those that are input continuously or with high frequency. Where large loads of sediments are constantly being introduced to the stream, the stream may become overwhelmed and may not be able to find a stable condition (Swanston 1991). Sources of long term sediment

inputs may include frequent small land slides, bank erosion, road erosion, runoff of sediment from fields, and sanding of roads in winter. Increased sediment loads affect spawning habitat by clogging spawning gravel with fine material which causes eggs, alevins, and fry in the gravel to suffocate.

The only information on sedimentation problems within WRIA 30 is available for the upper portions of the Little Klickitat subbasin, gathered as part of the Upper Little Klickitat Watershed Analysis (Raines et al. 1999). Sediment delivery within the analysis area can be grouped into two general source categories; sediment delivered from mass wasting (i.e., landslides), and sediment delivered to streams from surface erosion processes.

With respect to mass wasting, 31 mass wasting failures were identified within the upper Little Klickitat area over 36 years of available aerial photo coverage. This represents an extremely low incidence of land sliding for forested areas. Consequently, sediment input to streams due to mass wasting is unlikely to be very significant.

The Upper Little Klickitat Watershed Analysis (Raines et al, 1999) found roads to be significant contributors of sediment to streams. Sediment input from roads was estimated to be 300% greater than natural background surface erosion. As was discussed previously, forest roads are being upgraded. The upgrades will not only reduce the effects on peak flows, but will also reduce the volume of sediments inputs to streams by those roads. Estimates of road sediment inputs for other areas in the basin are not available.

Surface erosion of lands other than roads was also evaluated in the Upper Little Klickitat Watershed Analysis (Raines et al. 1999). That analysis did not identify significant inputs associated with forest practices, however, potentially significant inputs arising from erosion of agricultural lands were identified in that analysis. The report estimates that 2,010 tons per year are transported to streams from agricultural lands, which is about 55 percent of the total sediment attributed to forest roads. The report discusses several assumptions that were made to develop the estimate from agricultural lands. The report indicates that the area from which sediment is delivered is likely overestimated, the area actually in crop production is likely overestimated, and presence of any vegetated buffers and topographic irregularities that would affect sediment delivery were not considered. As a result of these assumptions, the report describes the estimated sediment inputs from agricultural lands as a “worst-case scenario”. Actual inputs are likely much lower.

7.6 ALTERED CHANNEL COMPLEXITY

The effects of land use have been extensively documented. The interactions between channels and land use are highly complex and the degree of affect is dependent upon numerous factors. The discussion below attempts to briefly discuss the most common effects of rural land uses on channel morphology. For a more thorough discussion of the subject, the reader is referred to one of the many texts on the subject such as *Applied River Morphology* (Rosgen 1994) and/or *River Flows and Channel Forms* (Petts and Calow1996).

Channels are constantly adjusting to changes in sediment inputs, flow, and erosion processes through time. The magnitude of natural adjustments are affected by the magnitude and timing of stream flow, sediment supply, riparian vegetation, stream gradient, in stream structures providing roughness (boulders, wood), the type of material underlying the stream bed, valley width and confinement, gradient of adjacent hill slopes, geology of adjacent hill slopes, and several other factors. Streams that are narrowly confined into bedrock canyons may slowly erode the bedrock, but in general tend to be stable in terms of lateral movement. Streams that flow over soft material in wide flat valleys will naturally meander, constantly moving across the valley. Channel morphology, including depth of channel, the number of side channels, channel sinuosity, substrate, and other channel characteristics, can be altered through human land use activities. The most common activities affecting channels are encroachment on the stream bed or floodplain by constructed structures, modifying stream adjacent vegetation, clearing rocks or wood from channels, and/or changing the sediment inputs into streams.

7.6.1 Channel Confinement by Structures

Structures such as roads and levees may be built within the active channel width. Such structures constrain the channel into a narrower area than it would naturally occupy. Often such structures cut off natural side channels. The confinement of the channel can also result in erosion of the bed to bedrock, which can trigger incision of the stream bed upstream of the structure. The degree of incision is controlled by the underlying geology of the affected stream segments. The presence of such structures also constrains the natural changes in channel meanders. The degree of effect here is dependent upon the geology of the adjacent hill slopes and the gradient of those slopes. The potential effect on meandering is more pronounced where wide valleys are present.

Structures that are in the floodplain but out of the normal wetted width of the stream constrain the stream during peak flow events. Larger events have a greater ability to mobilize sediment; hence, significant incision of the stream bed can occur during large magnitude events.

Narrowing of the channel or floodplain also tends to result in erosion of adjacent hill slopes. Where those hill slopes are composed of erodible material, banks can be undercut, triggering landslides along the stream channel. The resultant sediment inputs can locally affect the channel conditions. Where the channel is constrained, these sediments are likely to be carried downstream over time and deposited at a location where the channel is less steep and the valley is wider. In these downstream areas, additional sediment can destabilize the channel, causing it to form unstable channels across the sediment deposits; channels that are continuous moving until the stream reworks the sediment and the channel finds a new more stable bed. One time inputs of sediment will be reworked over time and the channel will stabilize. Continuous inputs of sediment can severely affect the channel's ability to find a stable bed.

A systematic inventory of areas where man-made structures constrain the stream channels or floodplains within the watershed has not been completed, except in the upper Little Klickitat watershed (Raines et al, 1999) and in the Swale Creek Canyon. In the

upper Little Klickitat, roads are the primary manmade structures that constrain channels. Plans are in place to address many of these situations.

The Swale Creek assessment (Inter-Fluve 2002) was recently completed and includes an assessment of flows, confinement of the railroad bed on the channel and floodplain, and develops a set of recommendations for channel improvement. Inter-Fluve used a modeling technique to estimate the flows in Swale Creek and evaluate the extent of the 2, 5, 25, and 100 year floodplain. The assessment was based on the assumption that the regional equations published by Sumioka et al (1999) are applicable in the Swale Creek subbasin. Given the unusual geology of the subbasin, the small runoff area for the basin, and the low rainfall, the regional equations are not applicable in this basin. The regional equations most likely predict flows that significantly larger than actual flows in the subbasin. Since the floodplain evaluations in the Inter-Fluve report are based on these regional equations, the floodplain assessment also likely overestimates the extent of the various magnitudes of floods. Therefore, the report does not provide an accurate depiction of the degree that the railroad constrains the channel and its floodplain. Nevertheless, the railroad is known to impinge on the channel in some locations.

Other known areas within WRIA 30 where roads, dikes, levees, and other structures constrain the channels and their floodplains include the roads paralleling the mainstem Klickitat River and the Little Klickitat River where these features are located within the floodplain of the river. The effect that the roads have on channel morphology is unknown.

7.6.2 Modification of Stream Adjacent Vegetation

Removal or modification of vegetation along stream channels can also affect the channel morphology. Where vegetation is removed or modified, reduced root strength in the adjacent banks can cause the channel to erode those banks (Platts 1991). As the banks erode, local small landslides may form. Overtime, the channel will try to move laterally. The degree of effect is dependent upon the degree of channel confinement and the soils and geology of the stream adjacent hill slopes. Streams that run through wide valleys are sometimes underlain by uncompacted material. Roots of streamside vegetation may grow under the stream bed, enhancing bed stability. In such situations, removal of stream side vegetation can also result in incision of the stream bed.

Removal of trees adjacent to streams also has the effect of reducing the rate that wood falls into the stream over time. Wood in streams assists with the formation of pools which are used by fish as rearing habitat (Bjornn and Reiser, 1991). The effectiveness of wood in channel formation varies with the gradient and size of the stream and the amount of boulders present in the channel. In some streams, wood is critical to in stream fish habitat. In others is plays only a minor role. In stream wood rots over time and needs to be replaced to maintain fish habitat.

The degree that streams have been cleared to stream side vegetation has been documented on forested lands in the Upper Little Klickitat (Raines et al 1999). Within these forest lands, riparian vegetation was found to be in various stages of maturity.

Numerous areas that are not suitable to support streamside trees were also documented. Clearing of other areas in the WRIA has not been inventoried, however vegetation has likely been extensively modified in many the areas dominated by agricultural, rural residential, industrial, and urban land uses.

7.6.3 Clearing Channels of Rocks and/or Wood

Removal of in channel roughness components, such as wood and boulders, also has the effect of destabilizing the channel and allowing it to incise. Loss of roughness does not always result in channel incision, but does tend to affect channel complexity. Pools tend to form around such structures and, in their absence, the bed may become uniform (Swanston 1991). Loss of pools can potentially affect the volume of rearing habitat available for fish (Bjornn and Reiser 1991).

The only documented cases of stream cleaning are in the Swale Creek Canyon and on forested lands. Within the Swale Creek Canyon, the railroad company used instream boulders to stabilize the railroad grade (Inter-Fluve 2002). The effect that removal of boulders had on the channel can only be guessed at. In the presence of large quantities of boulders, sediment likely accumulated behind those boulders and may have developed deep enough to allow some pool formation. On forested lands, the Department of Natural Resources routinely required forest landowners to clean wood out of channels in the 1960s and 1970s (Raines et al 1999). This, as well as logging of riparian areas, contributed to the low wood volumes that are seen in forested streams today.

