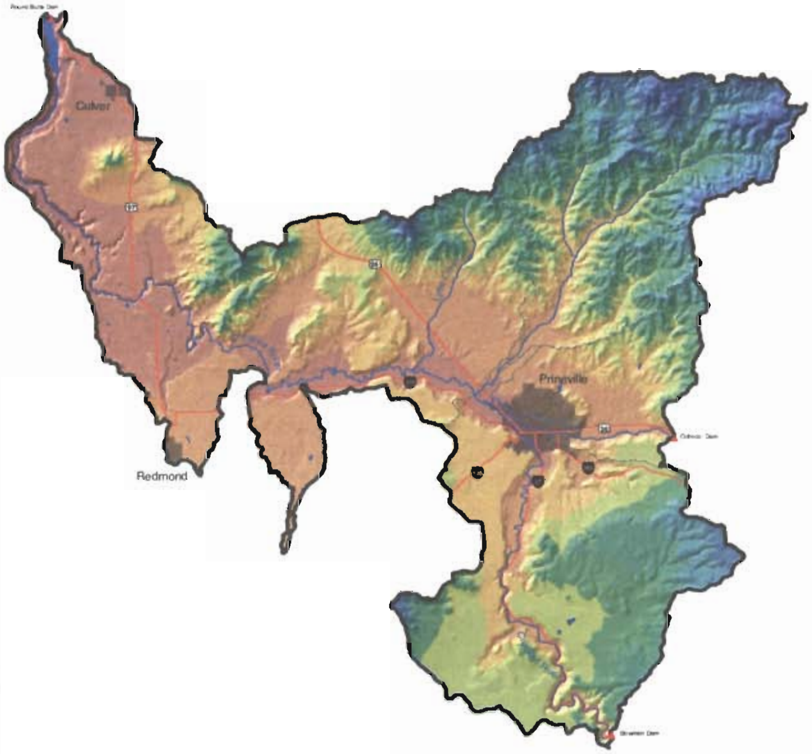
# *Lower Crooked River Watershed Assessment*




**Crooked River Watershed Council**

# Lower Crooked River Watershed Assessment

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*Cover:*

*Lower Crooked River Watershed Topography (Upper Left)*

*McAllister Slough and the Lower Crooked River looking downstream towards O'Neil and Mt. Jefferson (Upper Right)*

*Lower Crooked River looking downstream towards O'Neil in 1905 (Lower)*

# ACKNOWLEDGEMENTS

Many partners and supporters are owed thanks for contributing to the process that made this watershed assessment possible. Foremost, the Crooked River Watershed Council is grateful for the funding received from the Oregon Watershed Enhancement Board grant number 204-296 that afforded the time to coordinate this effort.

The idea for the Lower Crooked River Watershed Assessment was pursued by Jason Dedrick (former Coordinator for the Council) who successfully made the case that an assessment of resource conditions specific to the area of anadramous reintroduction in the lower basin was needed. John Eustice, a University of Oregon RARE Program participant coordinated the data collection and compilation, developed the framework, and wrote the initial draft of the assessment. Without the efforts of these two individuals this assessment would not exist.

The Crooked River Watershed Council is extremely grateful to the numerous technical contributors whose time generating ideas, collecting and analyzing data, reviewing drafts, and reviewing drafts again was invaluable. Specifically the Council owes it gratitude to Tim Deboodt, Kate Fitzpatrick, Barb Fontaine, Brett Hodgson, Ed Keith, Steve Lent, Michelle McSwain, Bonnie Lamb, Rob Tanner, Sandy Wyman, and Berta Youtie. Your help pulling together this final document was tremendous.

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The Lower Crooked River Watershed Assessment went through quite an evolutionary and transformative process. A turnover of staff at the Watershed Council left a draft of

over two years of work in the hands of two people new to the watershed. The forthright and candid thoughts and counsel of the Crooked River Watershed Council board members was crucial in setting a direction for completing the project. Devin Best, the new restoration project manager for the Council, immediately took the lead in beginning to revise the assessment and spent several months working with the technical contributors to concisely pull each chapter together. Thank you Devin for your commitment to making this document ready to edit.

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Finally, thank you to Rick Craiger from the Oregon Watershed Enhancement Board for diligently proofreading the final document, and returning it filled with a rainbow of sticky tabs pointing out grammatical and spelling errors, and blue tabs for deeper conceptual issues. Any errors that remain are my responsibility only.

Thank you!

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## Abbreviations and Acronyms

| | |
|---|---|
| BLM | Bureau of Land Management |
| BOR | Bureau of Reclamation |
| cfs | Cubic Feet Per Second |
| CRWC | Crooked River Watershed Council |
| EPA | Environmental Protection Agency |
| ESA | Endangered Species Act |
| GIS | Geographic Information System |
| NOAA | National Oceanic and Atmospheric Administration |
| NRST | National Riparian Service Team |
| NWPPC | Northwest Power Planning Council |
| ONF | Ochoco National Forest |
| ODA | Oregon Department of Agriculture |
| ODEQ | Oregon Department of Environmental Quality |
| ODF | Oregon Department of Forestry |
| ODFW | Oregon Department of Fish and Wildlife |
| OWEB | Oregon Watershed Enhancement Board |
| RM | River Mile |
| TMDL | Total Maximum Daily Load |
| UGB | Urban Growth Boundary |
| USDOI | United State Department of the Interior |
| USFWS | United State Fish and Wildlife Service |
| USFS | United States Forest Service |
| USGS | Unites State Geological Survey |
| WSPE | Warm Springs Power Enterprises |
| WPN | Watershed Professionals Network |

# TABLE OF CONTENTS

# LIST OF TABLES

## Chapter 1



## Chapter 2



## Chapter 3



## Chapter 4



## Chapter 5



## Chapter 6

## Chapter 7



## Chapter 8



## Chapter 9

# LIST OF FIGURES

## Chapter 3



## Chapter 4



## Chapter 5

## Chapter 7



## Chapter 8

## Chapter 9

# LIST OF MAPS

## Chapter 3



## Chapter 4



## Chapter 5



## Chapter 6



## Chapter 7

## Chapter 8



## Chapter 9

# PREFACE

The Lower Crooked River Watershed Assessment summarizes existing information on watershed conditions for the area that spans the hydrologically active river reaches of the Crooked River and its tributaries from Lake Billy Chinook to the Bowman Dam, including the tributary watersheds of McKay Creek and Ochoco Creek below the Ochoco Dam. This assessment describes watershed conditions at a moderate level of detail, and is intended to provide the necessary information to direct the future restoration, monitoring, and education efforts of the Crooked River Watershed Council (the Council).

## 1.1 PURPOSE

Watershed assessments and action plans are increasingly relied upon by government agencies and private foundations as a source of context and background data, and as a well-organized rationale to justify grant proposals and funding requests. The summary and analysis of resource conditions provided by watershed assessments is critical to developing a strategy for the restoration, monitoring, and education efforts conducted by watershed councils and other non-governmental organizations. This watershed assessment creates the foundation for the technical and financial assistance that the Council provides to public and private landowners in the Lower Crooked River Watershed. This assistance facilitates the enhancement of resource values, improves the stewardship capacity of both public agencies and private landowners, and benefits the public good.

The objectives of this assessment include (1) answer critical questions on resource conditions in the watershed by synthesizing existing data, (2) identifying and, where possible, filling data gaps, and (3) providing a set of action priorities for the watershed. Where data gaps exist, the assessment identifies research recommendations for finer scale data collection and analysis. Together, the three objectives of the assessment represent the development of a baseline dataset for the Lower Crooked River Watershed.

The framework for the Lower Crooked River Watershed Assessment is derived from the Oregon Watershed Enhancement Board's (OWEB) *Oregon Watershed Assessment Manual* (Watershed Professionals Network [WPN], 1999), which provides a detailed assessment protocol. The Lower Crooked River Watershed Assessment attempts to answer the critical questions outlined for each major component of the manual.

## 1.2 TECHNICAL TEAM

The assessment was conducted with the assistance of a technical team that was comprised of regional natural resource experts. The technical team included representatives of the following disciplines: wildlife biology, fish biology, water quality, hydrology, and range and watershed management. The technical team provided assistance in the definition of key issues, the refinement of the assessment protocol, data collection and analysis, identifying data gaps, and developing management recommendations. The technical team also provided immeasurable help in the review and revision of earlier drafts of the assessment.

The assessment Technical Team, the Council, and the Council Coordinator were instrumental in formulating an assessment structure that focuses on local conditions. Most notably, an additional component (Component 9: Uplands) is included that is not suggested in the *Oregon Watershed Assessment Manual.* This component was added to reflect the importance of upland health to the health of watershed.

## 1.4 BACKGROUND

Watershed assessment is a process used to characterize the human, aquatic, riparian, and terrestrial features, conditions, functions, and interactions within a watershed. Rather than attempting to develop a comprehensive ecosystem assessment, the assessment focuses on core topics of watershed-specific concerns. Assessments identify and describe ecological processes of greatest concern, establish how well or poorly those processes are functioning, and determine the conditions under which management activities should take place. The results of a watershed assessment establish the context for subsequent decision making processes, including planning, project development, and regulatory compliance (Federal Guide for Watershed Analysis, 1995).

The Lower Crooked River Watershed Assessment is a product of the Crooked River Watershed Council. The Council is a voluntary, non-regulatory group formed to provide a local and collaborative forum for addressing watershed issues within the Crooked River Watershed. Watershed assessments and analyses that include the Crooked River Watershed have been conducted at coarse scales including, a statewide assessment of watershed health, an ecosystem assessment of the Columbia River Basin, and the Deschutes Subbasin assessment. These assessments provide coarse scale information that does not contain sufficient detail for smaller subwatersheds. The Council's current Action Plan, identifies the Lower Crooked River Watershed as a high priority for the development of a detailed and comprehensive watershed assessment.

Scale is an important issue in watershed analysis. The hierarchical structure of watersheds allows for the systematic identification of increasingly nested drainages, as described in the *Ecosystem Analysis at the Watershed Scale: Federal Guide for Watershed Analysis* (Regional Ecosystem Office, 1995) and OWEB *Oregon Watershed Assessment Manual* (Watershed Professionals Network, 1999). The US Geological Survey (USGS) developed a watershed classification system called the Hydrologic Unit Code (HUC). Watersheds and the streams, creeks, and rivers they contain are identified by HUC numbers. Fine scale headwaters streams are classified as 1$^{st}$ field HUCs, while larger main rivers and sub-basins are classified as lower order HUCs. Watersheds are nested so that 1$^{st}$ field HUCs combine to create 2$^{nd}$ field HUCs; 2$^{nd}$ field HUCs combine to create 3$^{rd}$ field HUCs and so on. The *Oregon Watershed Assessment Manual* (WPN, 1999) suggests that watershed assessments be done on the scale of 5$^{th}$ field HUCs, also called watersheds. Watersheds at the 5$^{th}$ field scale generally range between 40,000 and 120,000 acres in size. Hierarchically above the watershed scale are 4$^{th}$ field HUCs, which are classified as sub-basins; hierarchically below the watershed scale are 6$^{th}$ field HUCs, which are classified as sub-watersheds. In 2002, the Council completed the *Crooked River Watershed Characterization* (CRWC, 2002). That assessment provides a general overview of resource conditions within the 3 million acre Crooked River Watershed, which contains 34 5th field watersheds.

Based upon the information gathered for the *Crooked River Watershed Characterization* (CRWC, 2002), the Council identified the Lower Crooked River Watershed as a priority for further data collection and evaluation. Specifically, with the pending reintroduction of anadramous fish into the Crooked River and its tributaries the Council identified the anadramous reintroduction area as critical for more detailed assessment. For this reason the assessment area does not follow a 4th field sub-basin boundary. The reintroduction area deviates from hydrologic unit boundaries in two major ways: (1) a major portion of the 4th field HUC has limited active surface hydrology, and (2) the Ochoco Dam (and Bowman Dam) serves as a man made hydrologic boundary. Citing these two reasons, the technical team decided to focus the assessment on an area with continuity of surface hydrology and fish passage within the 4th field Lower Crooked River Sub-basin.

At approximately 300,277 acres and encompassing four 5th field watersheds, the Lower Crooked River assessment area is considerably larger than the OWEB recommended assessment area. Nonetheless, the assessment area is a priority for the Council for a number of reasons. First, throughout the assessment area there is a lack of coordinated data in part because land ownership is fragmented mainly among private landowners. Second, resource conditions in the assessment area are of concern due to erosion, riparian vegetation, fish habitat, and water quality. Third, the reintroduction of anadromous fish into the Crooked River Watershed is limited to the assessment due to fish passage barriers at the Bowman and Ochoco Dams. Understanding resource conditions for the assessment area is critical to developing a strategic approach to restoration, monitoring, and educational activities that will improve the probability of a successful reintroduction.

The assessment was funded through an OWEB technical assistance grant. The Council chose to use the University of Oregon Rural Assistance for Rural Environments (RARE) program to hire an assessment coordinator. The RARE program places participants in rural communities for extended time periods, and allowed the Council to hire a coordinator for the assessment, who would act as a visiting local resident as opposed to an outside contractor conducting site visits. The RARE program has a strong statewide reputation for providing rural communities with graduate students who are looking for dynamic professional development experiences.

## 1.3 ASSESSMENT STRUCTURE

Major issues for inclusion in the assessment were determined through a review of watershed assessment methodology (WPN, 1990) and then refined in an iterative process between the Council and the technical team. A list of relevant topics for inclusion in the Lower Crooked River Watershed assessment was compiled based on the following sources: the *Oregon Watershed Assessment Manual* (WPN, 1999); the *Crooked River Watershed Assessment* (CRWC, 2002); other watershed assessments from throughout the state of Oregon, including the *Long Tom Watershed Assessment* (Long Tom Watershed Council, 2000), the *Upper Deschutes Subbasin Assessment* (Upper Deschutes Watershed Council, 2003), and the *Revised Draft Upper Williamson Watershed Assessment* (Evans and Associates, 2005); regional planning documents, including the *Interior Columbia Basin Ecosystem Management Project* (ICBEMP, 1999) and the *Northwest Power and Conservation Council Deschutes Subbasin Plan* (NPCC, 2004).

The assessment is comprised of nine chapters that together offer an overview of resource conditions in the Lower Crooked River Watershed. Chapter 1 gives an overview of the assessment area and its natural and human environment. Chapter 2 provides an outline of the relevant local, state, and federal regulations impacting watershed management. Chapter 3 reviews the history of the resource conditions and human culture in the watershed. Each of the first three chapters begin with an overview list of important findings, and recommendations for further research where appropriate. Chapters 4 through 9 ask critical questions about resource conditions from the various scientific perspectives on watershed health including: uplands (Chapter 4), riparian and wetland conditions (Chapter 5), channel conditions (Chapter 6), hydrology and water use (Chapter 7), water quality (Chapter 8), and fish habitat (Chapter 9). Each of these six chapters begins with critical questions, a summary of key findings, a listing of significant data gaps and research recommendations, and an enumeration of action priorities. A bibliography of cited references is provided after the nine chapters. Finally, a list of organizational contacts and websites that are pertinent to the assessment area are included.

# Chapter 1 – Introduction

*Avulsed Bank on the Lower Crooked River*

*(Photo Credit: M. Nielsen-Pincus)*

Overview of the Natural and Human Environment

- Incised stream channels, altered flow regimes, and land management practices limit riparian vegetation.
- Soils in the majority of the watershed have little moisture holding capacity and are subject to erosion, when vegetative cover is diminished.
- Exclusion of fire and other land management practices have led to large increases in young western juniper woodland and a decrease in native grass and forb cover.
- Agriculture dominates land use within the assessment area, particularly livestock and forage production.
- Growth and development pressures are increasing in the larger region, including the urbanization of the area surrounding the City of Prineville and rural residential development.
- The natural hydrologic system is closely linked to human irrigation systems.

## 1.1 Watershed Definition

A watershed is defined as any area of land that drains to a common point, and can refer to natural drainage areas of a wide variety of sizes. Watersheds, like the HUC codes used to classify them, are hierarchical: little ones nest within larger ones. Words such as catchment, draw, drainage, basin, and sub-basin are also used to describe natural areas that drain water. For the purpose of this document, the term "Basin" refers to the Deschutes River Basin which contains the Crooked River Watershed. In turn, the Lower Crooked River Watershed is defined as the "Watershed" or more commonly the "assessment area." Within any watershed there are subwatersheds and the terms "drainage", "draw", or even "watershed" may be used to refer to subwatersheds.

## 1.2 Assessment Area

The assessment area encompasses five 5th field watersheds including: the Lower Crooked River Valley (river mile 0 to 56), the Lower Crooked River Chimney Rock Reach (river mile 56-70), McKay Creek, and Lower Ochoco Creek (river mile 0 to 10). The assessment area is broken down into four study areas:

(1) Crooked River Lower Section – 129313 acres – 43% of assessment area
Minimum elevation: 1942 ft (northern tip of area along the Crooked River)
Maximum elevation: 5616 ft (NE boundary close to Jefferson County boundary)

(2) Crooked River Upper Section – 81593 acres – 27% of assessment area
Minimum elevation: 2828 ft (the Crooked River at the boundary of the lower section)
Maximum elevation: 5209 ft (far SW tip of area)

(3) McKay Creek – 63508 acres – 21% of project area
Minimum elevation: 2828 ft (SW tip of area)
Maximum elevation: 5925 ft (NE tip of area)

(4) Ochoco Creek – 25862 acres – 9% of project area
Minimum elevation: 2828 ft (western tip of area along the Crooked River)
Maximum elevation: 4799 ft (NE tip of area)

The assessment area is part of the Lower Crooked River 4th field sub-basin, which is one of three sub-basins within the Crooked River Watershed. The assessment area is located along the edge of the Columbia Basin Plateau, the John Day ecological province, and the high desert, and encompasses a range of ecological conditions from desert to moist forest. Landforms in the assessment area include valleys, plains, foothills, mountain ranges, headwaters streams, and rivers. Elevation ranges from a low point of 1942 ft at Lake Billy Chinook to a high point of 5925 ft located in the Ochoco National Forest between

Little McKay and McKay Creeks. Communities within the assessment area include Prineville, Terrebonne, the eastern edge of Redmond and a portion of Culver.

## *1.3 NATURAL ENVIRONMENT*

### 1.3.1 Geologic and Vegetation Conditions

The Lower Crooked River Watershed is within the John Day ecological province. The province is characterized by extensive geologically eroded dissected hills of thick, ancient sedimentary materials interspersed with buttes and plateaus capped with basalt or tuffaceous rock (Anderson et al. 1998). Elevations in the province range from about 1,000 feet near Lake Billy Chinook to 7,360 feet at Fields Peak in the Ochoco Mountains.

The soils of the John Day province are derived from ancient sedimentary and tuffaceous parent materials and are finely textured, sticky when wet, and highly susceptible to precipitation driven erosion. Irrigated agriculture occurs in this province around Prineville, but cropland in the rest of the province is limited to narrow irrigated valleys. The dominant land use within this province is for the production of livestock and livestock forage. In much of the assessment area the current vegetative communities are departed from their historic conditions due to the expansion of western juniper and other invasive weed species.

According to a 1936 State of Oregon Forest Type Map, approximately 50% of the John Day ecological province was once covered in pine, fir, and mixed conifer forests. About 40% of the province was non-forested, with sagebrush-grassland communities dominant at the lower elevations. Less than 10% of the province was occupied by Western Juniper woodland according to the 1936 map. The portion of the John Day ecological province with historical juniper distribution is within the Crooked River Watershed. The concentration of juniper within this area is likely a result of the seed source provided by junipers in the adjacent Mazama province, as juniper is considered a climax species for the pumice soil type characteristic of the Mazama province (Anderson et al 1998). Notably, Western Juniper has spread rapidly throughout the John Day ecological province. The spread of this species is the result of three factors including climate, livestock grazing, and fire exclusion (Miller et al. 2005). In addition, juniper has an affinity for calcium, and the clayey ancient sediments of the John Day province are typically calcareous (Anderson et al., 1998).

### 1.3.2 Climatic Conditions

The assessment area is located in the south-central Oregon climatic zone, which is a semi-arid area of high desert prairie punctuated by small mountain ranges and isolated peaks. Climate is characterized by cold nights throughout the year, particularly at higher elevations, and hot daytime summer temperatures. Average annual precipitation is between 8 and 15 inches at lower elevations, and may reach 30 to 40 inches at higher elevations in the Ochoco Mountains. Precipitation in the higher regions is typically in the form of snow during the winter months. The highest monthly precipitation totals occur in the winter months, with a secondary maximum during the late spring and early summer. High intensity thunderstorms can contribute large proportions of local annual rainfall in the late spring and summer precipitation events. Flooding is largely controlled by the Ochoco Dam (built in 1921) and the Bowman Dam (built in 1961). Summer temperatures are warm at lower elevations, but the growing season is relatively short; frost has been recorded in every month in Priveville. Climate data for the period between 1971 and 2000 for the City of Prineville is listed in Tables 1-1 (Oregon Climate Service 2005).

### 1.3.3 General Hydrology

As noted before, this assessment area is not a 4th field HUC; instead, it is delineated by surface hydrology and fish passage boundaries. The six major dynamic waterbodies in the assessment area are the Crooked River, Ochoco Creek, McK ay Creek, Little McKay Creek, Allen Creek and Lytle Creek. The total river mileage for the major water bodies in the watershed is approximately 132 miles. In addition to the major waterbodies, the watershed also includes numerous minor intermittent and perennial streams, numerous small reservoirs, and wetland areas. Average annual discharge of the Crooked River is 1,131,000-acre feet; approximately 1560 cfs per day (at Lake Billy Chinook).