7.6.4 Sediment Inputs

Sediment inputs to streams can have highly variable effects on channel morphology. Large sediment inputs that are deposited in flatter areas can overwhelm the channel, resulting in destabilization of the channel and possible braiding of the channel as water disperses over and within the deposits. Sediment studies conducted in the WRIA are summarized in Section 7.5. The Upper Little Klickitat Watershed Analysis (Raines et al. 1999) did not report any areas where sediment deposits were causing significant aggradation. Inter-Fluve (2003) reported an area of sediment deposits in the lower reaches of Swale Creek Canyon.

7.6.5 Cumulative Effects of Land Uses on Channel Incision

Disturbance of riparian vegetation, channel confinement, removal of roughness elements in the stream bed, and changes in sediment inputs can all contribute to channel incision. Often, channel incision is the cumulative result of many of these disturbances. Systematic inventories of incised channels and the factors likely contributing to the incision have not been completed across the entire WRIA; however such inventories were completed within the upper portion of the Little Klickitat subbasin (Raines et al 1999). Within that portion of the subbasin, roughly 6 miles of incised channels spread over 18 channel segments in the Prong, Brooks, and Butler drainages were identified. The potential causes of this incision are numerous, but uncertain. The authors indicated that

causes may include past and/or present agricultural ditching of streams, channel straightening, removal of large wood from channels, increased runoff from roads, and compaction, dam-break floods triggered by culvert failures, and road building up channels. In some areas, incision probably started lower in the channel segment and migrated upstream until it stopped at a road crossing. Disturbance of vegetation along banks may also have contributed to the observed situations. The development of floodplains within many of the entrenched channels suggests that incision occurred over a long period of time. Aerial photos indicate extensive incision prior to 1945 with increased incision through the mid-1960s.

7.7 VEGETATION REMOVAL EFFECTS ON HYDROLOGY

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). Rain-on-snow flood events may occur in areas having significant wintertime snow packs, and are independent of land use. While the events themselves are climatic in nature, land use may affect how the event is manifested on the landscape.

Timber removal 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. ROS peak flows are likely to be augmented by forest harvesting in Washington State in the 1,400 - 4,000 foot elevation range (WFPB, 1997).

As discussed in section 2.0 of this report, none of the Swale Creek or Columbia Tributaries subbasins contains area that is considered to be in the ROS zone, consequently, these subbasins are considered to have a low sensitivity to augmentation of ROS peak flows by forest harvest. Conversely, less than 10% of the Upper Klickitat subbasin is within the ROS zone. The majority of that subbasin is located within the snow-dominated or highland zones. Consequently, the Upper Klickitat subbasin also has a low sensitivity to augmentation of ROS peak flows by forest harvest. The remaining subbasins, Middle, Little, and Lower Klickitat, have significant areas within the ROS zone and are therefore sensitive to augmentation of ROS peak flows by forest harvest.

The only information on augmentation of ROS peak flows by forest harvest within WRIA 30 is available for the upper portions of the Little Klickitat subbasin (Raines et al, 1999). Predicted changes in the two-year recurrence interval peak flow (the peak flow most sensitive to ROS effects) under current forest canopy conditions ranged from a 5% decrease in a small unnamed tributary stream in the downstream portion of the assessment area, to a 12% increase in the upper portions of the West Prong Little Klickitat River. The areas where increases were modeled were not considered to be of sufficient size to merit special attention in the watershed analyses.

The potential effects of modification of vegetation in other portions of the WRIA are unknown. In non-forest areas, effects of removal of vegetation on hydrology can occur when infiltration capacity becomes lower than the rate at which precipitation of snow melt occurs. The situation seldom occurs because most precipitation or snow melt occurs at rates much lower than the limits of the infiltration capacity (Satterlund and Adams 1992). However, under certain circumstances, infiltration capacity can become limiting with resultant effects on hydrology.

The effects of land use on infiltration capacity are primarily tied to modification vegetation, soil exposure and compaction. Vegetation and litter protect soil from packing by raindrops and provide organic matter for binding soil particles together in open aggregates (Dunne and Leopold 1978). Plowed soils not only lack the vegetative cover, but the action of plowing can break up soil aggregates, resulting in reduction of soil pores. As a result, infiltration capacity can be affected.

Compaction has a higher potential to affect infiltration capacity. There are many factors that can cause compaction. Compaction forces include raindrops, machinery, hooves of livestock or wildlife, or even foot traffic. The degree of compaction varies with soil type (Satterlund and Adams 1992) and is most pronounced when compaction forces are applied to wet soils. Generally, compaction is most pronounced when vegetation and litter are removed.

There is no information to assess whether land uses in the WRIA have affected infiltration capacity.

7.8 SUMMARY

The review of land use impacts in WRIA 30 presented here is based on the results of existing studies and incorporates only minimal new analysis (e.g., the assessment of impervious area based on road density). It is limited to the information that is on hand and as such provides a very incomplete picture for the area. Most of the data provide a "snapshot" of conditions at the time that a given study was done (e.g., the Upper Little Klickitat Watershed Analysis). However, these limitations notwithstanding, the data and studies summarized here provide us with the means to make some limited conclusions about land use impacts in WRIA 30, and help us identify the data gaps that limit further analysis.

Several processes discussed above could potentially have significant impacts on stream flows within portions of WRIA 30. In most cases, the presence of an effect through these processes has not been documented. Key points from this section include the following:

- Altered channel capacity due to deposition of sediments, resulting in a reduction of effective summer low flows has occurred in some areas of the WRIA. This situation was identified as a concern as it related to sediment inputs from forest roads in the upper Little Klickitat subbasin. The forest owner, Boise Cascade, is currently involved in an aggressive program to address that identified problem. Sediment inputs originating from surface erosion of fields may also be significant, however further investigation to refine preliminary "worst case" estimates are recommended.

- Dikes and levees may have had a measurable effect on peak flows and groundwater recharge. However, the total area of the WRIA affected by constructed features is unknown; hence the effect of land use on floodplain storage is unknown.

- Wetland function and potential avenues for land use to affect those functions are discussed. However, there is no information available to quantify the effects of land use on wetland functions.

- Land uses have affected channel complexity. However, the extent of the effect is not documented.

- Hydrology effects due to modification of vegetation are unlikely but possible, particularly through soil compaction.

- Incision of channels has been document in several locations in the watershed. This incision appears to be related to a number of interacting factors including loss of roughness in channels, modification of riparian vegetation, channel confinement, and changes in sediment inputs. Although channel incision is ongoing in some areas, the majority of the incision apparently occurred prior to the mid 1960s. Current information on channel incision is largely limited to the Little Klickitat subbasin. Further investigation into the extent of channel incision situations would be merited.

APPENDIX A

Chapter 8: Data Gaps and Recommendations

Table of Contents

8.1 High Priority Data Gaps ***8-1***

8.2 Lower Priority Data Gaps (Recommended For Future Monitoring) ***8-4***

8.3 Other Gaps ***8-5***

Chapter 8: Data Gaps and Recommendations

The Level 1 watershed analysis team identified several recommendations for future work that would provide better confidence in our understanding of water quantity, water quality, and fish habitat in the Klickitat watershed. Recommendations are discussed in detail below. The first eight recommendations are likely the highest priority in that they will either improve the confidence in results or will improve the ability to assess water quantity situations in the future.

8.1 HIGH PRIORITY DATA GAPS

The following recommendations reflect the areas of uncertainty that have the greatest potential to affect interpretation of data. Other recommendations and data gaps are discussed following this section.

- **Nitrate concentrations in watershed:** Several well water quality samples collected since the mid-1990s indicate nitrate concentrations in excess of the State water quality standard and high enough to potentially cause health concerns. The extent of the problem is unknown. We highly recommend that this situation be investigated further.

- **Fish Passage into Little Klickitat Subbasin:** There is little known about how often the falls at river mile 6.1 is passable for steelhead or other migratory fish species. We recommend an in-depth study be conducted to assess the frequency (number of years) that this falls is passable.

- **Groundwater Connectivity, Storage, and Recharge:** There are some potentially unique groundwater-surface water interactions in Swale and Little Klickitat subbasins. There is little known about the connectivity of groundwater between the two basins and the size of the subsurface storage area, particularly in Swale Creek, and the effect of that storage on surface water. We recommend further study of the groundwater distribution in these subbasins.

- **Assess contribution of groundwater baseflow (related to above):** There are limited data to assess the level of hydraulic continuity of groundwater to surface water within the WRIA. The current understanding is largely based on mapping of the extent and elevation of geologic units and springs relative to surface water drainages, and regional water level data collected over 20 years ago. Late season surface water flow in many subbasins is largely dependent on sustained groundwater baseflow (discharge) during periods of low precipitation as the contribution of snowmelt runoff diminishes. Stream flow conditions vary considerably in the Klickitat River basin, largely due to the relative contribution of snowmelt to

streamflows. The upper and western portions of the watershed and the mainstem benefits from year-round snowmelt derived from Mount Adams, whereas late season flows in surface water tributaries in the eastern portion of the basin may be controlled more by groundwater baseflow conditions. A data collection program is recommended to better understand the extent of groundwater - surface water interaction and contribution of baseflow, with the focus on the eastern half of the WRIA comprising the Little Klickitat River and Swale Creek subbasins. These subbasins are of greatest interest because they include waterbody segments that are listed on Ecology's 1998 303(d) list based on low instream flows (Swale, Bloodgood, Blockhouse, Bowman, and Mill Creeks; Little Klickitat River).