Table 1-1. Precipitation and Temperature for Prineville (1971 – 2000)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Average Number of Days of Precipitation** | | | | | | | | | | | | | |
| ≥ 0.01" | 8.6 | 8.9 | 9.0 | 7.9 | 7.3 | 5.1 | 3.4 | 2.9 | 4.4 | 5.7 | 9.8 | 8.7 | 83.3 |
| ≥ 0.10" | 3.7 | 3.4 | 3.6 | 2.7 | 3.3 | 2.3 | 1.5 | 1.3 | 1.7 | 2.6 | 4.3 | 3.8 | 34.0 |
| ≥ 0.50" | 0.5 | 0.3 | 0.2 | 0.2 | 0.4 | 0.3 | 0.3 | 0.2 | 0 | 0.3 | 0.5 | 0.6 | 4.0 |
| ≥ 1.0" | 0.1 | 0 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0 | 0 | 0 | 0.1 | 0.6 |
| **Temperature (Degrees Fahrenheit)** | | | | | | | | | | | | | |
| Mean max. | 41.9 | 48.1 | 54.5 | 60.7 | 68.5 | 77.0 | 85.8 | 85.7 | 77.8 | 65.7 | 49.4 | 41.7 | 63.1 |
| Mean min. | 21.0 | 23.7 | 25.3 | 28.0 | 34.1 | 40.3 | 42.8 | 41.6 | 34.7 | 28.6 | 25.2 | 20.8 | 30.5 |
| Mean temp | 31.5 | 35.9 | 39.9 | 44.4 | 51.3 | 58.7 | 64.3 | 63.7 | 56.3 | 47.2 | 37.3 | 31.3 | 46.8 |
| Extreme max | 67 | 75 | 79 | 90 | 99 | 102 | 105 | 105 | 107 | 93 | 77 | 67 | 107 |
| Extreme min. | -21 | -18 | 6 | 10 | 18 | 25 | 29 | 28 | 19 | 6 | -11 | -34 | -34 |

### 1.3.4 Riparian Zones

The condition of riparian areas in the assessment area varies. Riparian ecosystem function and health are determined by the amount and type of vegetative cover. In the assessment area, vegetative cover has changed from historic conditions. Riparian woodlands that historically occurred in the lower elevation flat alluvial valleys have been replaced by pastures, agricultural fields, roads, homes, and other developed features. The reduction in late-seral riparian woodland vegetation, as well as the extensive spread of western juniper, exotic grasses and forbs into riparian areas reflects findings from larger scale studies that have occurred throughout the Columbia Basin (ICBEMP, 1996; USDA

USFS, 1998b). Recruitment of woody debris is minimal, except in forested upper reaches that lay within the Ochoco National Forest boundary. Riparian areas are impacted by agriculture, livestock grazing, logging, roads and urban/residential development. Restoration of riparian vegetation is inhibited by a number of factors including channel modifications, alterations in flow regimes, incised channels, lowered water tables, juniper expansion, the spread of noxious weeds, and residential development. Means to protect riparian areas include set-back regulations, reducing livestock impacts by developing off-site watering and riparian fencing, modifying grazing schedules, and restoring channel – floodplain connectivity.

### 1.3.5 Upland Conditions

Upland conditions are affected by agriculture, livestock grazing, logging, road building, fire suppression, and urban/residential development. Significant changes to the ecological structure of uplands within the assessment area have occurred since Euro-American settlement of the assessment area. The density and extent of woody species has increased on rangelands. A large portion of this increase is accounted for by the expansion of western juniper into areas traditionally vegetated by shrub and grass species. Forest stands tend to be composed of high densities of young conifer trees. Noxious weeds are also present in many areas of the watershed. Other issues of importance to the upland conditions of the watershed include off-road vehicle usage and other recreational impacts to upland resources. Changes in upland habitat, recreational patterns, and fragmentation by roads, fencing, residential development and intensive land use have impacted wildlife habitat and the ecology of the upland landscape.

## 1.4 HUMAN ENVIRONMENT

Agencies that manage public land are limited in staff and other critical resources to protect and restore ecological functions due to restricted budgets at a time when demand of public lands for recreation and other non-traditional uses is increasing. In contrast, many private landowners have a strong conservation ethic and are able to respond quickly to resource needs, but may be unable implement conservation and restoration objectives due to limited resources or technical assistance. Organizations such as watershed councils, the Natural Resource Conservation Service, and Soil and Water Conservation Districts assist private landowners in developing the financial and technical resources needed to encourage conservation and restoration practices on private lands. Through advocacy, education, collaboration, restoration, and funding, the Council promotes and supports conservation and enhancement efforts on both private and public lands.

An understanding of the human environment will set the stage for the watershed issues discussed in this assessment. The mission of the Crooked River Watershed Council is to promote the socio-economic and environmental sustainability of the region. These two goals cannot be pursued in isolation, especially when stakeholder involvement is critical to success. The human environment conditions discussed in this section include the ownership, jurisdiction and management of the assessment area. The current population demographics, land use, economics, transportation, and hydrological management of the assessment area are also discussed.

### 1.4.1 Ownership, Jurisdiction and Management

Privately owned land comprises 68% of the assessment area (205,208 acres). The federal government manages 30% (86,970 acres) of the assessment area, with the remaining area in state and local government ownership. Jurisdiction within the assessment area is divided among three counties:

(1) Crook County with 227,084 acres (76%),

(2) Jefferson County with 54,129 acres (18%),

(3) Deschutes County with 19,064 acres (6%).

The majority of the federal land in the assessment area is managed by the United States Forest Service (USFS) and the Bureau of Land Management (BLM), including the USFS Ochoco National Forest, USFS Crooked River National Grassland, and the Prineville District of the BLM. A small amount of Bureau of Reclamation (BOR) land includes the upper most sections of both the Crooked River and Ochoco Creek just below the dams that constitute sections of the assessment area boundary. The City of Prineville's Urban Growth Boundary (UGB) accounts for 8,598 acres (approximately 3 % of the assessment area).

Various other agencies and organizations are stakeholders in the assessment area; these entities include the Soil and Water Conservation Districts for Crook, Jefferson and Deschutes Counties, and various irrigation districts including the Ochoco Irrigation District (OID), the Central Oregon Irrigation District (COID), the Crooked River Central

Irrigation District, and the People's Irrigation District. The OID distributes irrigation water in a large portion of the assessment area along Ochoco and the lower portions of McKay Creek. The COID distributes water to land owners in Powell Butte and Terrebonne. Powell Butte irrigation water drains into the Dry Canyon Irrigation Canal that in turn discharges into the Crooked River, as does irrigation water from properties in Terrebonne. Irrigation districts play a significant role in the management of water quantity throughout the assessment.

The Confederated Tribes of the Warm Springs Reservation of Oregon also have a vested interest in the assessment area. The Lower Crooked River Watershed is part of the 10 million acres of historical tribal territories known as the ceded lands. Although these territories were ceded to the United States government in the treaty of 1855, Article 1 of the Treaty states that the Tribe has:

> "the exclusive right of taking fish in the streams running through and bordering said reservation is hereby secured to said Indians; and at all other usual and accustomed stations, in common with citizens of the United States, and of erecting suitable houses for curing the same; also the privilege of hunting, gathering roots and berries, and pasturing their stock on unclaimed lands, in common with citizens, is secured to them (Confederated Tribes of the Warm Springs Reservation of Oregon, 2005)."

Other state and federal agencies as well as non-governmental organizations with an interest in resource management have a stake in the assessment area necessitating a collaborative approach to environmental planning and natural resources management.

### 1.4.2 Population and Demographics

The primary population center within the assessment area is the City of Prineville, which has an estimated population of 9,990 (Population Research Center [PRC], 2007). Other incorporated cities in the assessment area include the City of Culver (estimated population of 1160; PRC, 2007), and the City of Redmond (estimated population of

23,500; PRC, 2007). Both cities are only partial within the watershed. Unincorporated communities do not have current population estimates; however 2000 census population estimates for the Crooked River Ranch, the Juniper Canyon Subdivision and the community of Terrebonne were 1,469 (US Census Bureau, 2000). The remainder of the population in the assessment area is rural residential.

Central Oregon is experiencing significant growth. Much of the increase in population is occurring in and around the cities of Bend and Redmond with a combined 2006 population estimate of 98,790, which represents 358 percent growth since 1990 (PRC, 2007). Growth is also occurring in smaller communities and rural areas. The resulting regional growth pattern indicates that all three counties in the assessment area - Deschutes, Jefferson, and Crook - are expected to grow at rapid rates over the next few decades. Projected annual growth rates for Crook County are presented in Table 1-3.

### 1.4.3 Economics

The primary industries in the assessment area are livestock, secondary wood products, agriculture, recreation and tourism. Recreation and tourism are a growth sector of the

Table 1-3. Population Growth for the City of Prineville and Crook County

| Year | City of Prineville | | | Crook County | | |
|---|---|---|---|---|---|---|
| | 2.5% | 4.4 % | 5.0 % | 2.5% | 4.4% | 5.0% |
| 2007 | 10,240 | 10,430 | 10,490 | 25,138 | 25,604 | 25,751 |
| 2008 | 10,496 | 10,888 | 11,014 | 25,767 | 26,731 | 27,039 |
| 2010 | 11,027 | 11,868 | 12,143 | 27,071 | 29,135 | 29,810 |
| 2015 | 12,476 | 14,719 | 15,498 | 30,628 | 36,134 | 38,046 |
| 2020 | 14,116 | 18,255 | 19,780 | 34,653 | 44,814 | 48,558 |
| 2025 | 15,971 | 22,640 | 25,244 | 39,207 | 55,580 | 61,973 |

*Growth projections are based on 2006 population estimate (PRC, 2007). 4.4% annual growth rate represents a continuation of the average growth rate between 2002 and 2006; 5.0% annual growth rate represents the average annual growth rate between 1990 and 2006. 2.5% annual growth rate represents a reduction in the population growth rate and is therefore a more conservative population projection.*

economy. The natural amenities of the Crooked River, Smith Rocks State Park, Crooked River National Grasslands and Ochoco National Forest provide a variety of activities that draw people to the area. Livestock and wood products still comprise two of the top three industries today. The primary wood products industry provided the top employment and income production for most of the 20th century. Declines in locally harvested timber have shifted the wood products role in the economy from primary to secondary manufacturing industries. Control of the western juniper expansion in the assessment area and the region in general represents a potential economic development opportunity, and research is currently underway to determine harvest and market viability. Crop production is also a significant sector of the local economy, producing hay, mint, potatoes, wheat, and alfalfa.

The Oregon Economic Development Department (OEDD) in 2002 rated Crook County as a distressed area with low socio-economic resiliency due in large part to unemployment, poverty, population density, economic diversity, and lifestyle diversity (OEDD, 2002). The 2000 Census indicates that, in the City of Prineville, 10% of families and 14.3% of individuals are living below the poverty level. Seasonal employment in industries such as forestry and agriculture add to the historic high levels of unemployment. Annual average unemployment rates in Crook County were above the State of Oregon average from the mid-1970's up through 2002 (OEDD, 2002); however, unemployment rates have been falling since 2002 (Table 1-4). Although population growth is also coinciding with growth in the labor force, Crook County in 2005 ranked 33rd in per capita income out of 36 Oregon counties (BEA 2007).

Table 1-4. Crook County Economic Indicators

| **Crook County** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** |
|---|---|---|---|---|---|---|---|
| Labor Force | 8,649 | 8,785 | 8,826 | 8,879 | 9,093 | 9,309 | 9,618 |
| Unemployment Rate (%) | 7.2 | 8.3 | 9.2 | 9.5 | 8.1 | 6.7 | 6.0 |
| Annual Per Capita Personal Income ($) | 20,357 | 21,191 | 21,525 | 22,197 | 23,141 | 23,802 | NA |

*Sources: Oregon Employment Department; Bureau of Economic Analysis. Data last updated: 05/10/2007*

### 1.4.4 Transportation

The assessment area is isolated from major transportation routes or centers. There are no interstate highways that transect the watershed and the closest international airport is three hours to the northwest in Portland, Oregon. A regional airport, located in Redmond, serves the entire Central Oregon region. There is a railroad within the assessment area, but its use is limited. The rail line runs 18.3 miles from the Burlington Northern Santa Fe and the Union Pacific Railroads at Prineville Junction north of Redmond to the City of Prineville. The assessment area has an extensive road system, although many are rural roads. The main paved roads that cross the assessment area are U. S. Routes 26 and 97 and State Routes 126 and 27.

### 1.4.5 Built Hydrology

The upper boundaries of the watershed are delineated by Bowman Dam on the Crooked River and by Ochoco Dam on Ochoco Creek. Timing of discharges from both dams for flood control and irrigation water reduces peak flows in the Crooked River and Ochoco Creek, while increasing the average summertime low flow period. The Lytle Creek and the Dry Canyon drainages, which contribute water to the Crooked River downstream of Prineville, are largely fed by irrigation water. Irrigation water and the infrastructure that services water users clearly have a significant influence on both surface and groundwater within the watershed.

# Chapter 2 – Regulations and Local Issues

*A group of real estate developers, ODFW employees, water users, Watershed Council and Crook County Parks and Recreation District staff discuss river restoration opportunities. (Photo Credit: M. Nielsen-Pincus)*

## Overview of the Regulatory Environment and Key Local Issues

- The Crook County Comprehensive Plan is the foundation for local regulations impacting watershed management at the City and County level.
- Oregon water quality statutes, Forest Practices Act, Groundwater Quality Protection Act, Removal-Fill law, and the Oregon Plan for Salmon and Watershed are the foundation of state regulations that impact watershed management in the assessment area.
- The Clean Water Act, the Endangered Species Act, the Wild and Scenic Rivers Act, the National Environmental Policy Act, the National Forest Management Act, and Federal Lands Policy and Management Act all impact watershed management in the assessment area.
- Key local issues:
    1. Growth and development impacts on stormwater, water quality, and flood hazard.
    2. Reintroduction of federally listed threatened mid-Columbia summer steelhead (*Onchorynchus Mykiss*).
    3. Reallocation of water in the Prineville Reservoir.

## 2.1 INTRODUCTION

This component discusses regulations and local issues that impact the condition and management of the assessment area's ecosystem and natural resources. The first section focuses on local, state, and federal regulations and plans. Local regulations, such as codes and ordinances, originate with city and county comprehensive plans. These plans are required for all Oregon cities and counties by state law, and address the protection and management of a number of natural resources, including water resources. The plans are based on resource inventories and are implemented through enforceable local ordinances that govern the location and execution of land uses and land management activities (Watershed Professionals Network, 1999). The local ordinances and codes that affect the assessment area are those developed by Crook County and the City of Prineville. The first part of this component discusses the local ordinance and codes, and is followed by an overview of State and Federal laws and plans that apply to the conservation of resources in the assessment area. The second part of this component explores local environmental issues, including stormwater management, the reintroduction of anadromous fish, and unallocated water in the Prineville Reservoir.

The principal references for this component include: the *Interagency Hazard Mitigation Team Report for Crook County Flooding Disaster* (National Riparian service Team, 1998); *Ochoco Creek Flood Assessment* (FEMA, 1998); *OWEB Watershed Assessment Manual* (1999); *Crooked River Watershed Assessment* (CRWC, 2002); *City of Prineville Ordinance* (2003); *Crooked River Agricultural Water Quality Management Area Plan* (Crooked River Local Advisory Committee, 2004); *Crook County Comprehensive Plan* (1978-2005); *Crook County Code* (Cited 2005); *City of Prineville Comprehensive Plan* (2005); information provided by the Oregon Department of Environmental Quality (ODEQ), the Crooked River Watershed Council, the Lower Crooked River Watershed Assessment Technical Team, and interactions with community members and interested stakeholders. Additionally, larger regional planning documents were reviewed including the *Interior Columbia Basin Ecosystem Management Project* (ICBEMP, 1999) and the *Northwest Power and Conservation Council Deschutes Subbasin Plan* (NPCC, 2004).

## 2.2 WATERSHED RELATED REGULATIONS

### 2.2.1 Local Regulations

Crook County

Crook County's comprehensive plan was developed in 1978, and has been amended numerous times. Although the plan is due for a general revision in order to reflect current conditions and community values (Kowalski, 2005), the existing plan provides the basis for the current County Code. According to the Crook County Code, goals for natural resource management include:

- To maintain and improve the quality of the air, water and land resources of the county.
- To minimize the impacts of developments on the surrounding environment.
- To direct growth in the most environmentally capable and satisfactory areas.

These goals are the basis for the following ordinances, (the parenthetical citations refer to the chapter and section each particular ordinance can be found within the Crook County Code:

- Weed Control (8.24)
- Public Services – regulation of sewage disposal and standards to protect ground and surface water (13)
- Surface Mining (16.04)
- Subdivision – including stormwater management for subdivisions, (17.16.060)
- Zoning – including zones (e.g. EFU-1 and EFU-2) that require protection of critical wildlife range
- Floodplain Combining Zone (18.84)
- Sensitive Bird Habitat (18.120)
- Aggregate Resource Sites (18.144)
- Resource Use Protection (18.148)
- Riparian Protection (18.124.090)
- Rimrock Protection (18.124.100)

City of Prineville

The City of Prineville's first comprehensive plan was passed in March 2007. Prior to the adoption of the City's comprehensive plan planning, ordinances, and existing City management were covered by the Crook County Comprehensive Plan. The City of Prineville regulates land use through its zoning and subdivision ordinances. These ordinances include:

- Chapter 51: Sewers – provides regulations concerning types of sewage treatment facilities, including requirements to connect to City sewer system and types of prohibited discharges.

- Chapter 91: Trees and Shrubs – regulates the types of trees that can be planted in the City and the pruning and cutting of trees and shrubs within the City boundary.
- Chapter 95: Fire Prevention and Protection – outlines a uniform fire code and establishes fire districts.
- Chapter 151: Flood Damage Prevention – regulates development on areas designated as special flood hazard areas.
- Chapter 153: Land Development – includes the zoning ordinances regulating land use within designated zoning districts. It also contains supplementary provisions including:
  - Section 153.087: Landscaping Requirements – requires conservation of existing vegetation and the installation of vegetative buffers for developed land usages.
  - Section 153.088: Riparian Habitat – requires a buffer of 25 feet for Ochoco Creek and 50 feet for the Crooked River.
  - Section 153.089: Cutting and Filling – addresses the removal and fill of soil, and contains sections relating to drainage planning and management, wetland conservation, and stormwater in relation to wetlands.
  - Section 153.097: Livestock – regulates the number and type of livestock allowed within the Urban Growth Boundary (UGB).
  - Section 153.157: Subdivision Applications – requires a stormwater and drainage plan.

### 2.2.2 State Regulations

Water Quality Statutes

The statutes, ORS 468B.010 through 468B.050, present a framework under which water pollution is defined and controlled to protect beneficial uses of water. A key portion of the statute, ORS 468B.025(1), states no person shall:

- Cause pollution of any waters of the state or place or cause to be placed any wastes in a location where such wastes are likely to escape or be carried into the waters of the state by any means.

- Discharge any wastes into the waters of the state if the discharge reduces the quality of such waters below the water quality standards established by rule for such waters by the Environmental Quality Commission.

The Oregon Department of Environmental Quality is responsible for enforcement of Statute ORS 468B, except as provided under ORS 561.191 for agricultural practices that affect water quality, which are regulated by the Oregon Department of Agriculture.

The Federal Clean Water Act (CWA) requires the State of Oregon to develop Total Maximum Daily Load (TMDL) standards and associated Water Quality Management Plans. In 1993, the State Legislature approved Senate Bill 1010, which was codified into ORS 568.900-568.933 and into Oregon Administrative Rules (OAR) 603-090. Statute ORS 568.900-.933 gave the Oregon Department of Agriculture (ODA) the authority to develop Agricultural Water Quality Management Area Plans and Rules where required by federal or State law. The statute and the administrative rules outline the process for the development and implementation of Agricultural Water Quality Management Area Plans to help prevent and control water pollution resulting from agricultural activities and soil erosion. The process includes the formation of a Local Advisory Committee that consists primarily of landowners in the affected area to assist the ODA in the development of the Area Plan and rules.

The Local Advisory Committee, with the assistance of the ODA and the Crook County Soil and Water Conservation District developed the Crooked River Agricultural Water Quality Management Area Plan (Oregon Department of Agriculture, 2006). The plan characterizes the management area, offers discussion on water quality and watershed health, identifies beneficial management practices, and develops rules and enforcement mechanisms for protecting water quality. The most significant rule protecting water quality and watershed health requires that "agricultural management allow establishment, growth, and active recruitment of streamside riparian vegetation" (Oregon Department of Agriculture, 2006, p.33).

Oregon Forest Practices Act

The 1971 Oregon Forest Practices Act (FPA) sets standards for forest management on private lands. The act sets best management practices for any acts related to the establishment, management, and harvesting trees in Oregon's forestlands for the benefit of streams and riparian areas, soils, protected wildlife, and future forest productivity. Although forest management on federal lands is not regulated by the Oregon FPA, federal agencies have agreed to meet or exceed the state standards. Notably important to the assessment area is the exemption of western juniper management from the Oregon FPA. Only commercial juniper harvests on units greater than 120 acres are subject to the Oregon FPA (ORS 527.610). This exclusion is based on the recommendations of the ad hoc Juniper Issues Group, which was created under Senate Bill 1151.

Ground Water Quality Protection Act

Oregon's Ground Water Quality Protection Act of 1989 sets broad goals for the state to prevent contamination of ground water resources, to conserve and restore ground water resources, and to maintain the high quality of ground water for present and future uses. Oregon implements a combination of programs through various state agencies, including the Department of Environmental Quality (ODEQ), Department of Forestry (ODF), Department of Human Services (ODHS), Water Resources Department (OWRD), and the Department of Agriculture (ODA). The ODEQ has primary responsibility for protecting ground water, cleaning up polluted ground water, and monitoring and assessing ground water quality. The ODHS and ODEQ implement Safe Drinking Water Act programs to develop source water assessments for public drinking water supply systems. The OWRD manages ground water to provide a sustainable resource, assess aquifers and available ground water in the state, and administers well construction, maintenance and decommissioning regulations. The ODA regulates farming practices to protect ground water (ODEQ, 2003). The protection of groundwater is a particular concern in the assessment area because there are high water tables in many portions of the area. High water tables lead to interaction between surface water and groundwater; contamination of either can impact the other.

<u>Removal-Fill Law</u>

Oregon's Removal-Fill Law (ORS 196.795-990) requires people who plan to remove or fill material in waters of the state to obtain a permit from the Oregon Department of State Lands (ODSL). The law applies to all landowners, whether private or public agencies. The purpose of this 1967 law is to protect public navigation, fishery and recreational uses of the waters. Waters of the state are defined as natural waterways including all tidal and non-tidal bays, intermittent streams, constantly flowing streams, lakes, wetlands and other bodies of water in this state, navigable and non-navigable, including that portion of the Pacific Ocean that is in the boundaries of this state. Permits or General Authorizations are required for the following actions (ODSL, 2005):

- Projects requiring the removal or fill of 50 cubic yards or more of material that is below the ordinary high water line.
- The removal or fill of *any material* in a stream designated as essential salmon habitat.
- The removal or fill of *any material* from the bed and banks of scenic waterways.

There are a number of exemptions for certain removal and fill activities. These include specific farming and ranching practices, restoration of anadromous salmonid habitat, irrigation and flood control structures, road maintenance and management activities on State Scenic Waterways. Exempt activities are expected to employ Best Management Practices (BMP's) to reduce erosion and minimize impacts habitat, vegetation and water quality. Removal and fill activities may also require a federal permit from the U.S. Army Corps of Engineers (ACOE).

<u>The Oregon Plan</u>

The Oregon Plan for Salmon and Watersheds (The Oregon Plan) and the accompanying Healthy Streams Partnership initiative impact the assessment area due to the planned reintroduction of anadromous fish into the Lower Crooked River Watershed and the Deschutes Subbasin. The Oregon Plan originated in 1997 as an effort to address declining populations of coastal Coho Salmon. Since then, the plan has expanded to include non-listed salmon and steelhead populations. The Oregon Plan aims to restore fish populations to productive and sustainable levels that will provide environmental, cultural, and economic benefits. While the Oregon Plan focuses on salmon, it is also designed to conserve and restore natural systems that support fish, wildlife, and people. The Oregon Plan relies on four fundamental approaches to accomplish the goal of securing and protecting healthy fish habitat: (1) community-based action, (2) government coordination, (3) monitoring and accountability, and (4) making improvements over time.

The Healthy Streams Partnership is a component of the Oregon Plan. The Healthy Streams Partnership was formed in an effort to find cooperative solutions to water quality problems. The partnership is made up of representatives from the agricultural community, forestry industry, environmental groups, local government and state agencies, and the governor's office. The partnership uses existing regulations under the Oregon Departments of Agriculture, Forestry, and Environmental Quality to address waterbodies that currently do not meet water quality standards. The partnership provides support to state agencies and ensures that landowners and other individuals have extensive opportunity for input into decisions. Watershed councils play a key role in facilitating the Oregon Plan by developing watershed assessments, restoration plans, and by engaging landowners in restoration and enhancement actions.

### 2.2.3 Federal Regulations

Approximately 30% of the land within the assessment area is managed by the USFS and BLM. Federal laws require a public management planning process for these lands, and the laws require that the plans be consistent with other state and federal environmental protection programs. The two federal laws that detail the planning processes are the 1976 National Forest Management Act (NFMA), which governs planning and management of the National Forest lands, and the 1976 Federal Land Policy and Management Act (FLPMA), which governs the planning and management of BLM administered lands. Finally, the National Environmental Policy Act (NEPA) prescribes a public involvement and review process for all federal actions impacting land management. The following are three additional laws that impact land and water management in the assessment area.

Clean Water Act

The 1972 Clean Water Act (CWA) as amended gives the state responsibility for setting water quality standards and developing water quality management programs that ensure that the CWA goals are met. The CWA is enforced by the Environmental Protection Agency, which delegates statewide oversight to the Oregon Department of Environmental Quality. Section 303(d) of the CWA sets criteria for assessing whether specific stream segments are water quality limited. Listing a stream segment as water quality limited requires the state to prepare a Total Maximum Daily Load (TMDL) plan, or a water quality management plan, that will function as a TMDL plan for nonpoint sources (e.g., forestry, agriculture, grazing, and untreated urban stormwater runoff). Information collected during a watershed assessment can be used to assist the state in evaluating the status for listing and in developing the management plans required by the CWA.

The Endangered Species Act

Another important piece of federal legistlation is the 1973 Endangered Species Act (ESA). The ESA lists species that are at or below critical levels of population viability as either endangered or threatened. An endangered species is defined as any species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is defined as any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. The Act provides criteria for determining whether a species should be listed, for determining critical habitat, and for protection against public or private actions that would further imperil a listed species. The US Fish and Wildlife Service (USFWS) is responsible for inland fish, wildlife, and plants, and the National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) is responsible for marine and anadromous fish, and marine mammals. These two agencies are charged with administering the key components of the law including:

1. Section 4 – defining criteria for listing populations of threatened and endangered species; determinations of the listing status must be made on "the best scientific and commercial data available."

2. Section 6 – entering into cooperative agreements with states and state agencies to promote the conservation of threatened and endangered species, and allocating funds to support such efforts.
3. Section 7 – offering a formal consultation process to all federal agencies on actions that may jeopardize a listed species or destroy or modify its habitat, and suggesting modifications to reduce the potential effect on the listed species if the effects of the action are determined likely to place the listed species in jeopardy.
4. Section 11 – enforcing the prohibitions on "takings" of listed species by both public and private entities. "Takings" are defined as any action that will harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt any such conduct towards a listed species.

The assessment area will be subject to the provisions of the ESA once the reintroduction of federally threatened summer steelhead (*Onchorynchus mykiss*) begins in 2008.

The Federal Wild and Scenic Rivers Act

The Wild and Scenic Rivers Act was passed in 1968 to balance development near rivers and streams with the conservation of river and stream corridors. To accomplish this goal, Congress created the National Wild and Scenic Rivers System. The Oregon Omnibus Wild and Scenic Rivers Act of 1988 designated 40 river segments in Oregon for inclusion in the wild and scenic rivers system and directed the United States Forest Service (USFS) and the Bureau of Land Management (BLM) to develop management plans for each designated river (USDI BLM, 1992a). The following river segments in the assessment area have been designated Wild and Scenic:

- Lower Crooked River, Chimney Rock Section, Lower Crooked River Sub-basin: Total of 8 river miles (river miles 63 to 71) from Bowman Dam to State Scenic Highway 27, mile-marker 12. Remarkable values for the Chimney Rock segment of the Lower Crooked Wild and Scenic River include scenic, recreational, and fish resources. This area is also managed as an area of critical environmental concern by the BLM, and the State Scenic Highway adjacent to the river is designated as a National Back Country Byway. The fisheries resource in this section of the Crooked River was determined to be an outstanding remarkable value based on its genetic diversity and adaptability of redband trout to a wide variety of habitats (USDI BLM, 1992a).

- Lower Crooked River, Lower Crooked River Sub-basin:

  Total of 9.8 river miles (river miles 8 to 17.8) from the National Grasslands Boundary to Opal Springs. Remarkable values for this river segment include recreation, scenic, geology, wildlife, and hydrology. This segment is adjacent to the community of Crooked River Ranch and approximately 10 miles from the communities of Redmond and Madras, and flows through Smith Rock State Park. Springs in the Lower Crooked River contribute to improved water flow, temperature, and quality (USDI BLM, 1992b).

### 2.2.4 Local Issues

Several local environmental issues that require mention include urbanization, stormwater management, the reintroduction of anadromous fish, flood hazards, and unallocated water in the Prineville Reservoir.

Urbanization

Growth and development is increasing at a rapid pace in the assessment area. Without appropriate planning mechanisms growth can create a number of water quality and water related habitat concerns. Concerns may range from increased demands on water supply to impacts to water quality and riparian habitat. These concerns are addressed in Table 2-1, which lists a variety of watershed impacts of urbanization.

Oregon voters passed Ballot Measure 37 by a margin 61% to 39%. The measure entitles property owners to receive compensation or a waiver when a land use regulation reduces the fair market value of the property. Oregon's land use planning statutes were passed in 1972. A major goal of the 1972 statutes was the conservation and protection of traditional agricultural and forest lands. Measure 37 may facilitate and increase in the pace of development in the assessment area by requiring local jurisdictions to waive land use regulations. Increased growth and development is also leading to the need for more

Table 2-1. Issues Presented by Urban Development

| Urban Activities | Potential Watershed Impact |
|---|---|
| Channelization and confinement of stream channels for urban land uses | Reduced channel complexity; increased velocities; loss of pools for holding and rearing of fish; loss of spawning gravel habitat; loss of side channels; loss of wood recruitment; loss of connectivity with floodplain and riparian zone |
| Removal of riparian vegetation to facilitate development | Reduced overhanging vegetation and shade cover; increased solar radiation; elevated water temperatures; loss of large wood recruitment; reduced terrestrial insect influx; reduced leaf litter influx; alteration of energy cycle |
| Development in forested areas | Altered runoff cycle with altered timing and magnitude of flows; increased erosion; changed channel morphology |
| Filling wetlands to accommodate urbanization | Altered runoff cycle with altered timing and magnitude of flows; reduced base flows; changed channel morphology and loss of connectivity with floodplain |
| Creation of impervious surfaces | Increased stormwater runoff, altered runoff cycle with altered timing and magnitude of flows; changed channel morphology; degraded water quality increased stormwater runoff |
| Water allocation for municipal uses | Altered flow regime; altered instream habitat availability |
| Producing Waste water treatment effluent | Altered water temperatures; reduced dissolved oxygen concentrations; released contaminants; degraded water quality related to sewage effluent (Addressed under ODEQ permitting authority) |
| Industrial effluent | Degraded water quality; released contaminants and toxins |
| Culverts, pipes, ditches | Obstructed upstream passage; reduced downstream movement of wood and gravel; stranded fish in ditches |
| Erosion and sedimentation | Increased turbidity and inputs of fine sediment during construction and prior to revegetation |
| Water related recreational activities | Increased potential direct contact with ESA-listed salmon; degraded water quality (e.g., fuel spills) |
| Fertilizer and pesticide use | Degraded water quality and increased toxicity; biological degradation |

Table 2-1 is adapted from information provided by the King County (Washington) Department of Natural Resources and Parks - Water and Land Resources Division and is being incorporated in the Oregon Watershed Enhancement Board's urban issues component of the Oregon Watershed Assessment Manual.

municipal water. Although municipal water demand is not discussed further here, increasing demand may lead to tradeoffs and conflict over water use unless collaborative proactive measures are taken.

Locally, growth and development are a concern specifically within proximity to riparian areas and flood hazard zones. The City of Prineville is currently collecting data to update flood hazard maps on Ochoco Creek and the Crooked River within the urban growth boundary. Current local ordinances may not adequately protect floodplain values and mitigate flood hazards from new developments.

Stormwater

Impervious surfaces and associated nonpoint source pollution created by stormwater runoff present significant concerns to water quality and flow. According to the EPA (2005):

> "Non-point source pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. These pollutants include:
>
> - Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;
> - Oil, grease, and toxic chemicals from urban runoff and energy production;
> - Sediment from construction sites, crop and forest lands, and eroding streambanks;
> - Salt from irrigation practices and acid drainage from abandoned mines; and
> - Bacteria and nutrients from livestock, pet wastes, and faulty septic systems."

Impervious surfaces such as concrete, asphalt and rooftops lack the infiltrative capacity of pervious surfaces such as agricultural, range or forest land. Impervious surfaces increase water runoff from precipitation. Unless filtered, this runoff may contain a variety of pollutants, such as sediment, hydrocarbons, and toxic substances. The process of urbanization commonly causes the percentage of land covered by impervious surfaces to increase. The City of Prineville's growth may contribute to water quality problems through stormwater run-off if appropriate mitigation measures are not undertaken. Proactive approaches to mitigating stormwater, including the development of stormwater detention areas, adopting green building standards, and riparian setbacks, can help communities mitigate the impacts of stormwater in a cost effective manner before problems require costly remediation. Proactive strategies may also help avoid the imposition of state and federal regulations.

The Subdivision Title 17 stormwater section in the Crook County Code requires a stormwater facilities plan for subdivisions over five acres as stipulated by State law, but does not include specific mitigation requirements. The Code only requires stormwater facilities plans for subdivisions, but does not require similar plans for commercial, industrial and individual residential developments.

The City of Prineville's stormwater regulations are similar to those in the Crook County Code. Both Codes cover stormwater mitigation for new subdivisions over five acres, but do not include other types of new development. In the County Code, the subdivision ordinance only contains a general statement regarding stormwater and does not require a specific level of mitigation. However, the City of Prineville Code has a policy which requires subdivisions over five acres to deal with stormwater on-site. Subdivision applicants to the City are required to plan and provide mitigation for a 20-year storm event. The use of the 20-year event is notable because it is more rigorous than the 2-year event standard that is suggested by Oregon's Department of Land Conservation and Development (ODLCD).

Other regulations influence municipal stormwater management, such as the CWA National Pollution Discharge Elimination System (NPDES) regulations and the TMDL plan for the area. Part of the ODEQ's CWA authority includes determining which municipalities require, and then issuing and enforcing, NPDES permits to discharge stormwater. Currently, the City of Prineville is not required to have a stormwater discharge permit. However, as the City's population increases to the 10,000 threshold, the City's stormwater management may require a storm-water discharge permit. The population threshold does not automatically require the ODEQ to impose regulations; however, as ODEQ develops a TMDL analysis and plan for the area, municipal stormwater concerns may arise. Additionally, the ODEQ has the authority to require the City to submit to a stormwater permitting process at any time, regardless of population, if ODEQ feels there is sufficient impairment associated with stormwater.

The City of Prineville is currently expanding its wastewater treatment facility capacity. As part of this expansion, the City is working with the Oregon Department of Transportation to develop a wetland mitigation bank and enhance river function throughout the site. The wetland will buffer the Crooked River from high groundwater flows in the area of the treatment lagoons. The City is aware of the trend towards greater regulation of nonpoint source pollution including stormwater and would like to proactively address this type of issue.

<u>Reintroduction of Anadromous Fish</u>

The active and passive reintroduction of anadromous fish species into the assessment area, specifically Mid-Columbia River summer steelhead (*Onchorynchus Mykiss*) and Upper Columbia River spring Chinook salmon (*Onchorynchus Tshawtscha*) will begin in the spring of 2008. The reintroduction will also include bull trout (*Salvelinus confluentus*) and pacific lamprey (*Lampetra tridentate).* The reintroduction of steelhead is an active reintroduction that according to current plans will begin with the out-planting of federally listed threatened steelhead fry in McKay Creek in 2008 above the National Forest boundary. The reintroduction of all other species into the assessment area will be facilitated in a passive manner through the creation of fish passage at the Pelton Round Butte hydroelectric complex on Lake Billy Chinook. The reintroduction effort will increase in intensity over time as the infrastructure and methodology is completed and refined. The presence of reintroduced species will create regulatory impacts on the assessment area, including those required by the Endangered Species Act. Regulatory concerns will likely include requiring fish screens at irrigation water diversions, actively managing water quality, strategically managing water flows, and requiring reduced impacts on riparian areas. Summer steelhead trout and bull trout are both listed as threatened under the ESA. Many local citizens are concerned about the impacts reintroduction will have on the regulation of land use practices, and many feel that reintroduction of these fish to their native habitat is a benefit to the resource base of the assessment area. Benefits may include increased revenues from recreational fishing, as well as improved water quality and water conservation. The reintroduction of anadromous fish will provide substantial financial and technical resources for the restoration and enhancement of aquatic and riparian habitat in the assessment area.

Flood Hazards

The assessment area has a history of flood events. Flood control is currently managed by the operations of Bowman Dam on the Crooked River and the Ochoco Dam on Ochoco Creek. The Bureau of Reclamation (BOR) and the Ochoco Irrigation District (OID) manage the discharges from the two dams, which also provide water for irrigation. Major flood events occurred in both 1964 and the 1998. Managing the reservoirs and the outflow of water is dependent on weather prediction and flow monitoring in upland areas. Incorrect predictions, unexpected flows, and human error can all lead to flood events. In the 1998 flood on Ochoco Creek, weather conditions and reservoir management led to flows from the Ochoco Dam that flooded much of Prineville, resulting in the declaration of a federal disaster area. Increased development adjacent to Ochoco Creek and the Crooked River in and around the City of Prineville indicate that future flooding could create a more substantial impact in the future. Restoring floodplain, enhancing riparian areas, and minimizing development along Ochoco Creek through and above the Prineville urban growth boundary may help to reduce the hazard presented by high flow events.

Unallocated Water in Prineville Reservoir

The primary uses of the water stored above the Bowman Dam in the Prineville Reservoir have been for flood control, irrigation, and recreation. The reservoir has become a popular site for a variety of recreational pursuits including fishing, boating and other water sports. The Bureau of Reclamation (BOR) controls the release of stored water, and contracts a specified volume of the water to local irrigation districts, such as the Ochoco Irrigation District, depending on the water rights serviced by the irrigation districts. The volume contracted to the irrigation districts is less that the total volume of water contained in the reservoir. Approximately 55% of the water stored in the Prineville Reservoir is uncontracted according to the BOR *Prineville Reservoir Resource Management Plan* (2003).

Numerous requests for reassignment of the additional storage space and unallocated water have been submitted to the BOR. These requests have included uses for recreation, fish, wildlife, domestic, municipal and industrial development, and irrigation. However, under the 1956 Crooked River Project authorization irrigation is the only authorized use of uncontracted stored water; other uses require Congressional reauthorization. Attempts to develop a consensus reallocation plan have been unsuccessful. The most recent reallocation attempt occurred between 1998 and 2000, and was not completed because of BOR funding constraints. At the current time, the BOR has suspended analysis and resolution of the issue.

Resolution of this issue could have numerous benefits to the communities and resources of the Lower Crooked River Watershed. A strategic increase in outflows from the Bowman Dam may enhance fish spawning and rearing habitat and increase the likelihood of success of the anadromous reintroduction effort. Increased flows could help restore natural channel formation processes, and would mitigate some water quality concerns by diluting pollutants. Allocation of presently uncontracted water could be used to provide water for irrigators in drought years when the ESA would otherwise mandate water be left instream for listed fish. Allocation of the presently uncontracted water could also help spread operational costs of the dam and reservoir more equitably among users.

# CHAPTER 3 – HISTORICAL CONDITIONS

*Lower Crooked River about 6 miles west of Prineville looking downstream (Photo Credit: Russell, 1905)*

## CRITICAL QUESTIONS

- What cultures have inhabited the assessment area, and what were their habitation patterns and resource impacts?
- What relationship existed between the Euro-American settlers and the resources of the assessment area?
- What have been the impacts of Euro-American settlement to the hydrological and ecological systems in the assessment area?
- What was the historic range of natural variability for the aquatic, riparian, wetland, and upland ecosystems in the assessment area?

## KEY FINDINGS

- Populations of native peoples were low and their semi-nomadic practices had limited impacts on the natural environment, except possibly through fire use.
- Early exploration of the region was conducted by fur companies trapping for beaver.
- Riparian, wetland, and floodplain vegetation was historically more extensive due to regular flooding, sinuous side channels, and extensive beaver dams.
- Riparian and wetland communities were reduced by the removal of beaver and subsequent land use practices.
- Water use expanded substantially in the early 1900s, augmenting the natural hydrologic regime.
- At least two species of anadromous fish were historically present throughout the assessment area, including summer steelhead and Chinook salmon.
- Uplands were characterized by bunchgrass communities and open forest stands, which were both maintained by a high frequency – low intensity fire regime.

## DATA GAPS AND RESEARCH RECOMMENDATIONS

- Historical image analysis of river and stream morphology and upland vegetation would increase the scientific understanding morphological changes in rivers and streams of the assessment area.

- The level of influence of Native American fire use is not well understood in the assessment area. Studies of historical fire regime could clarify fire management objectives for the assessment area and separate historical impacts of native fire use and climatic controls on fire regime.
- An environmental history of the assessment area would add detail and structure to the relationship between humans and their environment over time.

## ACTION ITEMS

- Continue to collect and compile historical documents relevant to understanding both hydrological and vegetative characteristics of the assessment area (e.g., photos, archived reports, maps, journals, etc.).
- Coordinate with other individuals and organizations that are collecting, assessing, and interpreting historical information.

## 3.1 INTRODUCTION

Central Oregon's post-settlement history begins in the mid to late 1800s. Prior to that time native peoples occupied the land for over 10,000 years (Cressman, 1981; Aikens, 1986; Minor et al., 1987). Information used to characterize historic human habitation patterns and resource conditions in the assessment area is drawn primarily from broader scale historic information for central Oregon. Data for presettlement history was primarily obtained from anthropological studies conducted for the Ochoco National Forest (Minor et al. 1987) and the Upper Deschutes Basin (USDI BLM 2001). Information was also provided by the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). A review of the General Land Office (GLO) surveys from the 1870's and 1880's also provides locally specific historical data on resource conditions in the assessment area in the late 1800s. The GLO data were collected systematically and help to establish a coarse scale natural conditions baseline at the time of Euro-American settlement. This component also discusses the post-settlement trends of land use and resource management, and offers historical accounts of resident and anadromous fish populations in the assessment area.

## 3.2 PREHISTORIC OVERVIEW

The Lower Crooked River Watershed straddles the boundaries of the Mazama, John Day, and High Desert ecological provinces at the northwestern edge of the Great Basin and the southwestern edge of the Columbia Basin. Ethnographic accounts indicate that prehistoric human habitation patterns were primarily nomadic or semi-nomadic (Minor et al., 1987; USDI BLM, 2001). Much of the assessment area was inhabited by two distinct types of native peoples: earlier Paleo-Indians and later Archaic peoples (Minor et al., 1987). Seasonal resource gathering was common among Columbia Basin peoples, who lived in small semi-nomadic groups (USDI BLM, 2001).

The first known people to inhabit central Oregon, the Paleo-Indians, are thought to be the earliest humans to occupy North America (Minor et al., 1987). Evidence of these earliest residents has been found in archeological sites, including the Three Sheep Rockshelter, near the confluence of the Crooked and Deschutes rivers (Minor et al., 1987). These sites include animal and human bones, crude tools, and projectile points. Paleo-Indians were big game hunters and lived in an environment and climate that may have been significantly different than what is found in central Oregon today. Paleo-Indians' occupancy of the assessment area likely coincided with the late glacial period of the last ice age (Minor et al., 1987).

Although, there appears to have been some overlap in habitation by Paleo-Indians and Archaic peoples, around 10,000 years ago the Paleo-Indians were gradually replaced by the Archaic peoples. This transition occurred as the post glacial climate shifted the environment towards the present ecological conditions of central Oregon (Minor, et al. 1987). The Archaic people commonly settled near lakes and marshes, but made use of arid uplands on a seasonal basis for hunting and gathering. Archaic habitation is characterized by the "winter village pattern" in which clusters of dwellings are situated together during the cold season (Claeyssens, 2005), often around central waterbodies. This pattern is considered by many archaeologists and anthropologists as the beginning of the pattern of culture in the Columbia Plateau and Great Basin, and is repeated by later inhabitants including Euro-American settlers. This pattern reflects the critical nature of water resources in the semiarid environment of central Oregon. The Archaic people inhabited the region until approximately 1000 A.D. when the Numic speaking peoples arrived in central Oregon (Minor et al., 1987). Numic peoples include the Northern Paiute tribes, which became the dominant Native American tribe in the assessment area.

## 3.3 NATIVE AMERICAN INHABITANTS

Of the tribes in central Oregon, the Northern Paiute most prominently occupied and utilized the resources of the assessment area (USDI BLM, 2001; Confederated Tribes of Warm Springs, 2005). Other tribes that occupied central Oregon at the time of Euro-American contact were the Warm Springs, and the Wasco tribes; the Tenino, Umatilla, Nez Perce and Cayuse tribes also may have occasionally inhabited the assessment area (Minor et al., 1987; Toepel et al., 1987). Similar to the earlier Archaic people, the Northern Paiutes generally occupied areas close to waterbodies but also ranged across the arid landscape to hunt and gather food (Cressman, 1981). Native American population estimates are not available, but they were likely sparsely dispersed in small transient groups (Minor et al., 1987; Toepel et al., 1987). The Northern Paiutes, like earlier inhabitants of the region, were semi-nomadic, and Buckley (1992) hypothesizes that human impacts on the natural environment were minimal, excepting perhaps impacts from human ignited fires.

The Northern Paiutes utilized "the resources available during different seasons of the year in order to survive" (Minor et al, 1987), including hunting, gathering of plant foods (berries, roots and seeds), fishing, and gathering of freshwater shellfish. Many Northern Paiute tribes were identified according to the primary food resources upon which they subsisted (Minor et al., 1987; Buckley, 1992). For example, Minor et al. (1987) and Buckley (1992) suggest, that "the Crooked River area was probably utilized by the Juniper-Deer Eaters or Wa'dihichi'tika." Other Northern Paiute bands that may have also utilized resources in the Crooked River Watershed are the Hu'nipwi'tika, or root eaters, and the Wada'tika, or Wada eaters. (Minor et al., 1987).

Finally, although Buckley (1992) hypothesizes that Native American habitation and utilization of the assessment area had little landscape level impact on the natural environment, there is little research into the effect of Native American fire use on the landscape of the Lower Crooked River watershed. Future studies should assess the possible effect of Native American fire use on landscape level ecological processes using methods such as those described in Barrett and Arno (1982) and Keeley (2002). Understanding the effects of Native American fire use may offer insight on the management of upland forests and range.