Recommended data collection to include:

- Collection of late season (August/September) geochemistry data (major anions and cations) from surface water bodies identified in Ecology's 1998 303(d) listing, and from select wells and spring discharge representative of the principal aquifer zones. Field mapping should include spring locations along Swale Creek and spring-derived tributaries discharging into the Little Klickitat River. There are up to four geologic units comprising the principal aquifer zones within these two subbasins, including recent Alluvium (Swale Creek subbasin), Simcoe Volcanics (principally in Little Klickitat River subbasin), Wanapum Basalt, and Grande Ronde Basalt. Further delineation of individual flow units within the basalts may be warranted for more detailed analysis. This data would provide a relative water quality "signature" of groundwater within principal aquifer zones to assess the recharge source of late season surface water flows. Spatial mapping of this data can also improve the current understanding of structural controls (e.g. faults) on groundwater flow across the WRIA;

- Implementation of a groundwater level monitoring program within these two subbasins, as a first priority. A monitoring network of baseline monitoring wells would be identified based on existing well log information and previous hydrogeologic investigations. The well network would include wells within each of the principal aquifer zones to provide sufficient spatial coverage to help refine regional groundwater flow conditions both within and between aquifer zones. A set of criteria would be established for selection of monitoring wells, including the availability of a well log (including well construction data and geologic description of the completion zone). Relative locations and elevations would be established using a portable field global positioning system (GPS). A minimum of bi-annual monitoring, prior to and after the irrigation season, is recommended. The City of Goldendale has already initiated this effort for a portion of the Swale Creek Subbasin.;

- Implementation of a water level monitoring program in the other subbasins comprising WRIA 30 is recommended, to the extent that resources are available. Available information suggests that there have not been significant land use changes in the other subbasins that would have substantially impacted

groundwater conditions to date. Establishing or confirming baseline conditions as defined by prior studies is recommended particularly in those subbasins where future land use changes are anticipated.

- **Stream Temperature in 303(d) Listed Streams**: Several stream segments are listed for violations of the State water quality criterion. These include one stream segments in Butler Creek, the Little Klickitat River, East Prong Creek, West Prong Creek, and Swale Creek. The State water quality standards include the numeric criteria plus a narrative standard that defaults to the "natural background temperature" where the criterion is naturally exceeded. No information exists regarding the natural background stream temperature. Therefore, studies to assess the natural background stream temperature are recommended. Those studies should incorporate the connectivity and interchange of water between surface and groundwater sources (see second bullet above) as well as natural background vegetation and water levels.

- **Stream Gage data**: Currently, there are only 3 gage sites that are operational. Two are near Glenwood and the third is near the mouth of the Klickitat River. We were not able to estimate flows in Swale Creek. There are no stream gages in the creek and no information in the vicinity that can appropriately be used to estimate flows. Therefore, we recommend that a USGS style gage be permanently installed and monitored for a number of years. In addition, we recommend that gages be re-established in the Little Klickitat River and the mid-Klickitat mainstem.

- **Improve Estimates of Actual Irrigation Water Use**

  Irrigation water use is the overwhelmingly largest water use in WRIA 30, yet the Level 1 Assessment estimates of actual irrigation use have considerable uncertainty. Because changes in assumptions used to estimate irrigation use would have the greatest effect on a watershed-wide water balance, refinement of these assumptions is warranted as part of a Level 2 Assessment. Specific recommended Level 2 data collection tasks include:

  - Additional coordination with Farm Service Agency (FSA), NRCS, and other agencies to refine estimates of irrigated acreages and water duties by subbasin. The estimates for irrigated acreages by subbasin, except Middle Klickitat, were provided by the FSA (discussed in Section 6.1). These estimates include only those farmers participating in FSA programs, so will not include all irrigating farmers in the watershed. For example, orchards are not accounted for in the FSA acreage estimates, which likely account for the low existing irrigated acreage estimates for the Columbia Tributaries subbasin.

  - For key agricultural areas, complete field reconnaissance of irrigated crops grown and conduct interviews with knowledgeable individuals in the farm community to better define the acreage in irrigated agricultural production, relative percentage of each crop type (e.g. alfalfa, winter wheat etc.), and land use trends.

- Consideration could be given to a more detailed assessment of land use changes over time in the Swale Creek and Little Klickitat subbasins, which have the most significant water resources issues within WRIA 30. These two subbasins include some of the driest areas within the WRIA, encompass a large portion of the urban population (e.g. City of Goldendale) and agricultural production (e.g. Swale Creek valley), and contain the surface waters identified as impaired under Ecology's 303(d) listing. Review of available aerial photographs over several time intervals up to the present would provide one approach to assessing the change in agricultural production.

- **Conservation District Stream Temperature Data:** The conservation district has collected extensive stream temperature data. This data was summarized for every fifth data of data collection. We recommend that the original data be re-analyzed to include DAILY mean, minimum, and maximum temperature as well as the 3-day and 7-day running means.

8.2 LOWER PRIORITY DATA GAPS (RECOMMENDED FOR FUTURE MONITORING)

- **Middle Klickitat Water Quality**: There is little water quality data available for the Middle Klickitat subbasin. The community of Glenwood and land uses in the vicinity could potentially be impacting water quality. Water quality monitoring is recommended in this subbasin.

- **Fish Habitat Information**: Little numeric information has been documented regarding the quality of fish habitat in the watershed besides the information covering the upper Little Klickitat subbasin addressed in the WDNR Watershed Analysis conducted by Boise Cascade. The Yakama Nation has collected habitat data in the watershed. Some of these projects were federally funded. Efforts should be made to acquire data collected through the federally funded projects and any other projects that the tribe is willing to share. Once all available data has been gathered, available data should be reviewed and additional monitoring conducted as appropriate to characterize habitat conditions in the watershed and identify opportunities for habitat improvement.

- **Sediment Inputs**: The limited habitat data available suggests that spawning habitat may be impacted by sediment inputs in several areas. A study estimating the sediment inputs associated with various land uses and the background inputs is recommended to identify areas where reductions in sediment may be beneficial.

- **Lower Klickitat Water Quality Data:** Temperature and dissolved oxygen levels exceed state criteria. The available data was collected as grab samples. We recommend that continuous recording water quality instruments be deployed to better

characterize stream temperature and dissolved oxygen in the lower mainstem Klickitat River. Data analysis should include DAILY mean, minimum, and maximum of the monitored parameters. Additionally, the 3-day and 7-day running means of temperature should be calculated.

- **Soil Data:** Digital information on soils for WRIA 30 is available from four separate sources. The USDA Natural Resources Conservation Service (Formerly Soil Conservation Service) has published data for the northern portion of the Upper Klickitat subbasin (NRCS, 2000), and has draft data available for a portion of Klickitat County (NRCS, 2001a) and for the Yakama Indian Reservation (NRCS, 2002). These draft coverages are currently incomplete and are subject to revision. We recommend that the draft coverages be finalized and expanded to include all areas within the watershed in need of revisions.

8.3 OTHER GAPS

- There is no information regarding flows or fish habitat in the Columbia tributaries. These streams are steep and very small. Most are dry in summer. These streams are highly unlikely to support fish populations in any portion of the stream except the lower few feet where the streams meet the Columbia River. Though this information has been identified as a data gap, no future studies and/or monitoring are recommended.

- There is little geologic information available within the northern watershed, particularly the Upper Klickitat Subbasin. Additional mapping of geology in this area could be completed should resources become available.

- There is little information regarding the current and/or historic distribution and function of wetlands. Additional information would aid in assessing hydrologic effects of land use.

APPENDIX A

Chapter 9: References

Ault, Bruce 2002. Memo to Ted Anderson & Karen Kuzis. September 19, 2002.

Aspect Consulting. 2003. Multipurpose water storage screening assessment report. WRIA 30. Prepared for WRIA 30 Planning Unit. Project No. 020070-002-05. Bainbridge Island, WA.

Bathurst, J.C. 1993. Flow resistance through the channel network. Pp. 69-98. *In*: K. Beven and M.J. Kirkby (eds.). Channel Network Hydrology. John Wiley & sons, Ltd. Sussex, England.

Bauer, H.H. and J.J. Vaccaro. 1990. Estimates of Ground-Water Recharge to the Columbia Plateau Regional Aquifer System, Washington., Oregon, and Idaho, for Predevelopment and Current Land-Use Conditions. USGS Water-Resources Investigations Report 88-4108. Tacoma, Washington. 1990.

Bauer, H.H., J.J. Vaccaro, and R.C. Lane. 1985. Maps Showing Ground-Water Level in the Columbia River Basalt and Overlying Materials, Spring 1983, Southeastern Washington. USGS Water Resources Investigations Report 84-4360. Tacoma, Washington. 1985.

BCC (Boise Cascade Corporation). 1999. Upper Little Klickitat Watershed Analysis. Boise Cascade Corporation, Yakima, WA.

Bjornn, T.C., and D.W. Reiser, 1991. Habitat requirements of salmonids in streams. *IN* Meehan, W.H., ed., 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society special publication 19, Bethesda, MD. 751 pp.

BLM (Bureau of Land Management). 2002. Ground Transportation GIS coverage for the Prineville District. Bureau of Land Management, OR/WA State Office, Portland, OR. Available on-line at http://www.or.blm.gov/gis/

Bonneville Power Administration (BPA) 1990. Environmental Assessment: Yakima-Klickitat Project. Office of Power Sales, Bonneville Power Administration.