## 3.4 EARLY EUROPEAN EXPLORATION

The earliest Euro-American exploration of the region was prompted by the quest for resources. Various nations including Spain, Great Britain, France, Russia and the United States sent expeditions to the Pacific Northwest to map the territory. While the Lewis and Clark expedition surveyed the Columbia River in 1805-1806, explorers did not enter the Crooked River Watershed until later (Minor et al., 1987). The earliest well-recorded Euro-American exploration of the Lower Crooked River Watershed is likely to have taken place in the Winter of 1825 and 1826, although some sources indicate that a detailed map of central Oregon already existed at that time. A party led by Peter Skene Ogden in 1825 explored the Upper Deschutes Basin trapping beaver, and passed through the lower Crooked River valley on their way to the John Day basin.

Expeditions of the Upper Deschutes Basin occurred mainly between 1825 and the late 1850s, and included those of fur companies and military parties led by Peter Skene Ogden, John C. Fremont, Robert Williamson and Henry Abbot (USDI BLM, 2001). During the early 1800's, beaver pelts were a major commodity and trapping expeditions ranged across the North American continent. Fur companies and trapping parties nearly eliminated the beaver population from the Crooked River valley by the time Euro-American settlers arrived. A review of harvest data from these and other explorations may provide interesting insight into the faunal density, specifically beaver, historically present in the assessment area.

## 3.5 EUROPEAN SETTLEMENT AND LAND USE

Hostilities between Euro-American settlers and native populations, the arid climate, and difficult access to the region discouraged initial European settlement (Minor et al., 1987; Buckley, 1992; USDI BLM, 2001). The Crooked River was named on official maps in 1832 and 1833, and the earliest settlers arrived in the area in the 1840's but did not stay long, moving on to the more fertile Willamette Valley (USDI BLM, 2001). Significant numbers of European settlers began to arrive in central Oregon in the 1860's and into the 1870's. In 1868, 26 families were settled on Mill, Ochoco, and McKay Creeks (Crook County Historical Society, 1994). The first major settlements occurred in the 1870's and were located in Prineville and the Lower Ochoco's. Early demographic information indicates that the population of Prineville between 1890 and 1900 was around 450 (Crook County Historical Society, 1994). Other residents were scattered throughout the assessment area on rural ranches, farms, and homesteads.

A number of federal acts passed in the late 1800's and early 1900's promoted settlement of central Oregon These included: the Homestead Act of 1862, which granted 160 acres per homestead; in 1866, public lands were given to the State of Oregon for construction of a military wagon road (the Paulina Highway); the Desert Land Act of 1877 granted land to those who would attempt to irrigate arid lands in the region; in 1904 the Homestead Act acreage increased to 320 acres for non-irrigable lands; and in 1916 the Homestead Act acreage increased to 1640 acres for non-irrigable land (Ontko, 1992; Crook County Historical Society, 1994; CRWC, 2002).

### 3.5.1 Livestock

Early explorers noted the abundance of lush valley grasses, calling the Crooked River basin a heaven for stock (Minor et al., 1987; Buckley, 1992; USDA USFS, 1994a; USDI BLM, 2001). From the time of European settlement in 1870s through the 1930's, livestock grazing was the major land use throughout the entire basin. The first settlements in the assessment area were largely based on livestock ranching. Initially, grazing was dominated by cattle, but sheep also were grazed beginning in the 1880s.

By the turn of the century the high numbers of sheep, cows, and horses were depleting the grasslands. Buckley (1992) indicates that prior to 1885, floodplains were dominated by bunchgrass, wild rye, and sedges, and that streams were perennial and not incised. After 1903, floodplains were dominated by sagebrush and the stream channels were described as trenched. This intense period of channel incision is believed to have been caused by the interaction between high grazing pressure, climate (drought followed by intense summer storms), and the loss of beaver (Buckley, 1992; USDA USFS, 1998b; Elmore and Beschta, 2005).

Range degradation required ranchers to begin growing hay for feed and increased the competition for rangeland forage. From 1890- 1905, in what were known as the range wars, 8,000-10,000 sheep and numerous men were killed, as cattle ranchers fought to establish control of the range (Steber, 1989; CRWC, 2002). No grazing regulations existed prior to the passage of the Taylor Grazing Act of 1934.

### 3.5.2 Irrigated Agriculture

Irrigated agriculture burgeoned after the turn of the 20th century. By 1912 diversion of water was so extensive that the riverbed of the mainstem Lower Crooked River, near river mile 35 where no springs provide water, was frequently dry. The Ochoco Irrigation District was established in 1918, and the Ochoco Dam and Reservoir were constructed in 1921 to service producers in the Ochoco Valley (Crook County Historical Society, 1994; Moore, 1999). The Bowman Dam on the Crooked River was completed in 1961 to provide flood control and irrigation water to expand the Ochoco Irrigation District.

### 3.5.3 Timber Harvest

Although timber harvesting became a major activity in the mid to late 1900's, early logging did not have landscape-scale impacts on the assessment region. From the period of Euro-American settlement in 1870 through 1910, timber harvesting was limited to small-scale operations for local utilization. Small sawmills were located in the McKay and Ochoco Creek watersheds during this period. The advent of the railroad into central Oregon in 1910 opened the region to a broader commercial market and created a boom in

Figure 3-1. Teamsters watering horses at the People's Irrigation Ditch before making their way up the grade towards Powell Butte (1890). Notice the band of trees (Crooked River) in the middle ground before Barnes Butte. The Crooked River has since been moved and is now adjacent to the People's Irrigation Ditch at this location near the US Highway 126 bridge (photo credit: Lent, 2007).

the timber industry. In 1918 the City of Prineville financed and constructed a railway to connect to the main rail system, but it was not until 1946 that private investment upgraded the rail line sufficiently to haul profitable loads of timber (City of Prineville, 2005a). As a result, although the assessment area had relatively little timber, Prineville became a timber center in the mid to late 1900's with major mills located in the City.

## 3.6 HISTORY OF PRINEVILLE

Prineville is the major population center in the assessment area and has been since the late 1800's. Established in 1868, Prineville is the oldest community in the central Oregon region, and one of the state's first incorporated cities. Prineville was initially incorporated into Wasco County and later into Crook County upon its formation. In 1882, the Legislative Assembly established Prineville as the county seat. The historic Crook County Courthouse has been in continuous use since its construction in 1909 and still stands as the community's dominant landmark. Similar to other towns in the region, Prineville's origins are tied to agriculture and forest products manufacturing.

Prineville was named in honor of the town's first merchant, Barney Prine. Barney Prine settled on the banks of Crooked River, where he built a blacksmith shop and a store-saloon. Prineville was the first and, for many years, the only town in the 10,000 square mile area, bounded by The Dalles to the north, Linkville (Klamath Falls) to the South, Eugene to the west and Canyon City to the east. Before 1902, when the first high school was organized, anyone wanting an education beyond the 8th grade had to go to The Dalles or Eugene.

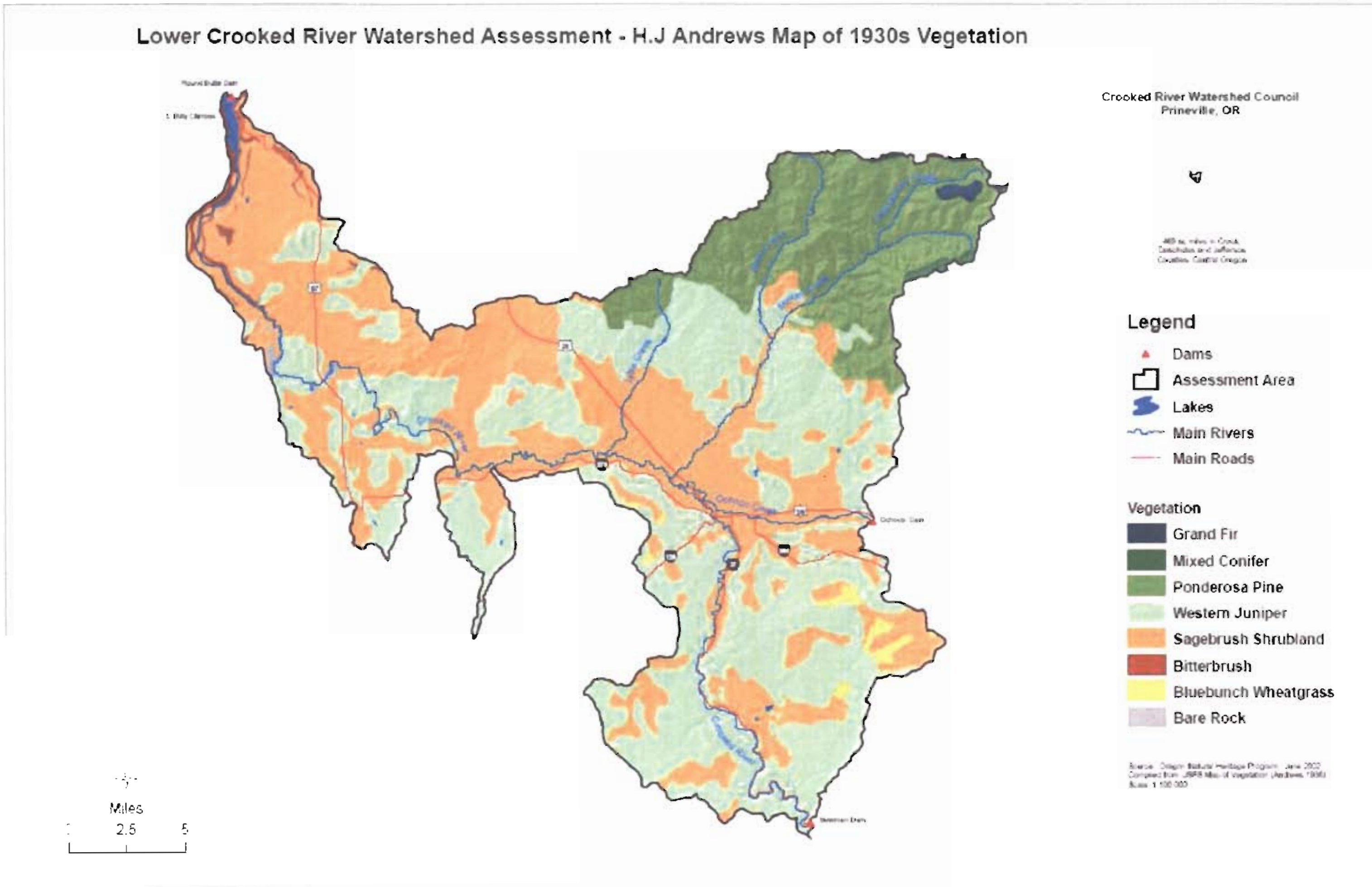
In March of 1877, Monroe Hodges rode horseback to The Dalles to file the first plat of Prineville. Prineville maintained its place as the trade center of central Oregon until 1911, when the Union Pacific and Oregon Trunk Railways were extended south from the Columbia River to the City of Bend. In 1917, recognizing that Prineville would fade unless adequate transportation was available, the citizens of the city voted to build their own railroad to join the new railway just north of Redmond. Through years of low revenues and high costs, the City operated the railway. However, in the late 1930s and early 1940s, the timber industry began to commercially utilize Ponderosa Pine from the Ochoco Mountains. This lumber was shipped over the City of Prineville Railway, resulting in the title of, "The Largest Ponderosa Pine Shipping Center in the World." The railway became an asset to the city and gained distinction by being the only city-owned and operated railroad in the U.S. (City of Prineville Draft Comprehensive Plan, 2005).

## 3.7 HISTORIC RESOURCE CONDITIONS

### 3.7.1 Vegetation

Vegetative structure and species composition in the assessment area have changed substantially since Euro-American explorers and settlers first arrived in the Crooked River country. Both forest and rangeland ecosystems in the assessment area were characterized by an open canopy stand condition (USDA USFS, 1994a; Anderson et al., 1998; Watershed Professionals Network, 1999). The distribution and density of western juniper was primarily restricted to the rocky outcrops and shallow soiled sites that were vegetatively unproductive and therefore more naturally resistant to fire. Subsequent juniper expansion is attributed to a number of factors including change in climatic patterns at the end of the 19th Century, grazing by domestic livestock, and fire suppression (Miller et al. 2005). In general, the western edge of the watershed (in the Mazama Ecological Province) had more juniper historically than the remainder of the basin. Early journals commonly note the valleys full of waist high grasses and the year round abundance of forage for livestock (Minor et al., 1987; Buckley, 1992; USDA USFS, 1994a). Willows and other hardwoods, sedges, and grasses dominated the vegetative regime around Prineville. One early Prineville homesteader noted that, "this was, certainly, as fine a country then as a stock man could wish to see. The hills were clothed with a mat of bunch grass that seemed inexhaustible. It appeared a veritable paradise for stock" (George Barnes, Prineville rancher, 1887). Early maps from the 1870s identify McKay Creek as Cottonwood Creek (Bowman Museum Map Collection), presumably for the widely distributed cottonwood galleries that existed along the creek at that time.

Forested areas in the Ochoco Mountains were covered by open Ponderosa Pine stands characterized by a low density of large trees; western larch was also more widely distributed than today (USDA USFS, 1994a). The riparian and floodplain areas of the watershed had significantly more woody vegetation than is currently present (Buckley, 1992). Willows and cottonwoods were the primary riparian species (Ochoco means willow in Paiute), but other common species included aspen, alder, chokecherry, hawthorn, and dogwood (Kovalchik, 1987; Buckley, 1992). Wetland vegetation was also more prevalent due to regular flooding, sinous side channels, and extensive beaver dams and activity (Buckley, 1992; David, 2005). Floodplains were dominated by sedges, bunchgrass, and wild rye with very little juniper or sage components prior to the 1900s (CCHS, 1994; USDA USFS, 1998b; CRWC, 2002). However, by the 1930s survey crews from the US Forest Service mapping vegetation in Oregon and Washington identified sagebrush shrubland and western juniper as the dominate vegetation in the uncultivated areas of the assessment area (Map 3-1).




**Map 3 -1. H.J. Andrews Map of 1930s Vegetation.**

### 3.7.2 Stream and River Systems

In general, there were more springs and perennial watercourses in the basin historically. Some waterbodies that are currently intermittent were perennial. Others waterbodies, such as the Crooked River, that ran dry in the late summer during low precipitation years in the beginning of the 20th Century; currently maintain continuous summer flows as the result of water storage from dams. Riparian communities were historically more extensive, including sedges, grasses, and woody shrubs and trees (Figure 3-2). Stream channels were well connected to broad valley bottom floodplains (Buckley, 1992; Elmore and Beschta, 2005). Furthermore, before being trapped out, beaver populations likely contributed significantly to the hydrologic regime by damming water during high flow events and slowly releasing water throughout the remainder of the year.

The Crooked River as well as other waterbodies flooded nearly annually (Figure 3-3), with meandering channels that occasionally occupied the entire valley floor. Flood control efforts began in early 1900s by moving the Crooked River from its historic location to a new channel (i.e., the current channel) at the base of the rimrock to the west of Prineville (Figure 3-3). Extensive flood control efforts, especially in the 1960s,

Figure 3-2. Lower Crooked River looking downstream towards O'Neil (Russel, 1905).

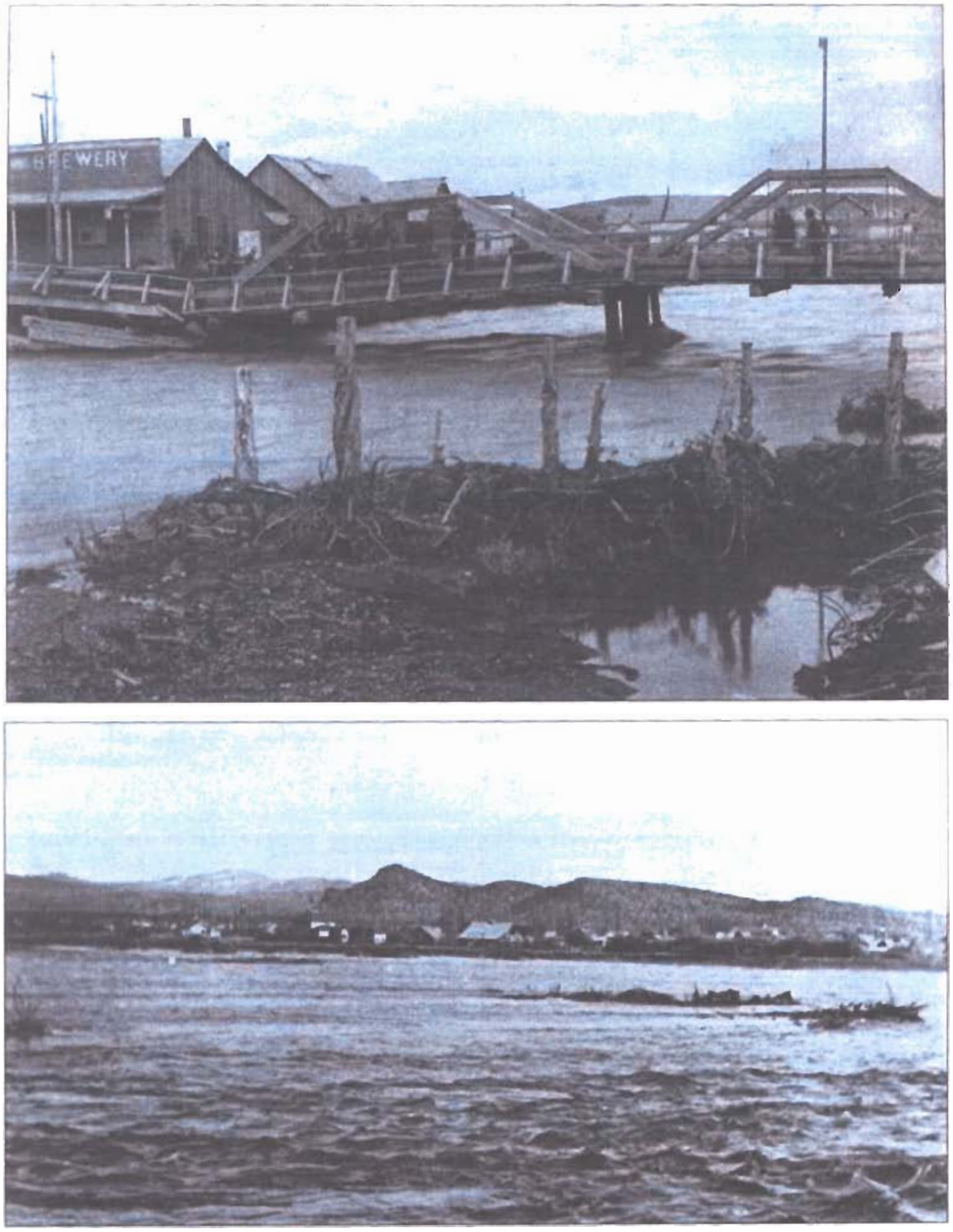



Figure 3-3. Flooding occurred nearly annually prior to the construction of dams on Ochoco Creek (top) and the Crooked River (bottom; photo credits: Lent, 2007).

straightened channels, diked channel corridors, disconnected channels from their floodplains, and eliminated wetlands flood prone areas.

### 3.7.3 Natural Disturbance Patterns

Regular flooding promoted the establishment of wetlands, native grasses, and the movement of sediment through the hydrologic system. In the uplands, fire occurred frequently and with low intensity through grass and open forest stands. Fire was a critical process in the ecological dynamics of the assessment area; it helped to constrain the expansion of western juniper and facilitated the spread and regeneration of native grass and shrub species therefore allowing water infiltration and reducing overland flow and peak stream flows (USDI BLM, 2001).

### 3.7.4 Beaver

The historical significance of beaver to the landscape of the assessment area was considerable. Beavers are a keystone species whose presence regulates ecological processes (Naiman et al., 1986; Yuskavitch, 2002; David, 2005). The presence of beaver impacts water quality and quantity; sediment transport, deposition, and production; wetland processes; vegetation; and fish habitat (Munther, 1983; Olson and Hubert, 1994; David, 2005).

Beaver build and maintain elaborate dam structures that alter the hydrologic regime. The structures and the alteration in flow attenuate peak flows, reduce hydraulic energy on stream banks, retain water in wetlands and wet meadows, create pools and ponds, increase groundwater recharge, maintain and raise the water table, increase water available for discharge during dry periods, create both terrestrial and aquatic habitat that increases fish and wildlife populations, and the build of the soil profile through sediment deposition (Elmore and Beschta, 2005). Furthermore, the creation of wetlands and ponds allows for the filtering of suspended solids and minerals which improves water quality. Beaver were largely extirpated from central Oregon before Euro-American settlement began in earnest. And although beaver populations have rebounded or recolonized extirpated areas, the extent of change to the hydrologic system due to the change in beaver populations is not known.

### 3.7.5 Fish

There are numerous references in the historical record to fish species, populations, and distributions within the assessment area. Steelhead trout, chinook salmon, bull trout, and redband trout were all present historically (Nehlsen, 1995; ODFW, 1996). Native American ethnographies cite the presence of salmon, steelhead, trout, and freshwater shellfish in the assessment area (USDI BLM, 2001). The first scientific fish presence surveys were undertaken by the Oregon State Game Commission in the 1950's. The 1952-54 surveys located steelhead up to 120 miles from the mouth of the Crooked River, above the assessment area (Nehlsen, 1995; ODFW, 1996). Historical accounts indicate that most historical spawning and rearing of salmon and steelhead in the Upper Deschutes Basin occurred in the main tributaries – Crooked River, Wychus Creek, and the Metolius River. In 1826, Peter Skene Ogden noted the presence of a Native American fish weir at the confluence of the North Fork Crooked River and the mainstem (CRWC, 2002). The Ochoco Creek watershed was noted in journals for good salmon and trout populations.

## *3.8 GENERAL LAND OFFICE SURVEYS*

The General Land Office (GLO) conducted detailed land surveys throughout the United States as settlers spread across the country. The assessment area was surveyed between 1869 and 1883. GLO surveys were organized by township ranges, which measure 36 miles square, within which 36 square mile sections are delineated (Map 3-2). The GLO surveys include general descriptions of the land and natural resources within each township range (Table 3-2). For example, the general description for T14S R15E (including Prineville in the southeastern corner) contains the following statements,

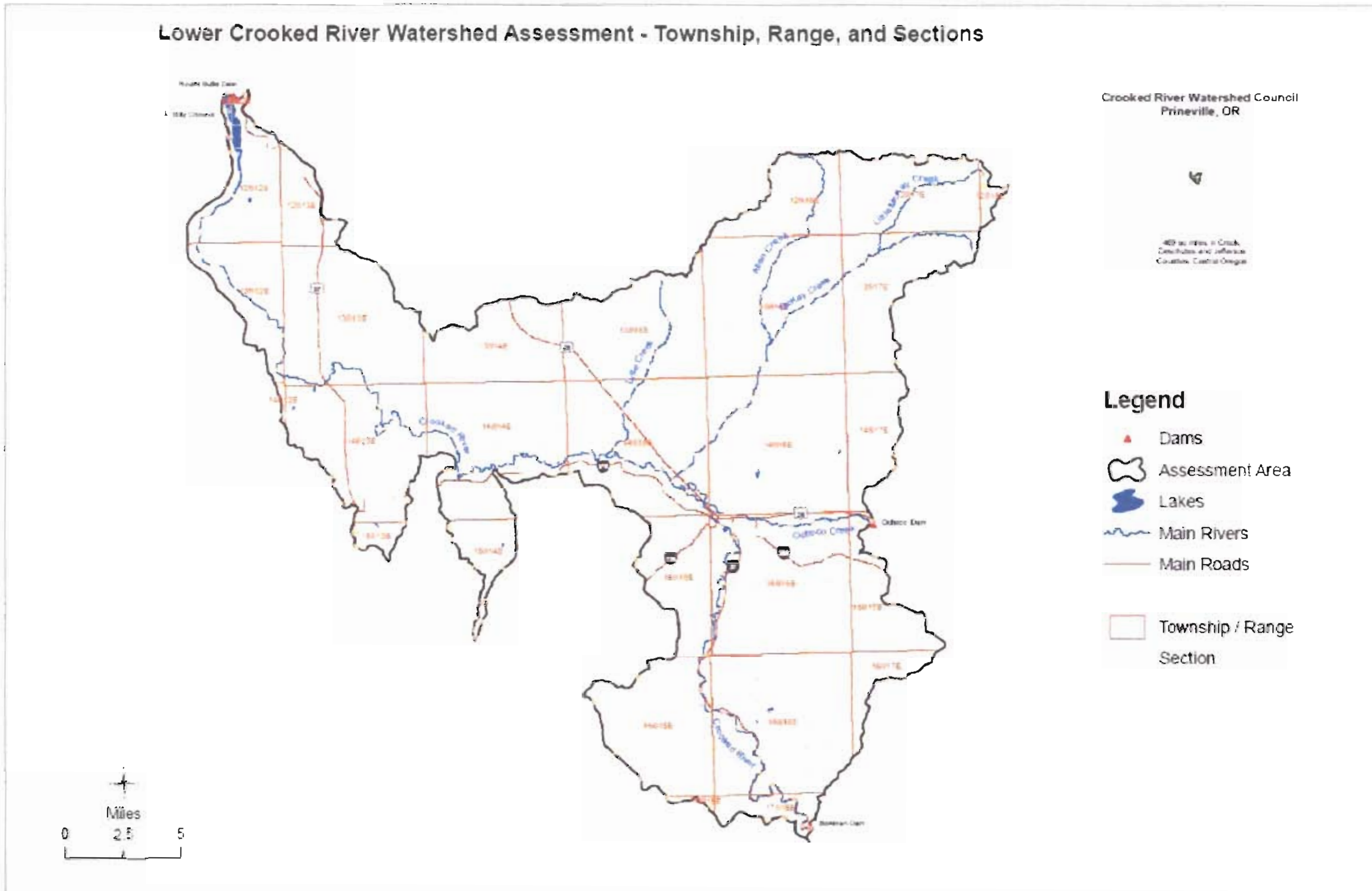
> "The greater part of this township is hilly and the soil is generally good 2nd rate and produces an abundance of good bunchgrass. The land is well watered by springs and small creeks which after running a short distance on the surface sink into the ground again. There is good pine timber in the southern and northeastern parts of the township and juniper in the southeastern part. In the northern part there are several settlers" (Surveyor J.W. Meldrum, August 30, 1872).

The data from these surveys provides a systematic examination of the natural conditions that existed around the time of Euro-American settlement. The data provides a coarse scale baseline for evaluating current conditions.

The surveys indicate that much of the assessment area was dominated by the growth of bunchgrasses and was well suited for grazing purposes. Today, the assessment area continues to support livestock, although forage production requires irrigation due to a combination of ecological changes and land tenure patterns. Many of the township range descriptions also indicate that the assessment area was well watered with creeks and springs. This observation is notable given that the surveys were generally conducted during the summer and early fall. Presently, except in a particularly wet year, much of the assessment area is dry in the late summer and into the fall.

### 3.9 Summary

The assessment area has been inhabited for the past 10,000 years. The Northern Paiute Indians were the most prominent inhabitants for the last 1,000 years, and likely shared the area with other tribes small bands that seasonally occupied specific areas. Most research hypothesizes that tribal inhabitants had little impact on the resources of the assessment area, but little empirical research has looked specifically at Native American fire use. Historically the landscape was well watered with springs, seeps, and creeks. Juniper existed primarily on rock outcrops and shallow soils where fire wasn't easily carried. Productive soils in bottom lands produced an abundance of bunchgrasses and riparian forest cover. European exploration began in 1825 with Peter Skene Ogden's party passing through the Crooked River country. Euro-American settlement began in earnest in the late 1860's with settlement in the Mill Creek area above the Ochoco Dam; Prineville, at the confluence of Ochoco Creek and the Crooked River, was established in the 1870s. Early inhabitants were drawn to the region for agriculture, livestock production, and later for timber resources. In the years following Euro-American settlement resource conditions generally degraded. Furbearers such as beaver were largely removed from the area. Today many streams have lost the riparian vegetation that characterized their pre-settlement conditions; rangelands have been invaded by juniper and forestlands tend to have higher than historical tree densities. The change in vegetation patterns has generally led to lower water tables, downcut stream channels, increased run-off as opposed to water storage. These issues and their impacts on hydrology, water quality, and fish habitat are the subject of the remainder of this assessment.




**Map 3-2 – Township, Range, and Section Map of the Assessment Area**

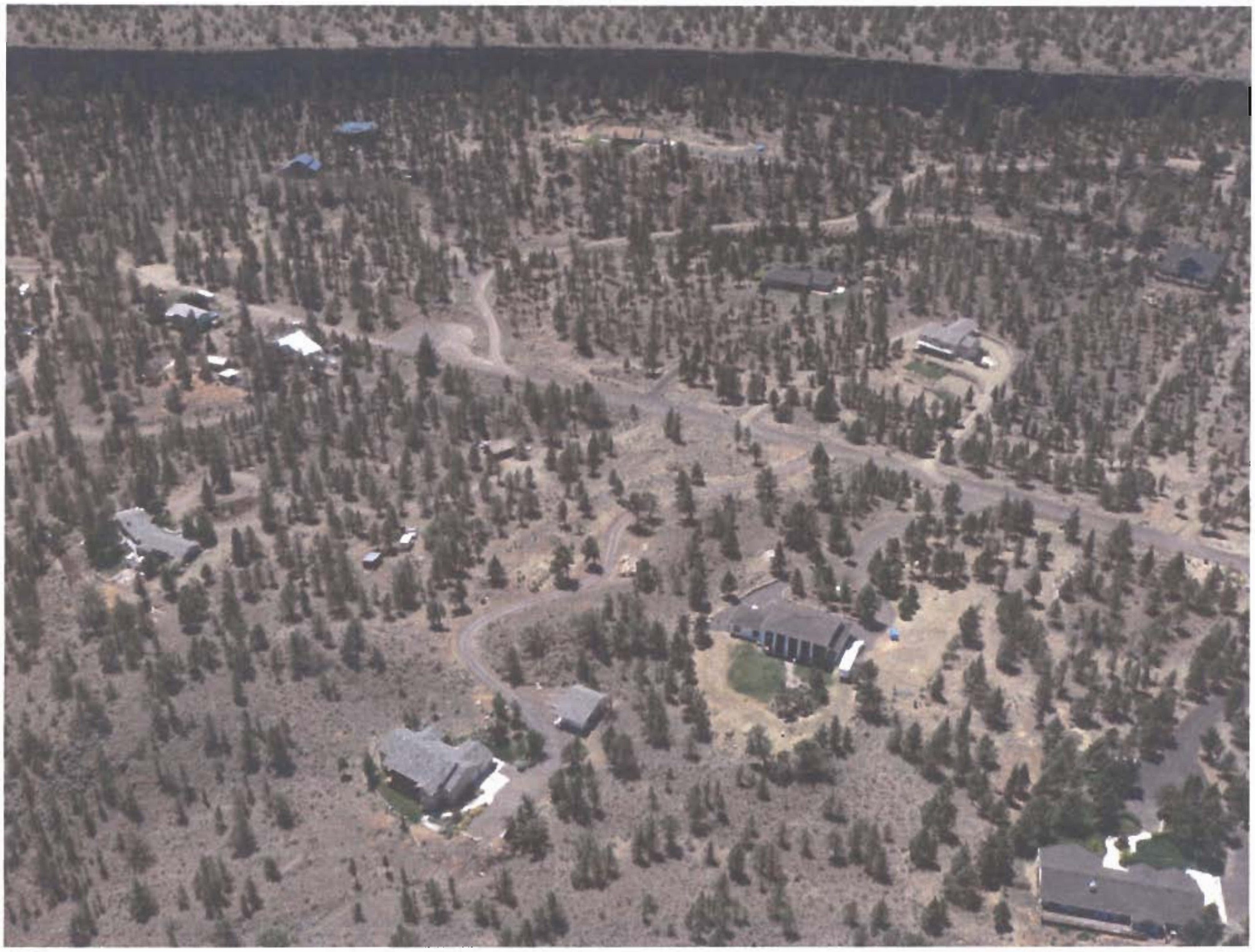
Table 3-1. GLO Survey: Township Range General Descriptions

| General Description | TR | General Descriptions | | | | Surveyor | Date |
|---|---|---|---|---|---|---|---|
| | | Soils | Water | Vegetation | Timber | | |
| LCR | T12S R12E | Sandy/Rich | Deschutes/Crooked Rivers | Bunchgrass | Juniper/Pine | Samual Lackland | 10/16/1883 |
| LCR | T13S R12E | 3rd rate | Crooked River | Grazing | None mentioned | Samual Lackland | 5/18/1883 |
| LCR Valley | T12S R13E | Good but not 1st Rate | None Mentioned | Good Grass | Scattered Juniper | J. W. Meldrum | 8/31/1870 |
| LCR Valley | T13S R13E | None mentioned | Crooked River/Springs | Grazing | Scattered Juniper | J. W. Meldrum | 8/17/1872 |
| LCR Valley | T14S R13E | None mentioned | None Mentioned | Prairie | Scattered Juniper | J. W. Meldrum | 8/12/1872 |
| LCR Valley | T13S R14E | 2nd Rate | Numerous Springs in West | Bunchgrass | Scattered Juniper | J. W. Meldrum | 8/23/1872 |
| LCR Valley | T14S R14E | 2nd Rate | None Mentioned | Good Grass | Scattered Juniper | McClung & Meldrum | 9/7/1869 |
| Allen Creek | T13S R15E | Good 2nd Rate | Springs and Small Creeks | Good Bunchgrass | Good Pine & Juniper | J. W. Meldrum | 8/30/1872 |
| Allen McKay & Crooked | T14S R15E | None mentioned | None Mentioned | Good Grass | Scattered Juniper | McClung & Meldrum | 8/27/1869 |
| Crooked River Upper Section | T15S R15E | 2nd Rate | Numerous Springs in South | Bunchgrass | Scattered Juniper | McClung & Meldrum | 8/8/1869 |
| CR US | T16S R15E | 2nd Rate | Crooked River | Good Bunchgrass | Juniper/Pine | Meldrum, Moore & Campbell | 5/16/1880 |
| Allen Creek | T12S R16E | 1st and 2nd Rate | Well Watered | Grazing | Pine, Fir & Tamarack | Gesner and Meldrum | 9/10/1870 |
| Allen & McKay Creeks | T13S R16E | 2nd Rate & 1st Rate | Springs and Small Creeks | Grazing | Pine and Fir | J. W. Meldrum | 9/21/1870 |
| McKay Creek | T14S R16E | 2nd Rate | McKay Creek | Agriculture | Some Juniper | McClung & Meldrum | 8/17/1869 |
| CR US | T15S R16E | None mentioned | Ochoco and Crooked | Bunchgrass | Juniper | McClung & Meldrum | 7/28/1869 |

**Table 3-1. GLO Survey: Township Range General Descriptions (Continued)**

| General Description | TR | General Descriptions | | | | Surveyor | Date |
|---|---|---|---|---|---|---|---|
| | | Soils | Water | Vegetation | Timber | | |
| CR US | T16S R16E | 2nd Rate | Crooked River | Bunchgrass | Scattered Juniper | Alonzo Gesner | 6/30/1877 |
| CR US | T17S R16E | 3rd Rate | Crooked River & Bear Creek | Bunchgrass | Scattered Juniper | Alonzo Gesner | 6/23/1877 |
| Little McKay Creek | T12S R17E | None mentioned | Abundant Water | Abundant Grass | Pine, Fir & Tamarack | Gesner and Meldrum | 8/25/1877 |
| McKay Creek | T13S R17E | None mentioned | Many Small Creeks | Abundant Grass | Pine, Fir and Larch | J. W. Meldrum | 8/31/1880 |
| McKay/Ochoco Creeks | T14S R17E | 1st Rate | Creeks and Springs | Good Grass | Pine and Juniper | McClung & Meldrum | 7/9/1869 |
| Ochoco Creek | T15S R17E | Bottom Land Good Soil | Not Very Well Watered | Bunchgrass | Pine in South | McClung & Meldrum | 7/20/1869 |
| CR US | T16S R17E | Excellent Soil | Well Watered | Good Bunchgrass | Plenty of Timber | Alonzo Gesner | 4/19/1877 |
| Little McKay Creek | T12S R18E | None mentioned | Well Watered | Not Mentioned | Pine, Fir & Tamarack | D.P. Thmpson | 10/14/1870 |

# Chapter 4 – Uplands



*Western juniper and rural residential development above the O'Neil Highway (Photo Credit: Max Nielsen-Pincus)*

## CRITICAL QUESTIONS

- How is the expansion of western juniper impacting uplands?
- What is the extent and impact of noxious weeds and how are they being managed?
- How has fire suppression impacted uplands and how is it being managed?
- What is the road density and how does it impact uplands?
- How is current and planned development impacting uplands?

## KEY FINDINGS

- Historical and current land uses include grazing, crop production, timber harvest and recreation.
- The range of juniper has expanded substantially over approximately the past 150 years.
- The juniper expansion has a number of negative impacts to the local ecosystem including impacts to upland vegetation as well as water and soil resources.
- Noxious weeds are a major issue impacting uplands.
- Fire historically was an important process element in the assessment area.
- Fire suppression is a major factor in expansion of juniper.
- Wildfire planning and protection is a necessary part of human habitation in central Oregon.
- The assessment area is characterized as rural; it also has medium density of road miles per square mile of area.
- Rapid population growth is leading to the development of open upland areas.

## ACTION ITEMS

- Encourage active management of upland forests, western juniper, and noxious weeds.
- Identify opportunities to use prescribed fire on the landscape.
- Educate landowners about best management practices for grazing, forest management, noxious weed control, and fire hazards.

## DATA GAPS AND RESEARCH NEEDS

- Quantification and mapping of landscape change through historical photographs could be used to determine uplands change over time, and the impact of development on forest management and wildlife habitat.

- A geospatial analysis of current upland conditions could offer a spatially explicit evaluation of upland conditions.
- The Crook County Soil Survey is not yet complete, but could improve understanding of potential upland vegetation types, erosion potential, and other soil based information.
- A comprehensive inventory and spatial mapping of noxious weeds in the assesement area could help to strategically develop a noxious weed management program for the assessment area.
- A comprehensive roads inventory including use status, surface type, dimension and condition could assist in quantifying fragmentation, recreational access, fire protection, and the likelihood of development.

## 4.1 INTRODUCTION

For the purposes of this assessment, uplands are defined as the areas within the assessment area that are not defined as waterbodies, or riparian or wetland areas. As a result, uplands make up the majority of the approximately 300,277 acres contained within the assessment area. Upland areas include agricultural, range, forest, urbanized and rural residential land uses. They are wide valleys, narrow drainages, mountains, rimrock buttes, high desert and deep canyon areas.

Upland areas occupy up to 99% of eastern Oregon's rangeland watersheds and are an essential component of any land-management program (Elmore and Beschta, 2005). Understanding upland conditions is critical for the following reasons:

- Uplands make up the majority of the land acreage, while riparian and wetland areas generally represent a much smaller total acreage.
- Water that falls as precipitation moves across or infiltrates from upland areas before it enters surface and ground water systems.
- Upland areas are frequently used and/or managed by humans and these activities have an impact on the ecological conditions throughout the watershed. Upland conditions and management affect the number of sediment sources within a watershed, water quality, and the quality of fish and wildlife habitat.

According to the Oregon Watershed Enhancement Board's (OWEB) *Oregon Watershed Assessment Manual* (Watershed Professionals Network, 1999), upland vegetation has several effects on a watershed. Vegetative composition and density can reduce or prevent soil erosion. Leaves and branches intercept the falling rain and reduce the effect of raindrop splash. Vegetative litter from dead leaves and branches builds up an organic surface that provides protection of the soil layer. Root systems help to keep soil material from moving downslope. When landslides do occur, they often bring large wood into the channels, which has an important influence on channel condition and fish habitat. In eastern Oregon, upland vegetation may change the process of snow accumulation and melt, potentially changing the timing and amount of runoff in the late spring and summer (Watershed Professionals Network, 1999). The Natural Resources Conservation Service (NRCS, 2000) sums up the importance of uplands as follows: with a protective cover of grass, shrubs or trees consistent with site capability, uplands will capture, store and safely release precipitation thereby reducing the potential for excessive soil erosion or pollution in spring and augmenting the volume of late season stream flows.

This section discusses how upland conditions have changed since European settlement, and how modern land uses have impacted upland conditions within the assessment area. Specifically, the following five upland issues are addressed:

1. The expansion of Western Juniper
2. Noxious weed management
3. Fire hazard management
4. Road density within the assessment area
5. Rapid population growth and development

These five issues create watershed-scale impacts and are of particular concern to local stakeholders. Given the broad scale nature of the assessment, these issues are discussed in general terms that represent the upland conditions in much of the Lower Crooked River Watershed.

## 4.2 UPLAND CONDITIONS

The examination of uplands within the assessment is largely based on secondary data. Secondary materials address both the general condition of uplands and a number of the five critical upland issues, including juniper, noxious weeds and fire. A GIS analysis utilized State of Oregon zoning data, Crook, Deschutes and Jefferson County roads data and United States Census Bureau census data from the 2000 Census to produce analysis and maps for the assessment.

### 4.2.1 Uplands: Historical Conditions

As discussed in Chapter 3 – Historical Conditions, the assessment area has undergone extensive environmental changes since the time of European exploration and settlement in the mid to late 1800's. The General Land Office (GLO) surveys conducted in the 1800's focused on evaluating the land for settlement and natural resource utilization. The surveys indicate that historically much of the assessment area had a growth of bunchgrass and was well suited for grazing purposes. At the time of European settlement, the watershed was characterized by a more open vegetation regime (USDA FS, 1994a; Anderson et al., 1998; Watershed Professionals Network, 1999). Early journals commonly note the valleys full of waist-high grasses and the year round abundance of forage for livestock (Minor et al., 1987; Buckley, 1992; USDA FS, 1994a). Sagebrush was also part of the vegetative mosaic but similar to Western Juniper, it was less prevalent than native grasses and forbs. According to one unpublished report, willows, sedges and grasses dominated the vegetative regime around Prineville (Jim David, USFS soil scientist, personal communication). The GLO surveys also indicate that there was timber in the assessment area that included pine, fir and western larch. Forested areas in the Ochoco Mountains had a higher occurrence of open Ponderosa Pine stands, larger individual tree sizes present in lower densities, and a more widely distributed population of western larch (USDA USFS, 1994a). Finally, the GLO surveys indicate that the assessment area was well watered with creeks and springs. That the GLO surveys recorded an abundance of water is notable because the surveys were generally conducted during what is typically the driest part of the year, late summer and early fall.

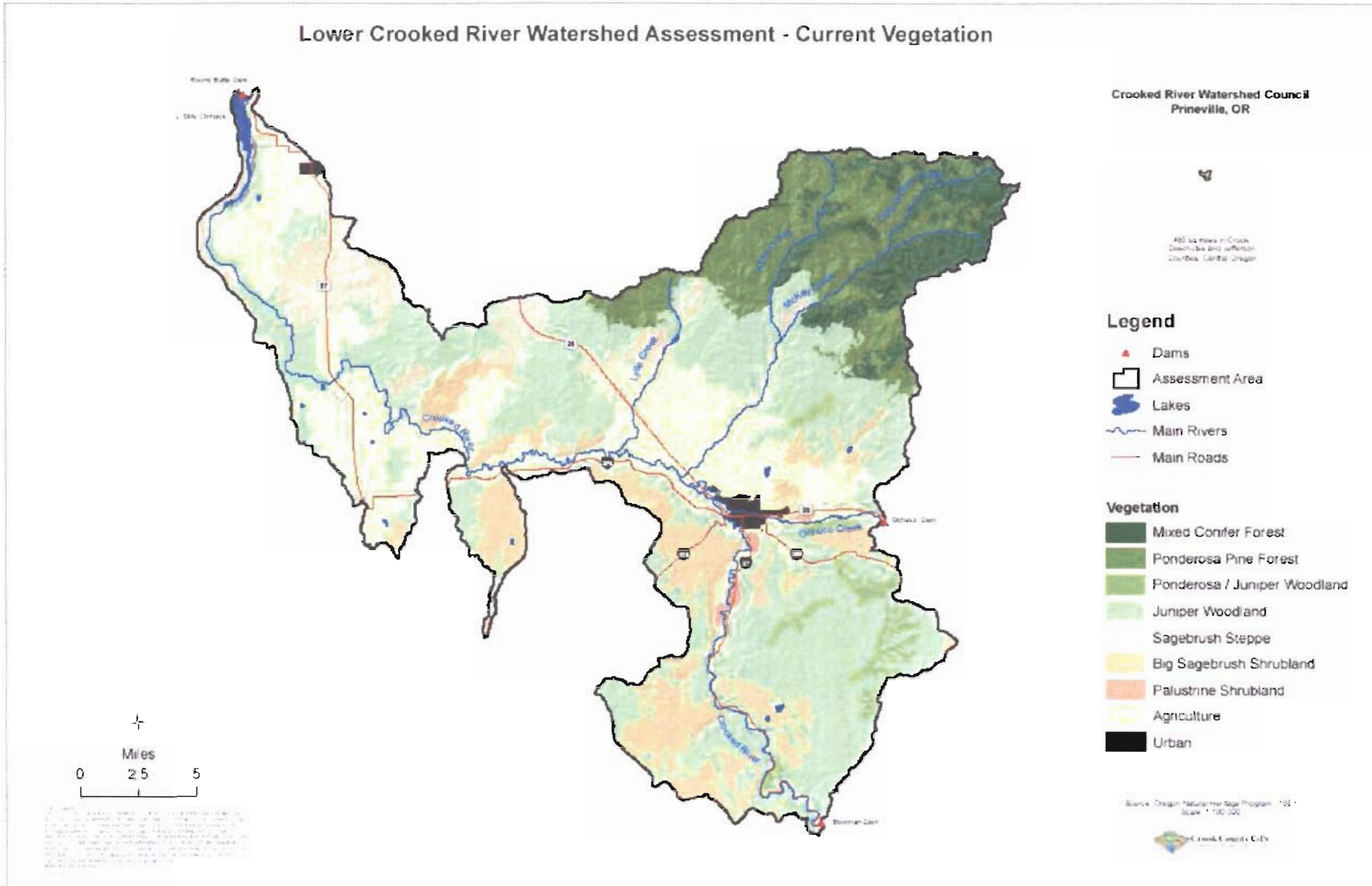
### 4.2.2 Uplands: Current Conditions

Upland conditions within the assessment area have been impacted by human management activities. Agriculture, livestock grazing, logging, road building, fire suppression and urban/residential development have all impacted the health of uplands, and current management practices may be beneficial or detrimental to upland health. Significant changes in the ecological structure of uplands within the assessment area have occurred (Map 4-1). Woody species, especially western juniper (*juniperus occidentalis*), have increased in density and extent on rangelands, which were historically vegetated by other woody shrubs and native grass species. The expansion of western juniper is the result of complex interactions between historic climate change and grazing practices, and nearly a century of fire supression.