Bosch, J.M., and J.D. Hewlett. 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology 55:3-23.

Bowling, L.C., and D.P. Lettenmaier. 1997. Evaluation of the effects of forest roads on streamflow in Hard and Ware Creeks, Washington. University of Washington, Department of Civil Engineering, Water Resources Series Technical Report 155, Seattle.

Brett, J.R., W.C. Clarke, and J.E. Shelbourn, 1982. Experiments of thermal requirements for growth and food conversion efficiency of juvenile chinook salmon. Can. Tech. Rep. Fish. Aquat. Sci. 1127. 29 pp.

Brock, S. and A. Stohr. 2002. Little Klickitat River Watershed Temperature total Maximum Daily Load. WA State Dept. Ecology. Publ. 02-03-031. (http://www.ecy.wa.gov/biblio/0203031.html).

Brown, J.C. 1979. Geology and Water Resources of WRIA 30. Washington State Department of Ecology Water Supply Bulletin No. 50. August 1979.

Brunengo, M. 1997. Hydrologic change module. In: Panakanic Watershed Analysis, Western Watershed Analysts, Lewiston, ID.

Bryant, F.G. 1949. A survey of the Columbia River and its tributaries with special reference to its fishery resources. 2: Washington streams from the Columbia River to and including the Klickitat River (Area 1). USFWS, Spec. Sci. Rep. 62. 51 pp.

Cherry, D.S., K.L. Dickson, J. Cairns, Jr., and J.R. Stauffer, 1977. Preferred, avoided and lethal temperatures of fish during rising temperature conditions. J Fish. Res. Bd. Can. 34(2): pp 239-246.

Cherry, D.S., K.L. Dickson, and J. Cairns, Jr., 1975 Temperatures selected and avoided by fish at various acclimation temperatures. J Fish. Res. Bd. Can. 32: pp 485-491.

Clayton, D.E. 1999. Lower Little Klickitat River Draft Watershed Management Plan, Central Klickitat Conservation District

Cline, D.R. 1976. Reconnaissance of the Water Resources of the Upper Klickitat River Basin, Yakima Indian Reservation, Washington. USGS Open-File Report 75-518. Prepared in cooperation with the Yakima Tribal Council. Tacoma, Washington. 1976.

Coffin, B.A., and R.D. Harr. 1992. Effects of forest cover on volume of water delivery to soil during rain-on-snow. Timber/Fish/Wildlife Report No. SH1-92-001. Washington Dept. of Natural Resources. 118 pp.

Crawford, Bruce 1979. Origin and History of the Trout Brood Stocks of the Washington Department of Game. Available at http://www.watrailblazers.org/science/crawford_rainbow_history. html

Currie, R.J., W.A. Bennett, and T.L. Beitinger. 1998. Critical thermal minima and maxima of three freshwater game-fish species acclimated to constant temperatures. Environ. Bio. Fishes 15:187-200.

Cusimano, B. 1993. Horseheaven/Klickitat Water Quality Management Area. October 11, 1993. WDOE publication number 93-e08

Daly, C., R.P. Neilson, and D.L. Phillips, 1994. A Statistical-Topographic Model for Mapping Climatological Precipitation over Mountainous Terrain. Journal of Applied Meteorology 33:140-158.

Davis, J.C., 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. J. Fish. Res. Bd. Can. 32(12): pp 2295-2332.Agencies and Indian Tribes of the Columbia Basin Fish & Wildlife Authority. 1990., Integrated System Plan for Salmon and Steelhead Production in the Columbia River Basin.

Drost, BW. and K.J. Whiteman. 1986. Surficial Geology, Structure, and Thickness of Selected Geohydrologic Units in the Columbia Plateau, Washington. USGS Water Resources Investigations Report 84-4360. Tacoma, Washington. 1986.

Dunne, T., and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Company, San Francisco, California.

EarthInfo. 1996. National Climatic Data Center Summary of the Day, Hourly Precipitation, and Surface Airways data on CD-ROM. Earthinfo, Inc., 1898 South Flatiron Court, Boulder, CO

EarthInfo. 1996. USGS daily stream flow data on CD-ROM. Earthinfo, Inc., 1898 South Flatiron Court, Boulder, CO

Envirovision Corporation. 2000. Chehalis River Basin Level I Assessment, Draft. Prepared for the Chehalis Basin Partnership by Envirovision Corporation (in association with WPN and SAIC), 203 Fourth Avenue East, Suite 501, Olympia, WA.

EPA NPDES Permits (http://www.epa.gov/enviro/html/pcs/pcs_query_java.html)

EPA Storet website database: www.epa.gov/storpubl/legacy/query.htm

FEMA (Federal Emergency Management Agency). 1996. Q3 digital flood data coverage for Yakima County. Federal Emergency Management Agency, Washington, DC.

FEMA (Federal Emergency Management Agency). 1998. Q3 digital flood data coverage for Klickitat County. Federal Emergency Management Agency, Washington, DC.

Flynn, T. 2002. Personal Communication between Mr. Tim Flynn (ASPECT) and Ms. Sara Martin (Envirovision) on July 22, 2002.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis, Oregon, USA. 452 pages.

Frye, R. Personal Communication between Mr. Rick Frye (Central Washington State Department of Ecology) and Ms. Sara Martin (Envirovision). August 26, 2002.

Golder and Entrix. 2001. An Interim Strategy to protect and restore salmonid habitat in the Klickitat, White Salmon and Little White Salmon Rivers.

Gray & Osborne, Inc. 1998. City of Goldendale Watershed Management Plan.

Harr, R.D. 1981. Some characteristics and consequences of snowmelt during rainfall in Western Oregon. Journal of Hydrology 53:277-304.

Harr, R.D. 1986. Effects of clearcutting on rain-on-snow runoff in western Oregon: A new look at old studies. Water Resources Research 22 (7):1095-1100.

Harr, R.D., and J.T. Krygier. 1972. Clearcut Logging and Low flows in Oregon Coastal Watersheds. Research Note 54. Corvallis, Oregon.

Hartman, G., J.C.Scrivener, L.B. Holtby and L. Powell. 1987. Some effects of different streamside treatments on physical conditions and fish population processes in Carnation reek, a coastal rain forest stream in British Columbia. Pages 330-372 In Salo and Cundy (ed.) Streamside management: forestry and fishery interactions. University of Washington, Inst. Forest Res. Contribution 57. Seattle, WA

Hicks, M., 2000. Evaluating standards for protecting aquatic life in Washington's surface water quality standards. Draft discussion paper and literature summary. Washington Dept. of Ecology, Water Quality Program, Publication 00-10-070. Olympia, WA.

Inter-Fluve. 2002. Swale Creek Channel Assessment Project. Submitted to the Yakama Nation Fisheries Program. Toppenish, WA.

Interior Columbia Basin Technical Recovery Team. 2003. Independent populations of chinook, steelhead, and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Working draft. July 2003.

Joy, J. 1986. Washington State Department of Ecology Memo to Jim Milton. Subject: Goldendale Wastewater Treatment Plant/Little Klickitat River Receiving Water Studies and Total Maximum Daily Load Evaluation. WDOE Publication No. 86-e22.

Kendall, M., and J.D. Gibbons. 1990. Rank Correlation Methods, 5th Edition. Oxford University Press. 260 pages.

Klickitat Conservation Districts (KCD) Central and Eastern Districts. 1991. Watershed Inventory Project. January 1991

La Marche, J., and D.P. Lettenmaier. 1998. Forest road effects on flood flows in the Deschutes River Basin, Washington. University of Washington, Department of Civil Engineering, Water Resources Series Technical Report 158, Seattle.

Lewis, J., S.R. Mori, E.T. Keppeler, and R.R. Ziemer. 2001. Impacts of Logging on Storm Peak Flows, Flow Volumes and Suspended Sediment Loads in Caspar Creek,

California. In: M. Wigmosta and S. Burges (editors), Land Use and Watersheds: Human Influence on Hydrology and Geomorphology in Urban and Forest Areas. American Geophysical Union Monograph, Water Science and Application Series, Volume 2. 227 pages.

Linden, M. 1994. Watershed Approach to Water Quality Management Needs Assessment for Horseheaven/Klickitat. Washington State Department of Ecology Water Quality Program. WQP-94-97A.

Little Klickitat River Adjudication Report of Referee (No. 12978), 1983.

Luzier, J. 1969. Ground-Water Occurrence in the Goldendale Area, Klickitat County, Washington. USGS Hydrologic Investigations Atlas HA-313.

MacKenthum, K.M. 1973. Toward a cleaner aquatic environment - Washington D.C., U.S. Environmental Protection Agency in U.S. Environmental Protection Agency 1986, Quality Criteria for Water, 1986; Washington, D.C., Publication No. 440/5-86-001.

Mantua, N. 2001. The Pacific Decadal Oscillation. In: Encyclopedia of Global Environmental Change, Volume 1 The Earth System: Physical and Chemical Dimensions of Global Environmental Change. John Wiley & Sons.

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. A Pacific decadal climate oscillation with impacts on salmon. Bulletin of the American Meteorological Society 78:1069-1079.

Mathews, J. 2002. Personal Communication between Mr. Jim Mathews (Yakima Indian Nation) and Ms. Sara Martin (Envirovision) on July 23, 2002.

Millar, J.B. 1971. Shoreline-area as a factor in rate of water loss from small sloughs. J. Hydrology 14:259-284.

Minobe, S. 1997. A 50-70 year climatic oscillation over the North Pacific and North America. Geophysical Research Letters 24:683-686.

Mitsch, W.J. and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York, NY. 539 pages.

Mix, T., 1976. A Review of the Water Resources of the Klickitat Basin, WRIA 30. Water Resources Analysis and Information Section Office Report No. 52. Department of Ecology, Olympia, Washington. July 1976.

Mote, P., M. Holmberg, and N. Mantua. 1999. Impacts of climate variability and change – Pacific Northwest. A report of the Pacific Northwest Regional Assessment Group for the US Global Change Research Program. Prepared by the JIASO/SMA Climate Impacts Group, University of Washington. JISAO Contribution #715.

Mueller, D.K. and Helsel, D.R. 1996. Nutrients in the Nation's waters -- too much of a good thing? U.S. Geological Survey Circular 1136, pp24.

Myers, J., C. Busack, D. Rawding, and A. Marshall. 2003. Historical population structure of Willamette and lower Columbia River basin pacific salmonids. National Marine Fisheries Service.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. US Dept. Commer., NOAA Tech. Memo. NMFW-NWFSC-35. 443 p.

National Marine Fisheries Service. 1995. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. National Marine Fisheries Service, Environmental and Technical Services Division, Habitat Conservation Branch, Washington, D.C.

National Marine Fisheries Service. 2003. Preliminary conclusions regarding the updated status of listed ESUs of west coast salmon and steelhead. West Coast Salmon Biological Review Team. Northwest Fisheries Science Center. Seattle, WA.

NCDC (National Climatic Data Center). 2002. Climatic data, and climate data station inventories. Available on-line at http://lwf.ncdc.noaa.gov/oa/ncdc.html.

Newcomb, R.C. 1969. Effect of Tectonic Structure on the Occurrence of Groundwater in the Basalt of the Columbia River Group of the Dalles Area, Oregon and Washington. USGS Professional Paper 383-C. Washington D.C. 1969.

NRCS (Natural Resource Conservation Service). 2001b. Snowcourse and SNOTEL data. Available on-line at http://www.wcc.nrcs.usda.gov/

NRCS (Natural Resource Conservation Service). 2002a. Snowcourse and SNOTEL data. Available on-line at http://www.wcc.nrcs.usda.gov/.

NRCS (Natural Resources Conservation Service). 2000. Soil Survey Geographic (SSURGO) database for Yakima County Area, Washington. U.S. Department of Agriculture, Natural Resources Conservation Service, Fort Worth, Texas. Available on-line at http://www.ftw.nrcs.usda.gov/ssur_data.html

NRCS (Natural Resources Conservation Service). 2001a. Draft Soil Survey Geographic (SSURGO) database for Klickitat County Area, Washington. U.S. Department of Agriculture, Natural Resources Conservation Service, Spokane, WA.

NRCS (Natural Resources Conservation Service). 2002b. Draft Soil Survey Geographic (SSURGO) database for Yakima Indian Reservation, parts of Klickitat and Yakima Counties, Washington. U.S. Department of Agriculture, Natural Resources Conservation Service, Spokane, WA.

NRCS (Natural Resources Conservation Service). 1986. Urban Hydrology for Small Watersheds. USDA-Natural Resources Conservation Service, Conservation Engineering Division, Technical Release 55.

O'Donoghue, D. 2002. Personal Communication between Mr. Dan O'Donoghue (Klickitat County Health Department) and Ms. Sara Martin (Envirovision) on July 17, 2002.

ODAS (Oregon Department of Administrative Services). 1998. City limits in the state of Oregon GIS coverage. Information Resources Management Division, Salem, OR. Available on-line at http://www.sscgis.state.or.us/data/index.html

Oregon Climate Service. 1998. Washington Average Monthly and Annual Precipitation, 1961-1990. Oregon Climate Service, Oregon State University, Strand Hall Corvallis, OR 97331. Digital maps available at http://www.ocs.orst.edu/prism/state_products/wa_maps.html

Pennell, W., and B.A. Barton, 1996. Principles of salmonid culture. Developments in Aquaculture and Fisheries Science 29. Elsevier, New York, NY.

Petts, G. and P. Calow. 1996. *River Flows and Channel Forms.* Blackwell Science. Oxford, England.

Platts, W.S. 1991. Livestock grazing. *In*: W.R. Meehan (ed.). Influences of forest and range management. American Fisheries Society Special Publ. 19. Bethesda, MD.

Raines, G. L. and Johnson, B. R. 1996. Digital representation of the Washington state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-684, 20 p.

Raines, M., J. Caldwell, K. Doughty, K. Vanderwal Dubé, K. Kuzis, S. Perkins, E. Salminen, and Y. Wold. 1999. Upper Little Klickitat Watershed Analysis. Prepared for Boise Cascade Corporation. July 1999.

Raleigh, R.F, T. Hickman, R.C. Solomon, and P.C. Nelson, 1984. Habitat suitability index models and instream flow suitability curves: rainbow trout. U.S. Fish & Wildlife Service Biological Report 82(10.60) (January 1984). Washington D.C.

Raleigh, R.F, WJ. Miller and P.C. Nelson, 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. U.S. Fish & Wildlife Service Biological Report 82(10.122). Washington D.C.

Renolds, L. 2002. Personal Communication between Ms. Lorane Renolds (Klickitat County PUD) and Ms. Sara Martin (Envirovision) on July 18, 2002.

Rosgen, D. 1994. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, Colorado.

Sampson, M. and D. Fast. 2000., Yakama Nation 'Monitoring and Evaluation" Project number 95-063-25 The Confederated Tribes and Bands of the Yakama Nations "Yakima/Klickitat Fisheries Project" Final Report 2000, BPA Report DOE/BP-00650-1, 265 electronic pages.

Sampson, M. R. 2002., Yakama Nation, 2002, Management, Data & Habitat Project No. 1988-120-25 Final Report 4/1/01-3/31/02 The Confederated Tribes and Bands of the Yakama Nations BPA Report DOE/BP-0004822-2-1, 65 electronic pages.

Satterland, D.R. and P.W. Adams. 1992. Wildland watershed management. John Wiley & sons, Inc. New York, NY

Scripter, Charles. GIS Specialist, personal communication, July 19th, 2002. Natural Resources Conservation Service, 316 W. Boone Ave., Suite 450, Spokane, WA 99201 (509) 323-2984

Sharp et. al. 2000., DRAFT Klickitat Subbasin Summary, NWPPC 83 pgs.

Sherwood, K. 2002. Personal Communication between Mr. Kim Sherwood (Central Region Washington State Department of Ecology) and Ms. Sara Martin (Envirovision) on July 19, 2002.

Sinclair, K.A. and C.F. Pitz, 1999. Estimated Baseflow Characteristics of Selected Washington Rivers and Stream, Water Supply Bulletin No. 60. Washington State Department of Ecology, Environmental Assessment Program, Olympia, Washington.

State of Washington (WAC 173-200). Water Quality Standards for Groundwater of the State of Washington.

State of Washington (WAC 173-201A). Water Quality Standards for Surface Waters of the State of Washington.

Sumioka, S.S., D.L. Kresch, and K.D. Kasnick 1997. Magnitude and Frequency of Floods in Washington. U.S. Geological Survey Water-Resources Investigations Report 97-4277.

Swanston, D.N. 1991. Natural Processes. Pp 139-180 *In*: W.R. Meehan (ed.). Influences of forest and range management. American Fisheries Society Special Publ. 19. Bethesda, MD.

Taylor Engineering, Inc. 1995. Comprehensive Water System Plan for The City of Goldendale, Washington. February 1995.

Technico Environmental Services. 1999. Klickitat Horsethief Landfill – 1999 Annual Water Quality Report.

Thiesfield, S.L., Ronald H. Peak, Brian S. McNamara, Isadore Honanie. 2001., Fiscal Year 2001 Annual Report. Bull Trout Population Assessment in the White Salmon

and Klickitat Rivers, Columbia River Gorge, Washington. Report to Bonneville Power Administration, Contract no. 00004474, Project No. 199902400, 77 electronic pages (BPA Report/BP-00004474-1)

Troendle, C.A. 1983. The potential for water yield augmentation from forest management in the Rocky Mountain region. Water Resources Bulletin 19(3):359-373.

United States Environmental Protection Agency (USEPA). 1986. Quality Criteria for Water 1986. U.S Environmental Protection Agency. Office of Water, Publication No. 440/5-86-001

USDA Forest Service. 1995. Elk River Watershed Analysis Report. Siskiyou National Forest, Oregon.

USDA, 1997. Census of Agriculture. http://govinfo.library.orst.edu/cgi-bin/ag-list?08-039.wac

USFWS (US Fish and Wildlife Service). 2002. Digital National Wetlands Inventory data for WRIA 30. Available on-line at http://www.nwi.fws.gov/

USGS (U.S. Geological Survey). 1962. Water-Supply Bulletin No. 15, Monthly and Yearly Summaries of Hydrograph Data. Division of Water Resources. Tacoma, Washington.