Fire suppression has reduced the natural disturbance regime and resulted in forest stands characterized by high densities of small young trees that are less resistant to fire, disease and insect infestations. Logging practices that focused on the removal of the largest trees further aided this transition from low density stands of larger older trees to high density stands of smaller younger trees. Additionally, noxious weeds that out-compete native species are increasingly common in the assessment area. Changes in the vegetative structure and composition in uplands have disrupted wildlife habitat and disturbance patterns. Native habitat is also fragmentated by roads, fencing, residential development, and other intensive land uses.

### 4.2.3 Uplands: Land Use

According to the 1996 Oregon State Zoning designations, land use in the assessment area was: Agriculture, 71% (or 211,959 acres); Forestry, 13% (39,600 acres); Rural Residential, 10% (29,991 acres); Urban, 2% (6,565 acres); Parks and Recreation, 2% (6,469 acres), and approximately 2% (5693 acres) other uses.




**Map 4-1. Ecological communities of the assessment area.**

Agriculture

Agriculture is the dominate land use within the assessment area, and as noted in the *Crooked River Watershed Assessment* (CRWC, 2002), the number of farms in Crook County was on the rise from 415 in 1987 to 521 in 1997. At the same time, the average farm size was decreasing from an average of 2,074 acres in 1987 to 1,759 acres in 1997 (USDA Oregon Agricultural Statistics Service, 1997). These trends have continued; as of 2002 the number of farms had grown to 685, but the average farm size has decreased to 1,369 acres (USDA Oregon Agricultural Statistics Service, 2002).

The general use of farm land shifted from 1997 to 2002. While total harvested cropland did not change substantially (43,745 acres in 1997 and 43,822 acres in 2002), acreage used for pasture increased nearly 50%, from 24,827 in 1997 to 34,614 in 2002. The commodity value of sold livestock in 2002 was $22,758,000, up 28 % from $17,719,000 in 1997. At the same time, the value of crops decreased from $13,170,000 in 1997 to $10,115,000 in 2002. The increase in acreage used for pasture may be a result of the decreasing economic viability of large scale crop production in central Oregon. Instead of producing crops, landowners appear to be more reliant on livestock, grazing leases, and hay crops to make a living. Best grazing management practices will promote and maintain adequate riparian vegetative cover and protect watershed health (Crooked River Local Advisory Committee, 2004).

Forestry

Approximately 47% of the non-juniper forest land in the assessment area is managed by the Ochoco National Forest. Currently, USFS policies restrict logging to harvesting practices that promote the restoration of historical stand structure and species diversity. These practices include selective harvests that target density reductions or alteration of species composition, removal of diseased trees, and salvage operations on burned areas. Forest harvest on both public and private forestland has declined in the last decade over previous decades. A combination of salvage harvests after outbreaks of spruce budworm in the 1980s and 1990s, and increased harvest pressure on private land due to restricted harvests on public lands has left less volume on private lands and a greater proportion of younger stands than historically occurred. Distance from processing infrastructure (mills) and inability to competitively harvest and market in an increasingly global economy has also affected the harvest levels in the watershed. Forest harvest data for Crook County between 1992 and 2003 shows a substantial decline in harvest volume from 105 million board feet (MBF) in 1992, to 1.5 MBF in 2003 (Figure 4-1). Forests in the assessment area are dominated by young stands of densely stocked timber that are at greater risk of stand replacing fire and insect infestation.

Urbanization and Residential Development

The City of Prineville is the major population center and focal point for urban development in the assessment area. The growth and development Central Oregon has experienced in recent years has influenced land use in and around Prineville. Prineville expanded its Urban Growth Boundary (UGB) from 5,375 acres in 1978, to 6,832 acres in 1997, and to 8,598 acres in 2004. The increased urban acreage reflects the City's need to

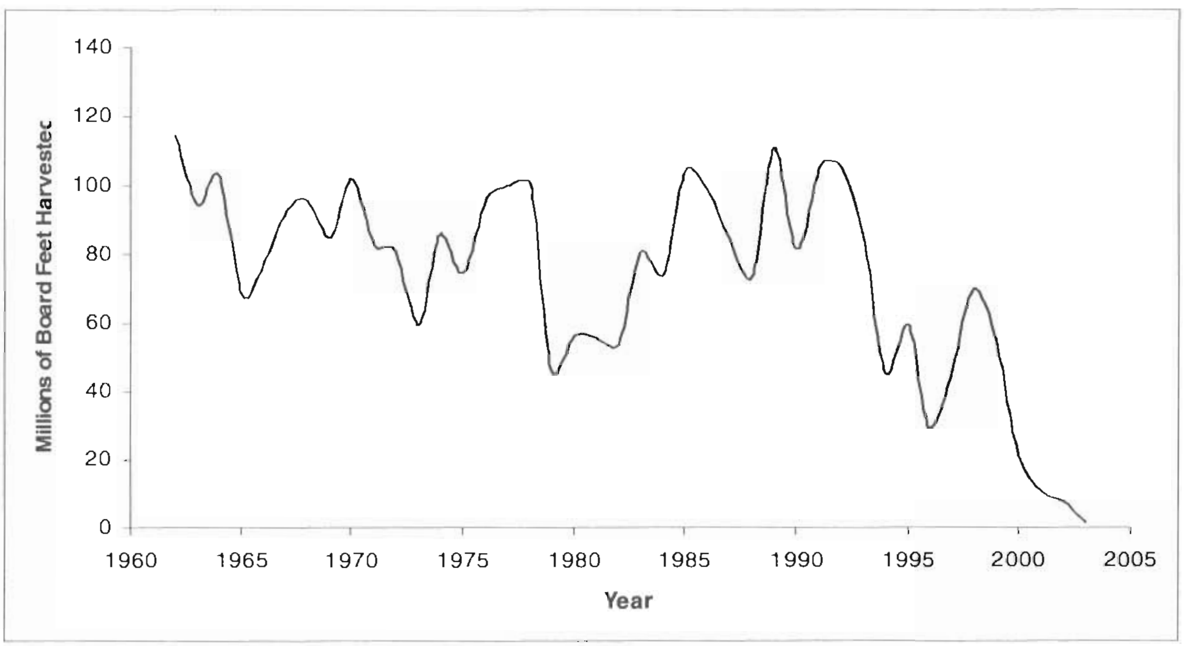



Figure 4-1. Forest harvest volume for Crook County 1962 to 2003 in millions of board feet

expand in order to accommodate the growing population and economic development opportunities. In addition to the growth in the City of Prineville several large scale subdivisions are planned, or have been developed within the assessment area, including Juniper Canyon, Crooked River Ranch, The Canyons Ranch, and Iron Horse development. These developments are notable because they represent a change of land use from agricultural uses to residential and commercial developments. For example, the Brooks Resources Corporation has submitted a concept plan for a development called Iron Horse to the City of Prineville to develop the Hudspeth Ranch property into over 2,000 home sites on small, medium and large lots, and approximately 500 apartment and town home units (The Business Journal: Portland, 2004). To mitigate some of the ecological impacts of development the City of Prineville has building restrictions that include riparian, wetland, and stream setbacks, flood hazard areas, steep slopes, and lot access or configuration. The Ochoco Irrigation District is also looking for opportunities to maintain its district base as agricultural land is converted to residential development.

To compliment development trends, the City of Prineville and Crook County Parks and Recreation are planning or have already set aside numerous areas as open space and zoned agricultural lands adjacent to urban areas to enhance the rural character of the city (City of Prineville Planning Department, 2005a). Planned and developed open space sites within the urban growth boundaries include: Meadow Lakes Golf Course, Ochoco Creek Park, Crooked River Park, Pioneer Park, Ochoco Wayside/Viewpoint State Park, Barnes Butte, Crooked River Rimrocks, Hudspeth Lake, the Crooked River and Ochoco Creek Greenways, and natural wetlands along Crooked River, Ochoco Creek, and Hudspeth Lake (Crook County, 1993; Prineville Planning Department, 1997; CRWC, 2002). The City of Prineville also has designated wildlife habitat, including the riparian and in-stream habitats of Ochoco Creek and the Crooked River. There are Bald Eagle and Golden Eagle nest sites located within or in close proximity to the greater Prineville area UGB. In addition to conserving open space and designating wildlife habitat, the City developed a local wetlands inventory, which indicates that wetlands are primarily located along the Crooked River, Ochoco Creek, and Hudspeth Lake and its drainage (David Evans and Associates 1994).

Recreation

Recreational land uses are also designated within the assessment area. Recreation areas include portions of the Ochoco National Forest and Crooked River Grasslands, Smith Rock State Park and the upper and lower canyons of the Crooked River that are designated Wild and Scenic. Recreational uses include hunting, fishing, hiking, horseback riding, camping, climbing, kayaking (and other boating), mountain biking, cross country skiing and off road vehicles (including snowmobiles). Of these recreational uses, hunting and fishing bring large numbers of people to the area on a seasonal basis. These users contribute substantially to the local economy. One notable recreational activity that has led to substantial impact in the assessment area is off-road vehicle usage. Increased off-road vehicle use has created substantial negative impacts to riparian habitat and hydrologic function especially on the Ochoco National Forest portion of the McKay Creek subwatershed. Impacts include increased erosion and sediment production, damage to wet meadows and riparian communities, soil compaction, and degraded non-motorized recreational trails and areas (CRWC, 2005). Impacts to streams, riparian area, and informational signs were so severe that the Ochoco National Forest imposed a sixth month emergency travel closure throughout much of the McKay Creek drainage in 2006 and 2007.

## 4.3 MAJOR UPLAND ISSUES

### 4.3.1 Juniper Expansion

The expansion in both range and density of western juniper throughout Washington, Oregon, Idaho, California, and Nevada has been faster during the past 130 years than any at other time period in the Holocene era (Miller et al. 2005). Western juniper forest and savannah now cover approximately 6.5 million acres in eastern Oregon, up from 1.5 million acres since the 1930s (Azuma et al. 2005). In the Deschutes River region, including Wasco, Sherman, Deschutes, Jefferson, and Crook Counties, western juniper forests (>10% canopy cover) expanded from an estimated 314,000 acres in 1936 to 964,000 acres in 1988 (Gedney et al. 1999). In Crook County western juniper forest and savanna now cover 60% of the landscape, up from 27% in 1936 (Azuma et al. 2005).

Azuma et al. (2005) predict the expansion of western juniper to continue as and management and climate trends favorable to juniper are predicted to prevail. The expansion of western juniper into rangelands and from savannas into woodlands has caused adverse impacts to watershed health, fish and wildlife habitat, and fire regime in the assessment area.

*Watershed Impacts*

Western juniper expansion has several important watershed health consequences that can be illustrated from the root system up. The root development of western juniper begins with production of a tap root that can penetrate deeply into soil, and is followed by lateral roots that may downturn towards subsurface moisture while lateral spread continues to occur (Bedell et al. 1993). The expansive root system of western juniper combined with its ability to use water early in the growing season reduces water availability to other plants, which can cause a reduction in perennial grass, forb, and shrub abundance (Adams 1975, Bedell et al. 1993, Gedney et al. 1999), and a shift in species composition towards annual and invasive species adapted to early growth, especially after disturbances like fire (Eddleman et al. 1994).

In addition to out-competing other plants for available soil moisture, the interception of precipitation by the canopy of juniper forests also contributes to the lack of soil moisture availability. In the windy, dry, and sunny climate of central Oregon, moisture held on the surface of a juniper forest canopy tends to be evaporated back into the atmosphere rather than stored in the soil (Young 1984, Bedell et al. 1993).

A decrease in native grass and forb abundance and the increase in shallow rooted annual plants amplify potential for soil erosion. Buckhouse and Gaither (1982) found that under simulated rainstorm events western juniper stands on productive sites in fair conditions produced a mean of 1,746 kg/ha of sediment through overland erosion, while unproductive sites in poor conditions produced a mean of 3,330 kg/ha. These two western juniper community types contributed to more soil erosion than all but one of 26 other vegetative communities in the Blue Mountains in northeastern Oregon, which collectively averaged 251 kg/ha of sediment production (Buckhouse and Gaither 1982).

Finally, due to the extensive use of available water and canopy interception and evaporation of precipitation, the expansion of juniper on the landscape scale has implications for the availability of ground water recharge (Thurow and Hester 1997). The OSU/Crook County Extension service is currently conducting a paired watershed study that uses a comparative case study design to assess the effects of western juniper removal on several measures of surface and subsurface hydrology. Initial observations of vegetative and ground water response to juniper removal indicate improved plant vigor and increased well water availability following juniper removal (Tim Deboodt, OSU/Crook County Extension staff chair, personal communication, March 1, 2007). The impacts to watershed health include decreased soil moisture availability, decreased plant biodiversity, increased abundance of annual and invasive species, increased soil erosion, and potential decreases in surface and subsurface water quantity.

*Fish and Wildlife Habitat Impacts*

Fish and wildlife habitat is also impacted by the expansion of western juniper. Studies of the impacts of juniper on wildlife habitat includes research on the relationship between stand structure and avian diversity, stand structure and avian life cycle, and stand structure and deer and elk winter survival. Avian diversity was reduced by half as juniper stands matured from open canopy stands with understory structure into late seral stands where grass, forb, and shrub components were in decline (Bedell et al. 1993). Research conducted on the Steens Mountain area of southeastern Oregon demonstrated a negative relationship between avian abundance and diversity with juniper density and extent (Schmitz et al. 2003, Noson et al. 2006). Sage grouse (*Centrocercus urophasianus*) populations are in decline due to increases in sagebrush habitat fragmentation much of which is due to encroachment of western juniper on historically rangeland ecosystems (Connelly et al. 2000, Knick et al. 2003). Finally, although mule deer (*Odocoileus hemionus*) winter range is improved by a moderate increase in juniper density due to increased thermal cover, juniper woodland densities decrease available forage offsetting the enhancements to winter range habitat (ODFW 2003, Eddleman et al. 1994, Miller et al. 2000).

*Fire Regime Impacts*

The expansion of western juniper is part of a feedback loop of a changing fire regime. Beginning in the late 1800s fire frequencies in the rangeland habitats of central and eastern Oregon began to decline. This decline is attributed to the introduction of large numbers of livestock, which successfully reduced the fine fuels necessary to carry fire, and to active fire suppression (Miller et al. 2005). The decline in fire occurrence is closely correlated to the expansion of western juniper. A summary of studies conducted on fire return interval in rangeland ecosystems in Oregon, California, Idaho, and Nevada indicates that fire return intervals less than 50 years are adequate to minimize encroachment of juniper into rangeland ecosystems (Miller et al. 2005). Furthermore, the authors found that increased fire return frequencies tended to lead to ecosystems more dominated by grasses rather than woody shrubs. Studies of historic fire regime in the rangelands of central Oregon show that pre-settlement fires tended to occur frequently and with relatively low intensity (Whitman 2001). The expansion of western juniper has increased coarse fuel loads that increase the intensity of fires when they occur. As western juniper density increases and fire return interval decreases a feedback loop reinforces a fire regime that is changed from frequent low-intensity to infrequent high-intensity.

*Management*

Methods to manage the expansion of juniper typically include mechanical (chainsaw and heavy machinery), fire, and chemical treatments. This subject is explored in detail in *Biology, Ecology and Management of Western Juniper* (Oregon State Agricultural Experiment Station, 2005). The removal of juniper is an intensive endeavor and the need for substantial post removal restoration and monitoring of treated areas is critical. Any approach to managing uplands in the assessment area must take into account the need to manage juniper expansion. This realization has caused the formation of the Prineville Juniper Working Group within Crook County (www.coic.org/juniper). This group is actively working to find funding to inventory and manage juniper. Their work includes possible commercial uses for juniper for wood products and as a biomass fuel to generate electricity.

### 4.3.2 Noxious Weeds

Noxious weeds are a threat to native ecosystems, competing with native vegetation and changing forage availability for wildlife and livestock. Noxious weeds negatively impact watershed conditions, often leading to reduced infiltration of precipitation and groundwater recharge, increased overland flow or runoff, erosion, and sediment (Crooked River Local Advisory, 2004; Bunch, 2005). Noxious weeds also have negative economic impacts by devaluing valuable agricultural land. According to a weed control program proposal submitted to Crook County in 1989 by OSU/Crook County staff chair Tim Deboodt, there was a critical need for the County to establish a noxious weed program. The impacts of not having a noxious weed program were described by Mr. Deboodt as unacceptable, including loss of tax dollars, increased cost of agricultural production, and negative impacts on wildlife and recreation (Deboodt, 1989).

Noxious weeds are a long standing issue within the assessment area and the central Oregon region. A County Commissioners journal dated September 6th, 1939 outlines the need for a Crook County Weed control district to deal with the spread of noxious weeds such as Canada thistle, White top, Russian knapweed, Morning glory and Leafy spurge (Deboodt, 1989). Notably, all of the same noxious weeds noted in 1939 are on a priority list of noxious weeds in the recent *Crooked River Agricultural Water Quality Management Plan* (Crooked River Local Advisory Committee, 2004).

There are currently many noxious weeds within Crook County that are a management concern. These noxious weed species have been organized into priority lists by the Crook County Noxious Weed Board (Table 4-1). No noxious weed data exists specifically for the assessment area; however, the majority of the assessment area is within Crook County, and the majority of the Crook County noxious weed species occur in the assessment area (Debbie Bunch, Crooked River Weed Management Area Coordinator, personal communication, April 18, 2007).

In Table 4-1 weeds are listed as either "A", "B" or "C" listed species, depending on their extent in the County and the magnitude of their impact. The "A" list includes weeds that occur in small enough infestations to make eradication or containment possible. Weeds that are actively managed by neighboring counties due to agricultural concerns are also on the "A" list. The "A" list weeds are a high priority for treatment and the management goal for this list is to eradicate or contain populations and prevent "A" listed species from becoming more abundant and moving onto the "B" list. The "B" list weeds are abundant and of great concern because they cause economic and ecological losses. Eradication of "B" listed weeds in the county may not be realistic presently; however, they are still high priority species for strategic treatment and control to prevent further spread. The management goal is to control "B" listed weeds to prevent their spread into new areas. Management strategies should focus on outlying populations to protect native ecosystems, as well as high public use areas. The "C" list weeds are abundant and are not high priority species to control. However, it may be desirable to treat localized populations to prevent their spread into new areas, and/or to protect from economic and ecological losses. The management goal is to treat "C" listed species as incidental and control on a case-by-case basis.

Weed management in the assessment area is conducted by the Crook County Weed District, the Crooked River Weed Management Area (WMA), and private landowners. The District employs a Weed Control Supervisor who works to control noxious weeds along County right-of ways and on private land. The WMA has a board with members representing land owners and other local stakeholders. The WMA board employs a Crooked River Weed Management Area Coordinator who provides technical and financial assistance to local landowners for the inventory, project prioritization, implementation, and monitoring of weed management actions within the Crooked River Watershed. The WMA also fosters and facilitates coordination between land owners and adjacent public lands. The WMA is currently in the process of inventorying and mapping noxious weeds on private lands. When this process is completed it will compliment similar research for public lands collected by the BLM and USFS.

At the state level the Oregon Department of Agriculture (ODA)/Oregon Weed Board (Board) supports a cost share program which is coordinated locally by the WMA. The Board has an appropriation to assist counties in special projects and to help support biological control work. The board and the ODA weed staff confer in setting statewide priorities for funding of projects. The board also develops and maintains the State Noxious Weed List. OSU/Crook County Extension is also a long time supporter of local weed management and provides administrative support and oversight to the WMA and its coordinator.

Table 4-1. Noxious weed species of Crook County by priority listing

| A Listed Species | | B Listed Species | | C Listed Species | |
|---|---|---|---|---|---|
| Jointed goatgrass | *Aegilops cylindricaa* | Whitetop | *Cardaria spp.* | Western waterhemlock | *Cicuta maculate* |
| Musk thistle | *Carduus nutans* | Diffuse knapweed | *Centaurea diffusa* | Bull thistle | *Cirsium vulgare* |
| Yellow starthistle | *Centaurea solsitialis* | Spotted knapweed | *C. maculosa* | Field bindweed | *Convolvulus arvensis* |
| Squarrose knapweed | *C. virgata* | Russian knapweed | *C. repens* | Common teasel | *Dipsacus fullonum* |
| Rush skeletonweed | *Chondrilla juncea* | Canada thistle | *Cirsium arvense* | Kochia | *Kochia scoparia* |
| Wild carrot | *Daucus carota* | Poison hemlock | *Conium maculatum* | Yellow sweetclover | *Melilotus officinalis* |
| Leafy spurge* | *Euphorbia esula* | Common houndstongue | *Cynoglossum officinale* | Bur buttercup | *Ranunculus testiculatus* |
| Perennial pepperweed | *Lepidium latifolium* | Scotch broom | *Cytisus scoparius* | Russian thistle | *Salsola iberica* ( = *S. kali*) |
| Dalmatian toadflax | *Linaria dalmatica* | St. Johnswort | *Hypericum perforatum* | Common mullein | *Verbascum thapsis* |
| Skeletonweed | *Lygodesmia juncea* | Sulfur cinquefoil | *Potentilla recta* | | |
| Purple loosestrife | *Lythrum salicaria* | Common groundsel | *Senecio vulgaris* | | |
| Scotch thistle | *Onopordum acanthium* | Spiny sowthistle | *Sonchus asper* | | |
| African rue | *Peganum harmala* | Medusahead rye | *Taeniatherum caput-medusae* | | |
| Mediterranean sage | *Salvia aethiopis* | Puncturevine | *Tribulus terrestris* | | |
| Tansy ragwort | *Senecio jacobaea* | | | | |

*Crooked River Water Quality Management Plan* (Crooked River Local Advisory Committee, 2004).

*All areas except Mill Creek drainage and within 50 feet of the high water mark on the Crooked River.