USGS (US Geological Survey). 1999. Washington Land Cover GIS Data Set, Edition 1. U.S. Geological Survey, Sioux Falls, SD. Available on-line at http://edcwww.cr.usgs.gov/programs/lccp/nationallandcover.html

USGS (US Geological Survey). 2001. Ten-meter Digital Elevation Model (DEM) data. Available on-line at http://www.gisdatadepot.com/

USGS (US Geological Survey). 2002. National Water Information System (NWIS) web page. Available on-line at http://waterdata.usgs.gov/wa/nwis/nwis

USGS National Stream Water Quality Monitoring Network website: http://water.usgs.gov/pubs/dds/wqn96cd/html/wqn/wq/region17/14112000.htm

Walsh, T.J., M.A. Korosec, W.M. Phillips, R.L. Logan, and H.W. Schasse (digital database by K.L. Meagher and R.A. Haugerud). 1999. Geologic map of Washington - southwest quadrant (digital edition). US Geological Survey Open-file Report 99-382, version 1.0. Available on-line at http://geopubs.wr.usgs.gov/open-file/of99-382/

Washington Administrative Code. 2000. Forest Practices Rules. Chapter 222 WAC. Olympia, WA

Washington State Conservation Commission (WSCC). 1991. Central and Eastern Klickitat Conservation Districts Watershed Inventory Project, Final Report. Prepared for the Washington State Conservation Commission, Grant Contract # 89-34-02.

Washington State Conservation Commission (WSCC). 1999. Salmonid Habitat Limiting Factors, final Report. WIRA 30; Klickitat Watershed

Washington State Department of Health. 2000. Updated in 2002. IOC database for WRIA 30. Division of Drinking Water.

Washington State University (WSU), 1982. Irrigation Requirements for Washington – Estimates and Methodology. WSU Agricultural Research Center Research Bulletin XB 025. Prepared by L.G. James, J.M. Erpenbeck, D.L. Bassett, and J.E. Middleton. 1982.

WDF & WDW. 1993. 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). WDF, WDW & Western Washington Treaty Indian Tribes.

WDFW (Washington Department of Fish and Wildlife) 1998. Washington State Salmonid Stock Inventory, Bull Trout/ Dolly Varden.

WDFW (Washington Department of Fish and Wildlife). 2000. 2000 Washington State Salmonid Stock Inventory, Coastal Cutthroat Trout.

WDFW (Washington Department of Fish and Wildlife). 2004. 2001-2002 Steelhead harvest summary.

WDNR (Washington Department of Natural Resources). 1991. Statewide precipitation zone GIS coverage. Washington Department of Natural Resources, Forest Practices Division, P.O. Box 47001, Olympia, WA

WDNR (Washington Department of Natural Resources). 1996. Transportation GIS coverage for WRIA 30. Information Technology Division, Olympia, WA

WDNR (Washington Department of Natural Resources). 2002. Soils GIS coverage for WRIA 30 (partial coverage). Washington Department of Natural Resources, Forest Practices Division, P.O. Box 47001, Olympia, WA

WDOE (Washington Department of Ecology). 2000. Washington Hydrography Framework 1:100,000 scale GIS coverage. Washington and Oregon Hydrography Framework Technical Work Groups, P.O. Box 47600, Olympia, WA. Available on-line at http://www.ecy.wa.gov/services/gis/projects/hydro100/wahyfw_100k.htm

WDOE Ambient Water Quality Monitoring Data website: http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?wria=30

WDOT (Washington State Department of Transportation). 1995. Counties of Washington State GIS coverage. GIS/Cartography Section, Olympia, WA Available on-line at http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

WDOT (Washington State Department of Transportation). 1998. Indian Reservations of Washington State GIS coverage. GIS/Cartography Section, Olympia, WA Available on-line at http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

WDOT (Washington State Department of Transportation). 2000. Washington State Highways, at 1:24,000 scale GIS coverage. GIS/Cartography Section, Olympia, WA Available on-line at http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

WDOT (Washington State Department of Transportation). 2001. Populated Places of Washington State GIS coverage. Data Management Services, Olympia, WA. Available on-line at http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

WDOT (Washington State Department of Transportation). 2002. City Limits of Washington State GIS coverage. GIS/Cartography Section, Olympia, WA Available on-line at http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

Watershed Professionals Network. 2003. WRIA 30 Nitrate concentration and distribution study. Prepared for Klickitat county Planning Unit. Gig Harbor, WA.

Wellman Associates. 1985. Comprehensive Water System Plan for the City of Goldendale.

Wemple, B.C. 1994. Hydrologic integration of forest roads with stream networks in two basins, western Cascades, Oregon. Unpublished M.S. Thesis, Oregon State University, Corvallis, Oregon. 88 pages.

WFPB (Washington Forest Practices Board). 1997. Standard Methodology for Conducting Watershed Analysis, Version 4.0. Washington Department of Natural Resources, Division of Forest Practices, Olympia, WA.

Wydoski, R. S. and R. R. Whitney. 1979. Inland Fishes of Washington. University of Washington Press. Seattle.

Yinger, M. 2002. Personal Communication between Mr. Mark Yinger (Mark Yinger and Associates) and Sara Martin (Envirovision) on July 17 and August 16.

Ziemer, R.R. 1998. Flooding and stormflows. In: Proc. Of the Conference on Coastal Watersheds: The Caspar Creek Story, Gen. Tech. Rep. PSW-168, pp. 15-24, USDA Forest Service, Albany, Calif.

APPENDIX A

Chapter 10: Glossary

100-year floodplain: See Floodplain (100- and 500-year)

50% Exceedance flows: See Exceedance flows (50% & 90%)

500-year floodplain: See Floodplain (100- and 500-year)

90% Exceedance flows: See Exceedance flows (50% & 90%)

Accretion Flow: Flow gained by a river between two points.

Acre-ft: Acre-feet – volume of water that covers one acre of land in one foot of water, equivalent to 325,850 gallons.

ADD: Average Day Demand is the average amount of water used by household.

Adfluvial: Refers to a life history where fish spawn in rivers and streams and rear in lakes. This life history is common in bull trout populations.

Allocation: the designation of specific amounts of the water resource for specific beneficial uses.

Alluvium: Sediments deposited by erosional processes, usually by streams.

Anadromous: Refers to a life history where fish spawn in rivers and streams and complete at least a portion of their rearing cycle in the ocean. All the Pacific salmon species are anadromous.

Andesite: Volcanic rock (or lava) characteristically medium dark in color and containing 54 to 62 percent silica and moderate amounts of iron and magnesium.

Annual Volume Limitation: Maximum volume of water per year allowed under a water right.

Antecedent wetness index: A measure of the decreasing influence of precipitation from previous days on current conditions.

Application: Here the term refers to a request submitted to obtain a water right certificate from the Department of Ecology.

Aquifer: Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Baseflow: That part of stream discharge from ground water seeping into the stream.

Beneficial Uses: Uses of water for domestic, stock watering, industrial, commercial, agricultural, irrigation, hydroelectric power production, mining, fish and wildlife maintenance and enhancement, recreational, and thermal power production purposes, and preservation of environmental and aesthetic values and all other uses compatible with the enjoyment of the public waters of the state.

Berm: A raised earthen area parallel to a stream, constructed for the purpose of containing the stream flow during periods of high water (see dikes).

BOD: Biochemical Oxygen Demand

Canopy interception: The process whereby vegetation surfaces 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.

Certificate: See Water Right Certificate.

CFS: An abbreviation for cubic feet per second. This is a measure of flow rate or discharge and is equivalent to approximately 7.48 gallons per second.

Channelized: The modification of a natural river channel; may include deepening, widening, or straightening.

Claim: See Water Right Claim.

Consumptive (water) use: The loss of water from a ground- or surface- water source through a human-made conveyance system due to transpiration by vegetation, incorporation into products during their manufacture, evaporation, diversion, or any other process by which the water withdrawn is not returned to the waters of the basin undiminished in quantity.

Correlation: A relation existing between variables which tend to vary in a way not expected on the basis of chance alone.

Cutslope: The face of an excavated bank required to lower the natural ground line to the desired road profile.

CWRIS: Certificate Water Right Information System - Water right certificate issued from Department of Ecology and identified under the old system of WRIS (Water Right Information System). Follows the control number of the water right.

DEM: See Digital Elevation Model.

Depletion: Here the term refers to a reduction in or diminishment of streamflow

Depressed stocks: Those stocks whose production is below expected levels, based on available habitat and natural variations in survival rates. Permanent damage to the stock is deemed likely. The management intent is to restore these stocks to fishable levels.

DHSVM: Distributed hydrology-soils-vegetation model. Developed as a collaborative effort between hydrologists at the University of Washington and at Battelle Memorial Institute.

Digital Elevation Model: Digital representation of the earths surface. Elevations are given in a grid format. Usually referred to by the spacing of the grid (e.g., a "10-meter" digital elevation model (DEM) has elevation values at a 10 x 10 meter spacing).

Dikes: A raised feature parallel to a stream, usually constructed of large rocks or boulders, built for the purpose of containing the stream flow during periods of high water (see berm).

Discharge: Outflow; the flow of a stream, canal, or aquifer.

Disturbance: Events that can affect watersheds or stream channels, such as floods, fires or landslides. They may vary in severity from small-scale to catastrophic, and can affect entire watersheds or only local areas.

DO: Dissolved Oxygen

DS: Domestic Single – purpose code for domestic single beneficial use of water.

DU - dwelling unit.

Effective Precipitation: The part of rainfall that can be used to meet the evapotranspiration of growing crops. This does not include surface runoff or percolation below the root zone.