At the federal level, the USFS and the BLM manage noxious weeds and invasive species. Current federal laws require agencies to control noxious weeds and prevent the further spread of noxious weeds. Noxious weed control of selected sites is necessary to protect native and desirable plant communities from being invaded by noxious weeds. Management includes mapping, removal and restoration of areas infested with noxious weeds.

### 4.3.3 Fire Regime

A fire regime is a classification of the historical role fire played in a given vegetative type as it relates to the common frequency and intensity that fire would have historically occurred (Morgan et al., 2001). Each vegetative type has adapted and is maintained by a certain disturbance regime. Wildland fires in fire-adapted ecosystems tend to maintain and reinforce the vegetative structure and composition of that ecosystem. Wildland fires that emulate both historic frequency and intensity tend to maintain and enhance the ecological function of that vegetative type. Departure from the historic fire regime, especially in ecological systems that evolved under frequent low to moderate intensity disturbances by fire can be detrimental to the ecological functions of the vegetative type. Wildland fires in fire-adapted ecosystems from which fire has been excluded for a substantial period of time can be detrimental to watershed function due to fire intensity, removal of overstory and ground cover vegetation, exposing or sterilizing bare topsoil, or destroying large downed wood in stream channels.

The frequency of stand-replacing fires varies in Oregon from west to east due to decreases in precipitation, and from north to south because of increasing temperature and occurrence of lightning. Fire regimes are also strongly affected by topography, e.g., south-facing slopes burn more frequently than wide valley floors. Insects and disease also affect the severity of fires. When dry, dead material derived from trees killed by insects or disease accumulate, the risk of fire increases and eventually most areas burn (Watershed Professionals Network, 1999).

Fire is a natural part of the high desert ecosystem of central Oregon and the assessment area. Ecosystems in the assessment area, "particularly those at low and mid elevations, are fire-adapted. [Vegetation] in these areas is dependent on relatively short fire return intervals to remain healthy and sustainable over time" (Crook County Wildfire Protection Plan Committee, 2005, 16). Prior to European settlement, fire was a regular occurrence, probably occurring on a return interval of ranging from 5 to 50 years depending on vegetation type and other site specific factors. Pre-European settlement fires were generally frequent, low intensity surface fires; high intensity stand replacing fires occurred less often (Kauffman and Sapsis, 1989) and were more likely to occur in higher elevation mixed conifer stands. Fire was a keystone disturbance mechanism that affected the Oregon's high desert landscape (Kauffman and Sapsis, 1989). Historically fires were ignited by lightning and native fire use, which Eddleman (1989) and others (e.g., Barret and Arno, 1982, Gruell 1985, Boyd 1999, Vale 2002) theorized was for hunting, to encourage forage for horses, and defense. Native ecosystems adapted over time to develop vegetative structure and composition resistant to the historical fire regime.

American society in the 20th Century generally considered fire a destructive and negative process that damages natural resources, properties, structures, infrastructure, crops, livestock, and human lives. These concerns were grounded in intense fire behavior that occurred in the early 1900s, national media attention, and agency policy. While wildland fire is an important disturbance element in the high desert ecosystem, a century of fire suppression has significantly altered the composition and structure of upland vegetation (Kauffman and Sapsis, 1989). Fire maintained a balance between grass-forb vegetation and woody plants, particularly sagebrush and juniper (Eddleman, 1989). The lack of balance resulting from fire suppression is evident in the spread of juniper throughout central Oregon. Fire suppression and forest management activities have altered this natural fire return interval, creating shifts in forest and range species composition and increases in stand densities and fuels. "This change has increased the susceptibility of the forest to insects, diseases, and [catastrophic] wildfire." (Crook County Community Wildfire Protection Plan Committee, 2005, 16).

Within the assessment area, wildfire hazard planning and management is a collaborative effort between private landowners, city, county, regional, state and federal entities. Local fire hazard management planning is detailed in the *Crook County Wildfire Protection Plan* (Crook County Community Wildfire Protection Plan Committee, 2005).

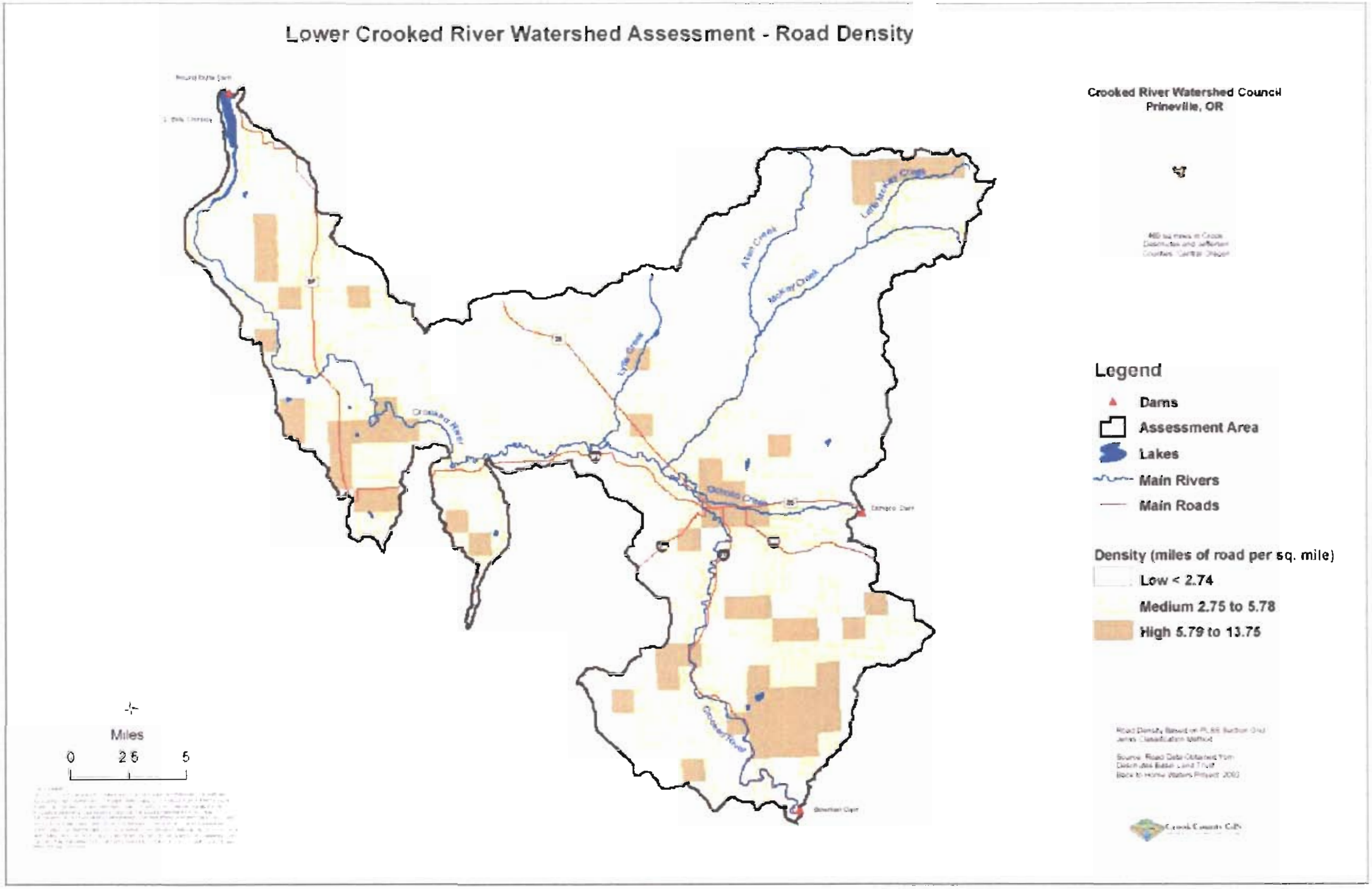
The need to plan for and protect against wildfires has to be balanced with the use of fire to reduce fuel loads and to perpetuate, improve or restore the high desert and forest vegetative communities. One of the primary issues involved in the use of fire for ecosystem management is liability. Federal agencies, such as the USFS and BLM, are insured and have professional staff trained to use fire for management purposes. With over 40% of the assessment in private ownership, there is a need to facilitate the use of fire for management of private land.

### 4.3.4 Roads

The assessment area is a rural area with an extensive network of roads that cross the landscape. Crook County GIS maintains a database of roads in the County, including all county, state, federal, and private roads, but not unofficial roads, trails, or ways. Road density is measured by dividing the miles of road (mi) by square miles of area ($mi^2$). Densities less than 2.74 are low, 2.75 to 5.78 are medium, and 5.79 to 13.75 are high (Deschutes Basin Land Trust, 2003; David Evans & Associates Inc., 2005). The analysis indicates that the assessment area as a whole has a medium road density (Map and Table 4-2). Roads that are not well maintained may create soil erosion, sediment, and water quality problems. Disturbed areas adjacent to roads commonly are infested with weeds.

Table 4-2. Assessment Area Roads Density (Crook County GIS, 2005)

| STUDY AREAS | STUDY AREA ($mi^2$) | ROAD MILES (mi) | ROAD DENSITY ($mi/mi^2$) |
|---|---|---|---|
| CROOKED RIVER LS | 202 | 795 | 3.93 |
| CROOKED RIVER US | 127 | 554 | 4.34 |
| McKAY CREEK | 99 | 259 | 2.61 |
| OCHOCO CREEK | 40 | 161 | 3.99 |
| **TOTAL:** | **469** | **1768** | **3.77** |




Map 4-2. Road Density of the Lower Crooked River Watershed.

### 4.3.5 Uplands: Population Growth and Development

As is the case with much of central Oregon, Crook County, and the assessment area in particular, is experiencing a period of rapid growth. Between April, 2000 and July, 2004, Crook County experienced an 11.7% population increase to 21, 424, making it the second fastest growing county in Oregon. There has been a corresponding growth in residential development within the urban growth boundary (UGB), rural areas, and in portions of the county traditionally occupied by natural vegetation (Crook County Community Wildfire Protection Plan Committee, 2005). In many cases, development impacts uplands by fragmenting natural habitat, introducing pathways for noxious weed invasions, and increasing fire hazard. Developing opportunities to educate new residential landowners and offer technical and financial assistance for best natural resource management practices is important to ensuring that impacts from development are minimized to the extent possible.

# CHAPTER 5 – RIPARIAN AND WETLAND AREAS

*Emergent Wetlands along the Lower Crooked River at Smith Rock State Park (photo credit: N. Nielsen-Pincus).*

## CRITICAL QUESTIONS

1) What is the current composition of riparian vegetation and wetlands in the Lower Crooked River watershed?
2) What is the historical context of the riparian corridor and wetlands?
3) What are the roles of riparian areas and wetlands in watershed health?

## DATA GAPS AND RESEARCH RECOMMENDATIONS

- Historic riparian vegetation and wetland patterns are not empirically well-understood. Interpretation of historical aerial photos should be conducted to understand the trajectory of riparian conditions.
- Quantitative data on survival, growth, and function of riparian planting projects are not available. A long-term riparian restoration monitoring project would provide useful information to landowners and resource managers in the assessment area.
- A full inventory of wetlands and riparian condition within the assessment area would provide a more comprehensive understanding of wetland and riparian conditions.
- An analysis of hydric soils in the recently updated Crook County soil survey would help to identify potential wetland locations.

## KEY FINDINGS

- Aerial photo interpretation indicates that woody shrubs are the dominant riparian vegetation type in the assessment area, followed by pasture and agriculture.
- Hardwood trees are the least abundant dominant riparian vegetation type.
- Potential riparian vegetation for the assessment indicates that hardwood trees such as black cottonwood should be a dominant species in riparian vegetation, and while a few reaches of cottonwood dominated riparian corridor remain, the hardwood tree component of riparian vegetation is starkly missing.
- Wetlands are primarily found in small pockets palustrine wetland or narrow corridors of riverine wetland.

- Wetland creation is occurring in the assessment area through constructed wetlands for stormwater detention and transportation project mitigation.

## ACTION ITEMS

- Identify opportunities with landowners to preserve and enhance riparian corridors and wetlands.
- Identify opportunities with landowners for riparian planting projects that focus on restoration of hardwood trees.
- Continue to coordinate and work with the Crook County Weed Management Program to reduce and eradicate non-native and noxious weeds from riparian areas.
- Engage the National Riparian Service Team to help develop a riparian restoration plan for the Lower Crooked River.
- Educate and inform the public about the ecological and environmental function of riparian corridors and wetlands.
- Assist ODFW, USFS, and BLM in future stream habitat surveys.
- Engage both City and County officials regarding the importance protecting riparian buffers on the Lower Crooked River, Ochoco, and McKay Creeks.
- Collaborate with wetland mitigation sponsors to ensure that watershed benefits are incorporated into constructed wetlands projects.
- Assist in developing a watershed level wetland inventory.

## 5.1 INTRODUCTION

Riparian areas are the vegetative corridors that border waterbodies. Riparian areas are dynamic zones of interaction between terrestrial and aquatic systems (Clarke et al., 2001). This Chapter focuses on the riparian areas of the Lower Crooked River, Ochoco Creek, McKay Creek, Little McKay Creek, Allen Creek, and Lytle Creek.

In recent years, regulations to protect riparian areas have been implemented on federal and forested lands in Oregon; riparian improvements by private agricultural and other landowners has also increased. In the Lower Crooked River Watershed, federal land management agencies have implemented riparian buffer zones and the State of Oregon Forest Practices Act has added riparian protection provisions for private forest operators. These provisions are an attempt to maintain riparian buffer zones where extra protection is required along fish bearing streams. The buffer zones vary in size from 50 to 100 feet depending on stream size. In addition to state and federal guidelines, Crook County established a 100-foot setback for new infrastructure (e.g. buildings, roads) under County jurisdiction, and the City of Prineville established a 50-foot riparian setback building ordinance. Both the County and the City have implemented no-cut zones intended to protect existing riparian vegetation; these no-cut zones are 50 ft within County jurisdiction and 25 ft within the City of Prineville jurisdiction. Actions have been taken to reduce livestock impacts to riparian areas; primary management changes include riparian fencing to exclude livestock coupled with off-site watering, and the creation of riparian pastures with modified grazing schedules (CRWC, 2002).

Riparian areas generally have higher soil moisture than adjacent upland areas giving them potential for distinctive vegetative communities (Watershed Professionals Network, 1999; Clarke et al., 2001). The distinctive vegetative communities can provide vital ecological functions, be the source of valuable natural resources, and enhance property values in both urban and rural settings. More specifically, benefits from riparian areas may include (Elmore and Beschta, 1987; USDA USFS, USDA NRCS & USDI BLM. 1998; Watershed Professionals Network, 1999; Clarke et al., 2001):

- Providing organic matter and terrestrial insects that serve as food for aquatic life;
- Contributing large wood that creates fish habitat and hydraulic complexity;
- Creating vegetation canopy to provide hiding areas for fish and shade to help moderate water temperatures;
- Providing woody inputs that promote channel and habitat diversity;
- Attenuating flood hazards by absorbing, slowing, and dissipating flood energy;
- Acting as a sediment trap;
- Reducing bank erosion by increasing bank stability through vegetation root strength;

- Filtering natural and man made polluted run-off, particularly from nonpoint sources;
- Providing critical wildlife habitat;
- Increasing groundwater recharge and the slow release of water during dry periods;
- Providing sources of forage for domestic and wild animals; and
- Increasing the diversity of natural resources and providing aesthetic value.

These benefits are most realized when riparian areas are established and diverse with multiple structural height components. Benefits from healthy functioning riparian areas accrue to both the watershed and the landowners whose properties include riparian zones. Riparian areas reduce bank instability, mitigate flood hazards, add aesthetic value, and add monetary value to the property.

The purpose of this component is to evaluate the present condition of riparian areas throughout the assessment area. Summaries of existing research with a riparian evaluation component are presented first. The summaries are followed by a current evaluation of riparian conditions in the entire assessment area. Differences between existing riparian conditions and potential riparian vegetation communities are discussed at the end of the riparian section.

## 5.2 POTENTIAL RIPARIAN VEGETATION

The assessment area is overlapped by four coarse scale ecoregions (WPN 1999). Ecoregional definitions characterize general potential for vegetative communities based on climate, geology, and elevation. The Deschutes River Valley ecoregion comprises most of the assessment area, followed by the John Day/Clarno highlands, the John Day/Clarno uplands, and small north facing ridge of Mesic Forest south of Little McKay Creek. Potential riparian vegetation in the valley and uplands ecoregions is characterized as hardwood dominant with shrub co-dominance (Table 5-1). In the highland and mesic (i.e., wet) forest zone hardwoods and shrubs tend to be co-dominant with conifers or replaced by conifers.

**Table 5-1.** Potential riparian vegetation for ecoregions in assessment area (Adapted from Watershed Professionals Network, 1999).

| Ecoregion | Potential Riparian Vegetation | Other factors affecting riparian vegetation |
|---|---|---|
| Deschutes River Valley | Hardwoods (Black & narrow leaf cottonwoods, aspen) & shrubs (willows, mountain alder, hawthorn, chokecherry, wood's rose & silver sage) | Land use patterns have removed much of the historic riparian vegetation. |
| John Day/Clarno Uplands | Hardwoods (cottonwood & alder) and shrubs (willow, mountain alder, Douglas spirea & common snowberry) Infrequent juniper or ponderosa pine | Fire suppression, historic grazing patterns, and climate over the last century have caused increase in juniper abundance and a decline in grass dominance. Also, there is the potential for riparian plant communities that have no woody vegetation and are dominated by herbaceous plants such as beaked sedge or aquatic sedge at higher elevations. |
| John Day/Clarno Highlands | *1st Riparian Area:* Hardwoods (alder & cottonwood) & shrubs (willow, Sitka alder, mountain alder, common snowberry & shrubby cinquefoil)<br><br>*2nd Riparian Area:* Conifers (infrequent true fir and ponderosa pine) | Fire suppression in recent decades has caused an increase in true fir dominance. Also, under certain circumstances there are a few potential plant communities which have no woody vegetation in 1st riparian area and are characterized by herbaceous plants such as beaked sedge or aquatic sedge at higher elevations. |
| Mesic Forest Zone | *1st Riparian Area:* Hardwoods and shrubs (willow, bogberry, dogwood, mountain alder, Pacific ninebark & common snowberry)<br><br>*2nd Riparian Area:* Conifers (Engelmann spruce, Douglas-fir, true fire, larch & lodgepole pine) | Disease, insects and fire often suppress one or more tree species. Under certain circumstances, there are a few potential plant communities which have no woody vegetation in 1st riparian area and are characterized by herbaceous plants such as aquatic sedge at higher elevations, queencup beadlily, widefruit sedge, beaked sedge, smallfruit bulrush & bluejoint reedgrass. |

## 5.3 METHODOLOGY FOR EVALUATING RIPARIAN CONDITIONS

The riparian evaluation was conducted using two methods: aerial photo interpretation and a field survey. The riparian assessment was done by a group of local experts, including an Ochoco National Forest hydrologist, an ODFW Fish Biologist, the Crooked River Watershed Council Coordinator, and the riparian assessment field technician. The protocol for the riparian assessment was based on the OWEB *Oregon Watershed Assessment Manual* (Watershed Professionals Network, 1999). The protocol classifies riparian conditions by identifying vegetative type, surrounding land use, shade, and potential woody recruitment conditions. A key of codes is used to identify riparian units either in the field or through photo interpretation.

The photo interpretation used 2000 USGS black and white aerial imagery with a one meter pixel resolution. The imagery was viewed by the riparian evaluation group by projecting the imagery on a wall with an LCD projector. Dominant vegetation type, size class, and tree density were assessed by stream segments. However, a portion of the Lower Crooked River runs through a deep canyon, obscuring riparian areas in aerial imagery. The evaluation group relied on previous riparian research to classify riparian conditions in the canyon areas. The evaluation did not assess riparian communities in areas of slack water where the Crooked River meets Lake Billy Chinook.

A non-random sample of sites deemed characteristic of riparian conditions within the assessment area was selected to ground-truth finding from the aerial photo interpretation analysis. These sites included private and public ownerships in urban, agricultural, forest and range lands. Each site was on or adjacent to a major waterbodies in the assessment area – four sites on the Crooked River, three on McKay Creek, three on Ochoco Creek, two on Lytle Creek, and one on Allen Creek. At each site, a GPS point was taken using a Trimble GeoXT. A narrative description of each was recorded focusing on dominant vegetation type, density, shade, and recruitment potential. Narrative descriptions provided by the field survey were used to verify the quality of aerial photo interpretation finding through a simple qualitative comparison of findings from both methods comparing the GPS point location with its respective stream segment used in the aerial photo interpretation analysis.

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## 5.4 FINDINGS OF CURRENT RIPARIAN RESEARCH

### 5.4.1 Aerial Photo Analysis

Riparian vegetation was categorized into nine major types of dominate or co-dominate vegetation: conifers, conifer – woody shrub mix, juniper, hardwoods, woody shrub – hardwood mix, woody shrubs, grass and/or managed shrubs, and agriculture. Riparian vegetation was classified for both left and right banks, and percent of total riparian area was calculated for each vegetation category.