El Niño/Southern Oscillation: A climatic variability pattern common in the Pacific Northwest. Similar to the Pacific Decadal Oscillation (PDO), except that El Niño/Southern Oscillation (or ENSO) events typically persist for only 6 to 18 months while Pacific Decadal Oscillation (or PDO) events typically persist for 20-to-30 year periods.

ENSO: see El Niño/Southern Oscillation.

Eocene: Second epoch of the Tertiary period; also the series of strata deposited during that epoch. The Paleocene epoch preceded the Eocene and the Oligocene epoch followed it.

EPA: Environmental Protection Agency

Equipotential surface: A surface in a three-dimensional ground-water flow field such that the total hydraulic head is the same everywhere on the surface.

Escapement: The number of fish that survive natural and human-caused mortality and spawn successfully. The sum of estimates of fishing harvest and escapement numbers result in a "run size estimate".

Estuarine (wetlands): Tidal marshes that are semi-enclosed by land and have changing salinity levels due to interaction with the marine environment.

ET: See Evapotranspiration.

Evapotranspiration: The scientific term which collectively describes the natural processes of evaporation and transpiration. Evaporation is the process of releasing vapor into the atmosphere through the soil or from an open water body. Transpiration is the process of releasing vapor into the atmosphere through the pores of the skin of the stomata of plant tissue. By this process vegetation removes moisture from the soil profile and returns it to the atmosphere.

Exceedance flows (50% & 90%): Flow exceedance, as used in this report, is an expression of the proportion of time that a specified mean monthly streamflow is equaled or exceeded during the period of record for a stream gage. The flow exceedance is presented here in terms of percentiles. The 50% flow is the flow that is equaled or exceeded in 50% of the months in the period of record. Hence, the 50% exceedance flow represents a median flow. The 90% flow is the flow that is equaled or exceeded in 90% of the months in the period of record. Hence, the 90% exceedance flow represents not the lowest flow seen at that location in a given month, but a very low flow.

Exempt Well: A well from which ground water is withdrawn and used without an explicit water right, usually for domestic use but also can include non-commercial irrigation of up to ½ acre or an industrial use. Under current regulation and policy, withdrawal allocation is set at 5000 gallons per day.

FERC: Federal Energy Regulatory Commission. An independent regulatory agency within the Department of Energy that, among other things, licenses and inspects private, municipal, and state hydroelectric projects.

Floodplain (100- and 500-year): The floodplain is a flat area of land adjacent to a stream that stores and dissipates floodwaters. The 100-year floodplain is the area that is inundated during a flood having an average 100-year recurrence interval. The 500-year floodplain is the area that is inundated during a flood having an average 500-year recurrence interval.

Gaging station: A selected section of a stream channel equipped with a gage, recorder, or other facilities for measuring stream discharge.

Gaining streams: A stream or reach of a stream where surface flow is increasing due to inflow of ground water. Also known as an effluent stream.

gcd: Gallons per capita per day – volume of water use per person per day.

Geohydrologic unit: A formation, part of a formation, or group of formations in which there are similar hydrologic characteristics allowing for grouping into aquifers or confining layers.

Glacial drift: Sediment deposited directly by glaciers or indirectly by meltwater in streams, in lakes, and in the sea. Also called drift.

Glacial outwash: Areas of sand and gravel which has been transported by streams of water coming from glaciers. It is highly permeable.

gpm: Gallons per minute – volume of withdrawal equivalent to .0022 cubic feet per second.

Ground water: The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer.

GWMA: Ground Water Management Area

Half-life: The time required for half the amount of a substance introduced into an ecosystem to be eliminated or disintegrated by natural processes.

Healthy stocks: Stocks covered a wide range of conditions, from robust to those without surplus production for harvest. A healthy listing in this assessment does not mean that managers have no concerns, or that production levels are adequate (WDFW AND WWTT 1994).

Holocene: Recent; that period of time (an epoch) since the last ice age (Wisconsin in North America; Wurm in Europe); also the series of strata deposited during that epoch.

HSG: See hydrologic soil groups.

HSPF: Hydrologic Simulation Program - Fortran. A continuous watershed simulation model designed to simulate all the water quantity and water quality processes that occur in a watershed, including sediment transport and movement of contaminants. HSPF has its origin in the Stanford Watershed Model. Revisions to the model are currently under the purview of the Environmental Protection Agency (EPA).

Hydraulic conductivity: A coefficient of proportionality describing the rate at which water can move through a permeable medium. The density and kinematic viscosity of the water must be considered in determining hydraulic conductivity.

Hydraulic gradient: The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Hydraulic head: The sum of the elevation head, the pressure head, and the velocity head at a given point in an aquifer.

Hydrography: The science which deals with the measurement and description of the physical features of the oceans, seas, lakes, rivers, and their adjoining coastal areas, with particular reference to their use for navigational purposes.

Hydrologic regime: The timing, magnitude, duration, and spatial distribution of peak, high, and low flows. Hydrologic regimes common in Washington include rain-, rain-on-snow, and/or snowmelt-dominated runoff patterns.

Hydrologic soil groups: Soils grouped by characteristics that affect the rates of water infiltration and transmission (rate at which the water moves within the soil).

IFIM: Instream Flow Incremental Methodology Assessment – A method used to determine fish habitat needs according to cross sections, profiles, and flow rates.

Infiltration: To permeate something by penetrating its pores or interstices.

Instantaneous Diversion Rate: Maximum rate of diversion at one point in time as specified under a given water right by Washington Department of Ecology.

Interception: See Canopy interception.

Intertidal: The near-shore zone above low-tide mark.

IR: Irrigation – purpose code for irrigation as a beneficial use assigned to a water right.

Kendall's rank-order correlation: A nonparametric method of determining an increasing or decreasing trend in a paired data set. Nonparametric statistical tests are do not assume that the difference between the samples is normally distributed whereas parametric tests do. All tests involving ranked data, i.e. data that can be put in order, are nonparametric.

Lacustrine: Pertaining to or associated with lakes.

Lahars: A mudflow composed of volcanic debris and water.

Land Segment: A land segment is a subdivision of the watershed, consisting of an area or areas with homogeneous hydrologic characteristics, such as mean annual precipitation, soils and vegetation cover. Land segments are represented by a set of parameters. Some of these parameters can be determined from known watershed characteristics, either by measurement

or by estimation. Other parameters must be determined by calibration, that is, by fitting computed hydrographs to the observed hydrographs.

Large Woody Debris (LWD) recruitment potential: The amount or size of large trees in a riparian area that could potentially fall in (recruit) to the stream channel. Mechanisms for recruitment include small landslides, bank undercutting, windthrow during storms, individual trees dying of age or disease, and transport from upstream reaches.

Large Woody Debris (LWD): Logs, stumps or root wads in the stream channel, or nearby. These function to create pools and cover for fish, and to trap and sort stream gravels.

Levees: An embankment for preventing flooding.

Limnetic: Of, relating to, or inhabiting the open water of a body of freshwater.

Littoral: Of, relating to, or situated or growing on or near a shore.

Losing stream: A stream or reach of a stream that is losing water by seepage into the ground. Also known as an influent stream.

LWD: see Large woody debris.

Mass wasting: Movement of soil and surface materials by gravity. Often synonymous with landsliding.

MDD: Maximum Day Demand which is estimated at 2 times the Average Day Demand (ADD) according to the Washington Department of Health, Water System Design Manual (1999).

Mean: Synonymous with the average.

Miocene: The fourth of the five epochs into which the Tertiary Period is divided. Also the series of strata deposited during that epoch.

Miscellaneous Measurements: A single measurement of streamflow at a particular point and time in a watershed; these measurements are typically in addition to streamflow measurements at a continuously recording gauging station.

National Wetland Inventory: The National Wetlands Inventory is an inventory of wetland ecological systems found throughout the United States. It was prepared by the U.S.

department of the Interior, Fish and Wildlife Service. The wetlands were identified on aerial photographs based on vegetation, visible hydrography, and geography in agreement with systems defined in Classification of Wetlands and Deep-Water Habitats of the United States, by Cowardin et al 1977.

Natural flow: Streamflow values as they would have occurred in a state of nature, preceding any human influences that might alter the flow including diversions from a river or changes in land use/land cover.

NCDC National Climatic Data Center (NCDC): A division of the National Oceanic and Atmospheric Administration (NOAA). NCDC archives and distributes NOAA climatic data.

NMFS: National Marine Fisheries Service

NRMP: See Nisqually Resource Management Plan.

NWI: See National Wetland Inventory.

On-farm Efficiency: Percentage of applied water that is potentially accessible to crop evapotranspiration.

Outfall: The outlet of a storm drain or sewer.

Pacific Decadal Oscillation: A climatic variability pattern common in the Pacific Northwest. Similar to the El Niño/Southern Oscillation (ENSO), except that Pacific Decadal Oscillation (or PDO) events typically persist for 20-to-30 year periods, while ENSO events typically persist for 6 to 18 months.

Palustrine wetland: Freshwater, shallow wetlands that are not riverine or lacustrine, such as marshes or bogs.

PDO: See Pacific Decadal Oscillation.

Permit: See Water Right Permit.

Pleistocene Epoch: The period of geologic time referred to as the "Ice Age". This period occurred 2 million to 10,000 years before present.

POD: Point of Diversion – location where surface water or ground water is diverted or withdrawn for use as allocated under a water right.

POU: Place of use – the area of land where water is used as legally described on the water right document.

PWS: Public Water System – purveyor of water within a specified service area.

Pyroclastic Rock: A rock formed by the accumulation of fragments of volcanic rock scattered by volcanic explosions

Quaternary: The younger of the two geologic periods or systems in the Cenozoic Era (providing Neogene and Paleogene are not used, *q.v.*). Quarternary is subdivided into Pleistocene and Holocene (or Recent) epochs or series. It comprises all geologic time or rocks from the end of the Tertiary to and including the Holocene (or Recent).

r^2: A number between 0 and 1 which measures the degree to which two variables are linearly related. If there is perfect linear relationship, the correlation coefficient is 1; a value of 0 means that there is no linear relationship between the variables.

Rain-on-snow: Wintertime weather conditions when relatively warm wind and rain combine to produce rapid snowmelt.

Rank-order correlation: See Kendall's rank-order correlation.

Reach: A segment of a stream channel. Simulation of the flow in the rivers is done by dividing the stream channel network into a number of reaches. A reach is represented by an element situated between two points. The cross section, slope and roughness within a reach are constant. Channel reach parameters represent the physical characteristics of each reach.

Recharge area: An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.

Recurrence interval: Also referred to as return period, is the average time, usually expressed in years, between occurrences of hydrologic events of a specified type (such as exceedances of a specified high flow). The terms "return period" and "recurrence interval" do not imply regular cyclic occurrence. The actual times between occurrences vary randomly, with most of the times less than the average and a few substantially greater than the average. For example, the 100-year flood is the flow rate that is exceeded by the annual maximum peak

flow once in 100 years, on average. Almost two-thirds of all exceedances of the 100-year flood occur less than 100 years after the previous exceedance, half occur less than 70 years after the previous exceedance, and about one-eighth occur more than 200 years after the previous exceedance. The recurrence interval for annual events is the reciprocal of the annual probability of occurrence. Thus, the 100-year flood has a 1-percent chance of being exceeded by the maximum peak flow in any year.

Regression analysis: Regression analysis is a statistical evaluation of a group of identifiable characteristics that together can predict the outcome of a specific event.

Regulation: With respect to streamflow, regulation refers to the degree that upstream runoff is controlled by human-made structures such as dams.

Residual variation: Unexplained (or residual) variation after fitting a regression model. It is the difference (or left over) between the observed value of the variable and the value suggested by the regression model.

Return Flow: Water withdrawn or diverted that is not used consumptively and thereby returns to the river via surface or subsurface pathways.

Riverine: A freshwater system associated with a river; riverine wetlands are those that occur within the river channel and are dominated by emergent vegetation that remains only through the growing season.

RM: River Mile measured from the mouth of the river or stream.

Road density: A measure of the quantity of roads within a given area of land. Usually represented in units of miles of road per square mile of watershed.

ROS: See Rain-on-snow.

Salt Wedge: The intrusion of salt water into the lower reaches of a stream during high tide. Since fresh water floats on salt water, this intrusion is often wedge shaped, hence the name.

Shapefile: Electronic ArcView (Geographic Information System) file format for storing geographic features and attributes

Side-cast road: Road constructed by moving excavated material onto the downslope side of the road surface during its construction.

Significant: In statistics the level of significance refers to the probability of rejecting the null hypothesis when the hypothesis is in fact true. (The null hypothesis represents a theory that has been put forward, either because it is believed to be true or because it is to be used as a basis for argument, but has not been proven. For example, in a clinical trial of a new drug, the null hypothesis might be that the new drug is no better, on average, than the current drug.) Usually, the significance level is chosen to be 0.05.

Snowpack: The total snow and ice on the ground, including both the new snow and the previous snow and ice that have not melted.

Spatial: Relating to, occupying, or having the character of space.

Specific capacity: An expression of the productivity of a well, obtained by dividing the rate of discharge of water from the well by the drawdown of the water level in the well. Specific capacity should be described on the basis of the number of hours of pumping prior to the time the drawdown measurement is made. It will generally decrease with time as the drawdown increases.

Specific yield: The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

ST: Stock Watering – a beneficial use for a water right that is intended to provide water to sustain farm animals.

Stade: A short period of time (less than 10,000 years) characterized by climatic conditions associated with maximum glacial extent.

Standard deviation: (often denoted as s). A measure of the spread or dispersion of a set of data. It is calculated by taking the square root of the variance (a non-negative number which gives an idea of how widely spread the values of a variable are likely to be; the larger the variance, the more scattered the observations on average). The more widely the values are spread out, the larger the standard deviation.

Stock: The fish spawning in a particular lake or stream(s) at a particular season, which fish to a substantial degree do not interbreed with any group spawning in a different place, or in the same place in a different season. Stocks can be comprised of fish of native genetic heritage, non-native heritage, or mixed genetic heritage. Production (reproduction) can be in the wild

natural, supported by hatchery operations (cultured), or sustained by both artificial and natural production (composite).

Stormwater discharge: Precipitation that does not infiltrate into the ground or evaporate due to impervious land surfaces but instead flows onto adjacent land or water areas and is routed into drain/sewer systems.

Substrate: The rock or soil material present in the bottom of the stream or river. This includes muck, sand, gravel, boulders, and bedrock. Salmon generally spawn in gravel that is roughly 2 inches or greater. Smaller trout will use smaller pebbles for spawning. A high concentration of fines (sand and finer) in spawning gravel will suffocate eggs and young fish developing in the gravel.

Subtidal: The near-shore zone below low-tide mark

Surficial geology: Surface or near surface geology.

Temporal: Of or relating to time as distinguished from space; of or relating to the sequence of time or to a particular time.

TES: Threatened or endangered species.

TIA: Total impervious area. A measure of the total amount of area within a watershed with the ability to repel water, or not let water infiltrate.

Tidal Influence (on streams): Tides often influence the flow in the lower reaches of streams draining to salt water. The influence includes both the intrusion of the salt wedge and the backup of freshwater above the salt wedge, which is caused by the increase in the height of water during high tide. Hence, the tidal influence can extend a substantial distance above the salt wedge.

TMDL: Abbreviation for Total Maximum Daily Load. Most water bodies that do not meet state water quality standards are listed under the Clean Water Act. Documents addressing water quality situation in these water bodies, human affects on water quality, allowable pollutant load are developed to address the water quality issue. The allowable pollutant load is expressed as the "Total Maximum Daily Load" or the maximum amount of pollutant that can be introduced to a waterbody per day. In practice, the term, TMDL, is also used as a

reference for the entire document that addresses the water quality situation and sets allowable loads.

TNC: Transient Non-Community water system such as a public rest area or a restaurant etc.

Transmission: Rate at which the water moves within the soil.

Transmissivity: The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.

TSS: An abbreviation for Total Suspended Solids. This is a measure of the volume of fine material suspended in a water sample. Suspended solids affect water clarity and water quality.

UAR: see unit-area runoff.

Unit-area runoff: Unit area runoff (UAR) is the stream flow normalized by contributing watershed area. For example, if the mean monthly discharge was 45 cfs at a stream gage having a watershed area of 100 mi^2, the UAR would be 45cfs/100 mi^2 = 0.45 cfs/mi^2

USFWS: United States Department of Fish and Wildlife Services

USGS: United States Geological Survey. Agency within the Department of Interior responsible for, among other things, collecting and distributing streamflow data for the nation.

Water balance budget: An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

Water Duty: The total volume of irrigation water required to mature a particular type of crop. It also includes consumptive use, evaporation and seepage from on-farm ditches and canals, and the water that is eventually returned to streams by percolation and surface runoff.

Water Right Certificate: A water right certificate is issued by the Department of Ecology to certify that water users have the authority to use a specific amount of water under certain conditions. These conditions are based on beneficial use of water under the water right permit. The water right certificate is a legal document recorded at the county auditor's office. The certificate completes the process of obtaining a water right. Once a certificate is issued, no expansion is allowed under the water right.

Water Right Claim: A water right claim is a statement of claim to a water use that began before the State Water Codes were adopted and is not covered by a permit or certificate. A claim may represent a valid water right if it describes a surface water use that began before 1917 or a ground water use that began before 1945, a water right claim that was filed with the state during an open filing period designated under RCW 90.14 (the Water Rights Claim Registration Act), or is covered by the ground water exemption.

Water Right Permit: A water right permit is permission given to water right applicants by the state to develop a water right. Water rights are developed when water right applicants follow the provisions outlined in their permit, using water for the purposes and up to the limits stated in the permit. Water right permits remain in effect until the water right certificate is issued, if all terms of the permit are met, or the permit has been canceled.

Watershed: an area of land that drains down slope to the lowest point. Drainage pathways may converge into a stream or river, or may end in a marsh or ancient lakebed.

WAU: Watershed Administrative Unit. Administrative and planning units that encompass smaller areas within WRIAs. There are 828 WAUs within the state of Washington.

WDFW: Washington State Department of Fish and Wildlife

WDNR: Washington State Department of Natural Resources

WDOE: Washington State Department of Ecology

WDOH: Washington State Department of Health

WRATS: Department of Ecology Water Rights Tracking System containing information describing water right certificates, permits, applications and water right claims.

WRIA: Water Resource Inventory Area. Administrative and planning units that encompass large river basins. There are 62 WRIAs within the state of Washington.

WSCC: Washington State Conservation Commission

WSU: Washington State University.