Hardwood tree dominated and co-dominant riparian communities are the least common riparian communities that occur in the assessment area, together covering only approximately 10.8 riparian bank miles or 4.3% of the riparian corridor (Table 5-2, Map 5-1). Hardwoods occur as individual trees with a co-dominant shrub component, or in small dominant stands. Common hardwood trees in the assessment area include Cottonwood (*Poplar trichocarpa*) and White Alder (*Alnus rhombifolia*). Hardwood communities are most common on McKay Creek where a 3.5 mile stretch of McKay Creek is bordered by varying densities of riparian Cottonwood forest and in the Canyons below the Prineville Valley (Map 5-1). Hardwoods also occur on Ochoco Creek mainly

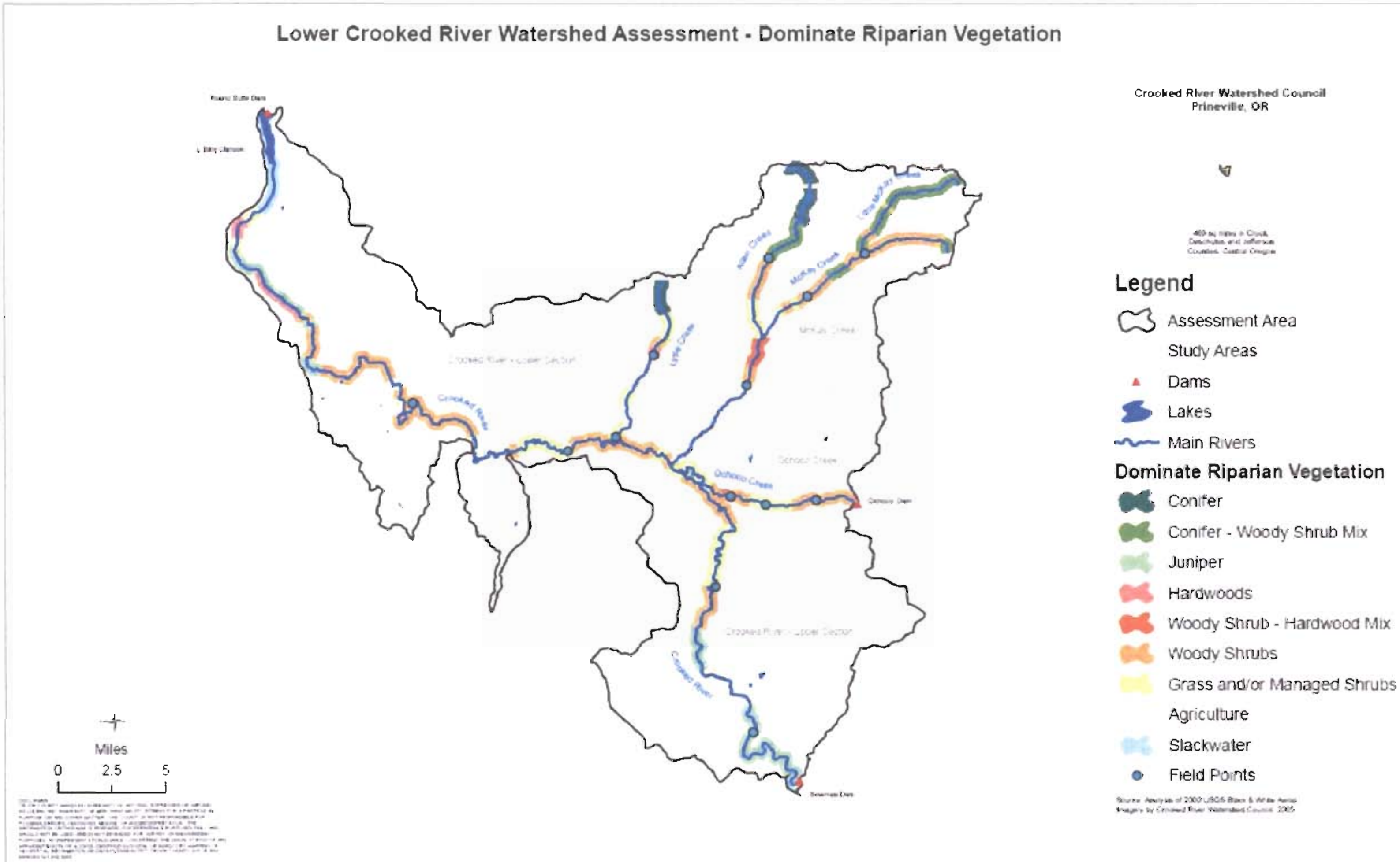
Table 5-2. Dominant riparian vegetation by study area.

| **Study Areas** | **Crooked River – Lower Section** | | **Crooked River – Upper Section** | | **Ochoco Creek** | | **McKay Creek** | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Dominant Vegetation Type** | **Miles** | **%** | **Miles** | **%** | **Miles** | **%** | **Miles** | **%** | **Miles** | **%** |
| Conifer | 3.4 | 3.1 | – | – | – | – | 7.30 | 9.4 | 10.7 | 4.2% |
| Conifer – Shrub Mix | – | – | – | – | – | – | 22.67 | 29.0 | 22.7 | 8.9% |
| Juniper | 9.6 | 8.9 | 21.6 | 48.9 | – | – | – | – | 31.2 | 12.3% |
| Hardwoods | 6.3 | 5.8 | – | – | 0.5 | 2.2 | – | – | 6.8 | 2.7% |
| Shrub – Hardwood Mix | – | – | – | – | 0.5 | 2.2 | 3.54 | 4.5 | 4.0 | 1.6% |
| Woody Shrubs | 50.3 | 46.3 | 6.1 | 13.8 | 10.9 | 48.6 | 22.9 | 29.4 | 90.3 | 35.6% |
| Grass and/or Managed Shrubs | 21.5 | 19.8 | 9.6 | 21.8 | 10.5 | 46.9 | 6.6 | 8.5 | 48.4 | 19.1% |
| Agriculture | 17.5 | 16.1 | 6.8 | 15.5 | – | – | 14.93 | 19.1 | 39.2 | 15.5% |

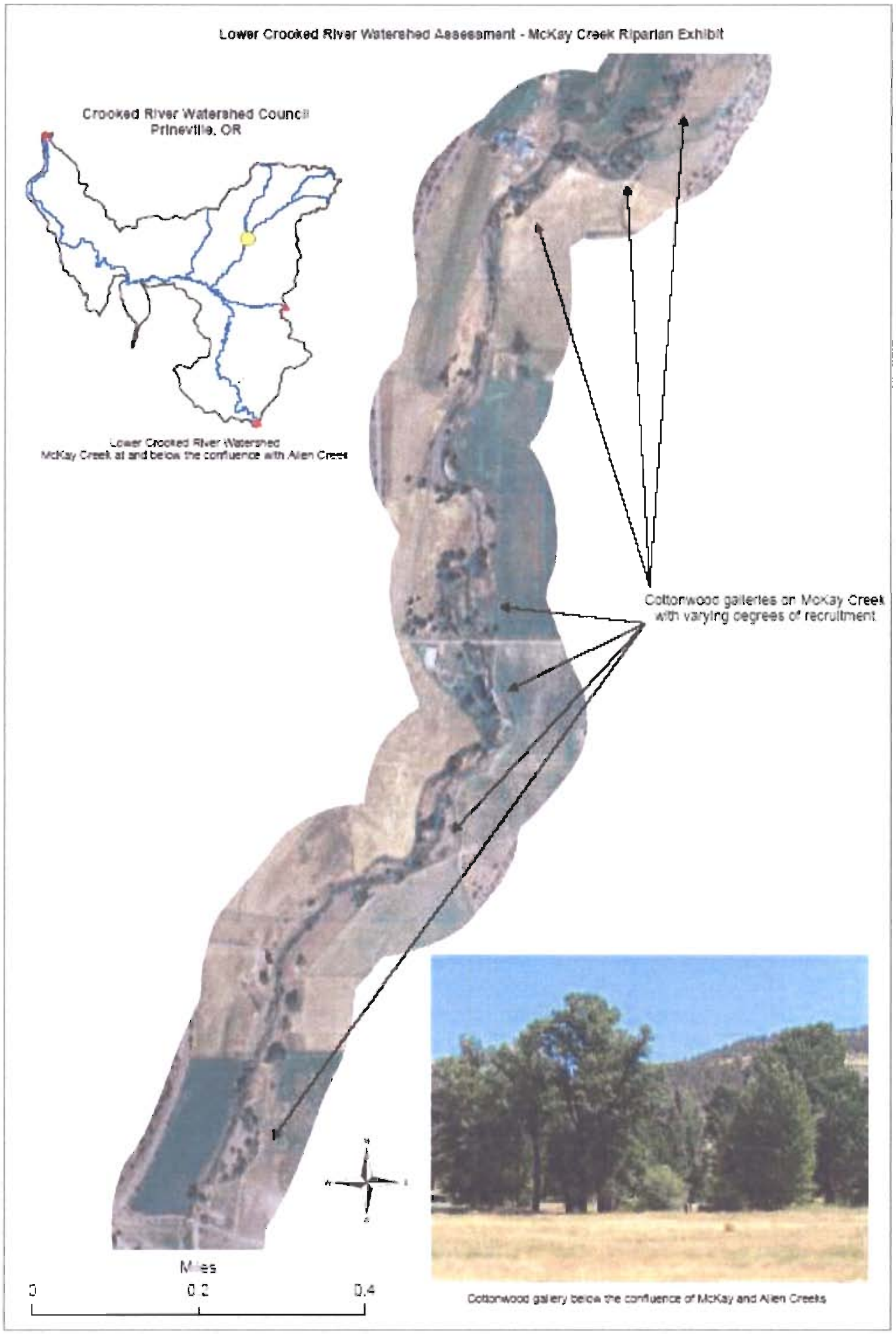
in the urban setting of Prineville, where a trail runs under the shade of riparian trees, dominated by Cottonwood, Box Elder (*Acer negundo*), and American Elm (*Ulmus Americana*). This riparian forest corridor through the City of Prineville is an important community asset and serves beneficial ecological functions. Although their overall extent is small, hardwood riparian vegetation is an important component of the riparian community of the assessment area providing canopy structure, shade, wildlife habitat, potential for large wood recruitment, and organic matter to the stream. An important restoration goal is to increase the proportion of hardwood riparian vegetation throughout the assessment area; however, focusing on expanding the current hardwood anchors may be a place to start.

Woody shrubs comprise the most dominate proportion of the riparian corridor throughout the entire assessment area, covering over one-third of the total assessment area and nearly 50% of both the Lower Crooked River (lower section) and Ochoco Creek. Common woody shrub species include several species of willows (*Salix* sp.), red-osier dogwood (*Cornus sericea*), golden currant (*Ribes aureum*), and thinleaf alder (*Alnus incana*) and black elderberry (*Sambucus racemosa*) in the higher elevations. On both the Lower Crooked River and Ochoco Creek, the second most dominate riparian community is grass and/or managed shrubs, which include pastures, parks, and other extensively managed open areas with individual shrubs separated by areas of low grass and forb vegetation. Recruiting increased numbers of shrubs and hardwoods to these lands through planting or alternative livestock management systems would improve riparian conditions throughout a large extent of these two study areas. Finally, providing an increased buffer between agricultural land uses and riparian corridors would further improve riparian conditions in at least three of the four study areas.

Riparian conifers are primarily present on McKay Creek near and above the Ochoco National Forest boundary. Encroachment of conifers into the riparian corridor is likely the result of a lowered water table reducing the competitiveness of water dependent riparian species compared to relatively more drought tolerant conifers. Conifer encroachment is evident at the forest boundary on McKay Creek where remnants of a




**Map 5-1. Dominant riparian vegetation for the Lower Crooked River Watershed.**




**Map 5-2. Riparian corridor on McKay Creek below the confluence with Allen Creek.**

cottonwood gallery exist as declining individual trees and snags among the mostly young and productive pine forest (Figure 5-1). While reducing conifer tree densities at the site may improve conditions for these individual hardwood trees in the short term, conifer tree densities are above the historical range of natural variability throughout much of the western United States. Landscape level treatments to reduce conifer densities are need to improve the conditions that lead to conifer encroachment. Another conifer species warranting a separate category is western juniper (*Juniper occidentalis*). Western juniper has expanded its range throughout the upland range of central Oregon with watershed scale impacts. Western juniper occurs as a riparian species primarily on the Lower Crooked River in the canyons below the Bowman Dam and the Canyons leading to Lake Billy Chinook.

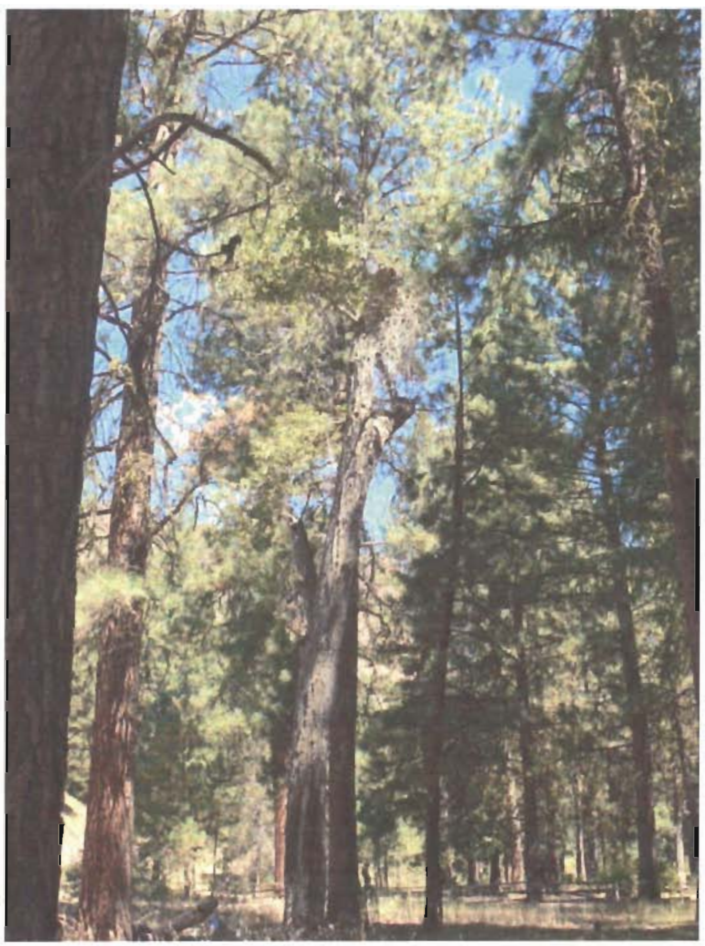


Figure 5-1. Conifer encroachment on riparian cottonwoods on McKay Creek at the Ochoco National Forest boundary (photo credit: M. Nielsen-Pincus).

### 5.4.2 Field Survey

A field survey was conducted in 2005 to help interpret the aerial imagery. The dominant riparian vegetation types identified during the field survey were woody shrubs and grass with managed shrubs. Recruitment of woody riparian vegetation, shade, and vegetation density were low at most of the sites sampled in the field survey, although some sites particularly on tributary streams did show some recruitment and shade. Riparian conditions along the Lower Crooked River, especially in the lower study area, tend to be especially challenging due to a wide river channel, active erosion and channel incision, and a lack of tall hardwood species.

Furthermore, the field survey revealed that the riparian corridor along the Lower Crooked River tends to act as a vector for noxious weed species such as spotted knapweed (*Centaurea stoebe*), white top (*Cardaria draba*), Russian thistle (*Salsola kali*), and leafy spurge (*Euphorbia esula*) among others. Noxious weed seeds are easily transmitted downstream in the water course. Combating noxious weeds through chemical treatments or hand pulling is a short term solution. In the long term the establishment of desirable riparian vegetation will provide the best weed control methods.

## 5.5 PREEXISTING RIPARIAN RESEARCH SUMMARIES

In addition to the above evaluation several studies that include riparian components were analyzed and assessed to add to our understanding of the conditions of riparian vegetation in the Lower Crooked River watershed. These studies indicate the diversity of assessment techniques and data available for the watershed. The information presented in these studies provides an additional base of knowledge of riparian conditions throughout the many reaches of the mainstem and tributary streams.

**General**

Interior Columbia Basin Ecosystem Management Project (ICBEMP, 1997)

*Survey Site:* Interior Columbia Basin

*Methodology:* Remote sensing and expert-based models.

*Riparian Characteristics:* Riparian ecosystem function, as determined by the amount and type of vegetative cover, has decreased in most sub-basins. Abundance of mid-seral vegetation in riparian woodlands has increased, and late seral vegetation has decreased. Extensive spread of western juniper and exotic grasses and forbs into riparian areas in grass, shrub and rangelands was also noted.

**Lower Crooked River**

Oregon Department of Fish and Wildlife - Lower Crooked River (ODFW, 1997b)

*Survey Site:* Confluence to Smith Rock State Park

*Methodology:* Oregon Department of Fish and Wildlife stream habitat survey protocol.

*Riparian Characteristics:* Land uses a combination of 'no use' based on the Wild and Scenic Waterway and agricultural use. Riparian area dominated by alder and some ponderosa pine in lower reaches, upper reaches dominated by shrubs and grasses and some juniper. Forest fire occurred in Smith Rock State Park area-reforestation efforts underway.

*Bank Stability:* 40% non-eroding bedrock banks in lower reaches. Of potentially eroding sections (upper reaches) approximately 80% are vegetatively stable and 20% actively eroding.

Ochoco National Forest – Crooked River (USDA USFS, 2003)

*Survey Site:* The Forest Service survey was conducted on the lower reaches of the Crooked River from Lake Billy Chinook to the upper end of the grassland boundary at river mile 17.

*Methodology:* Level II Stream Inventory Region 6 protocol (United States Forest Service, Pacific Northwest Region 2003) including CHT, riparian conditions assessment and fish presence/habitat noted.

*Riparian Characteristics:* Upper river section dominated by dogwood, some elderberry, rose and willow with grasses and forbs understory. Trees are mostly juniper with scattered ponderosa pines. This mosaic is broken down as shrub/seeding (55%), grass/forbs (15%), bare ground and rock (15%), small trees (10%) and large trees

(5%). The lower section transitions into a small tree successional class. The dominate overstory consists of alders and other hardwoods with grasses and forbs as understory.

Oregon Department of Fish and Wildlife - Lower Crooked River (ODFW, 1997b)

*Survey Site*: Stearns Dam to Bowman Dam

*Methodology*: Oregon Department of Fish and Wildlife survey

*Riparian Characteristics*: Beaver activity present. Common trees in riparian zone (30 meter- width) include juniper, with lesser amounts of willow and cottonwood. Land use is agricultural and Scenic Waterway, including BLM upper portion of reach- Chimney Rock segment. Ponderosa pine planting project in upper reaches on west bank

**McKay Creek**

Crooked River Watershed Council Research - McKay Creek (Walter, 2000)

*Survey Site:* Entire creek, 37.7 miles

*Methodology:* OWEB methodology. P. Walter. 2000. Based on 1996 and 1998 aerial photos and field verification in 2000.

*Riparian Characteristics:* Land use in McKay Creek is predominantly irrigated agricultural (64%) and forestry (35%) with a small proportion of built infrastructure (1%). The lower 25 miles are private while the upper 13 miles are on public lands (Ochoco National Forest). Riparian vegetation types are grasses in the lower watershed and medium sized sparse conifers in the upper reaches. A significant portion (15%) of the riparian area is characterized as un-vegetated. The riparian recruitment situation is inadequate for just under 90% of stream reaches.

Oregon Department of Fish and Wildlife - McKay Creek (ODFW, 1997c)

*Survey Site:* The ODFW McKay Creek survey was conducted on the lower reaches, from its confluence with the Crooked River to the United States Forest Service (USFS) boundary. Not all reaches were included due to access.

*Methodology:* Oregon Department of Fish and Wildlife stream habitat survey protocol.

*Riparian Characteristics:* Riparian habitat dominated by shrubs and grasses with low canopy cover. Land uses within the riparian area (30 meter width) include agriculture and light grazing.

*Bank stability:* 50% vegetatively stable, 50% actively eroding banks.

Ochoco National Forest - McKay Creek (USDA, 1997)

*Survey Site:* The survey was conducted on the upper reaches of McKay Creek from just below the confluence with Little McKay Creek to the headwaters of McKay Creek. One reach was not surveyed because it is on private land. Total length surveyed was 6.3 miles.

*Methodology:* Rosgen Level II Stream Inventory with Wolman pebble count technique used; flow reading taken at reach 1 using March-McBirney meter; stream temperature reading taken with hobo XT's; riparian conditions assessment and fish presence/habitat noted.

*Riparian Characteristics:* Dominant vegetation is Alder (*Alnus incana*) with secondary conifer overstory and grass/forbs understory.

Crooked River Watershed Council Research - Little McKay (Walter, 2000)

*Survey Site:* Entire creek, 12.5 miles

*Methodology/Date:* OWEB methodology. P. Walter. 2000. Based on 1995, 1996 and 1998 aerial photos and field verification in 2000.

*Riparian Characteristics:* All public ownership (Ochoco National Forest). Riparian land use dominated by forestry (2/3) and roads (1/3). Riparian area vegetation primarily conifer trees of medium size (12-24 DBH average), with roughly half of the vegetated areas in dense stands, and half in sparse stands. The riparian recruitment situation is inadequate for roughly two-thirds of stream reaches.

**Ochoco Creek**

Crooked River Waterhsed Council Research - Ochoco Creek (Walter, 2000)

*Survey Site:* Entire creek, 48.8 miles

*Methodology:* OWEB methodology. P. Walter. 2000. Based on 1995, 1996 and 1998 aerial photos and field verification in 2000.

*Riparian Characteristics:* Ownership is primarily private, with the upper 1/3 of the creek on public lands (Ochoco National Forest). Land use is dominated by agriculture (67%), forestry (23%), and roads (10%). Dominant riparian vegetation types are grass and brush, with sparse conifers in the upper channel. The riparian recruitment situation is inadequate for 80% of stream reaches.

Ochoco Flood Assessment - Ochoco Creek (National Riparian Service Team, 1998)

*Survey Site:* Lower Ochoco Creek, from Ochoco Dam through the City of Prineville to the confluence with the Crooked River.

*Methodology:* The team (NRST, ODFW, USFS, BLM) walked the creek at the request of City and County officials following the May 1998 flood event, looking specifically at channel stability, channel capacity, fish and wildlife habitat, flood damage and riparian management opportunities.

*Riparian Characteristics:* Upper Reaches: Low in woody vegetation, some willows and rose. Riparian areas mostly vegetated in grasses. Lower Reaches: Riparian area often mowed, predominantly grasses and some willows where vegetated. The survey concluded that areas without riparian shrubs was most heavily impacted.

Ochoco Riparian Conditions and Recent Development (CCNRPC, 2005)

*Survey Site:* Entire Creek where accessible from Ochoco Dam to confluence with Crooked River.

*Methodology:* Photo inventory with some cross sections surveyed and general dimensional data gathered 2005.

*Riparian Characteristics:* Increase in green space (primarily grass) from City of Prineville Park. Increasing development is encroaching on the stream channel and riparian areas causing a general loss of riparian areas and potential flood water storage.

## 5.6 RIPARIAN CONDITIONS SUMMARY

Riparian conditions vary greatly from the potential vegetation type for two of the ecoregions in the assessment area, which comprise most of the Lower Crooked River Watershed. Potential vegetation for the Deschutes Valley and John Day/Clarno Uplands ecoregions is dominated or co-dominated by hardwood trees, primarily cottonwoods or alders. While several pockets of cottonwoods remain along McKay Creek in the John Day/Clarno highlands ecoregion, along the Lower Crooked River in the Deschutes Valley ecoregion no cottonwood tree communities were identified in the riparian evaluation, while alder communities persist in the lower canyons. The riparian corridor in the Lower Crooked River – lower study area is split between woody shrubs and a mix of agriculture and grass with managed shrubs either in the form of parks or pastures. In the upper portions of the watershed, in the John Day/Clarno Uplands and the Mesic Forest Zone, dominant riparian vegetation is closer to its potential vegetation type, composed primarily of alders. These ecoregions do show signs of conifer encroachment, which can be managed to encourage a greater dominance of riparian species. Many other studies have evaluated riparian conditions on smaller segments or reaches of the Lower Crooked River Watershed. The studies corroborate the findings of this watershed-wide riparian evaluation, suggesting that riparian conditions throughout the watershed, and especially in the lower elevations, could be greatly improved.

## 5.7 WETLANDS INTRODUCTION AND BACKGROUND

The Clean Water Act defines wetlands as, "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support … a prevalence of vegetation typically adapted for life in saturated soil conditions" (EPA, 2006a).

Wetlands can include marshes, swamps, bogs, wet meadows, and similar areas that are in riparian zones or surrounded by dry lands (EPA, 2006a). Wetlands vary widely due to local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Wetlands are also among the most productive ecosystems in the world, comparable to rain forests and coral reefs, and are a substantial source of biodiversity relative to extent on the surrounding landscape (EPA, 2006b).

Wetlands are a transition zone where the flow of water, the cycling of nutrients, and photosynthesis produce a unique ecosystem. In the assessment area wetlands can be found in a variety of forms (Figure 5-2). For example, in forested headwater tributaries,

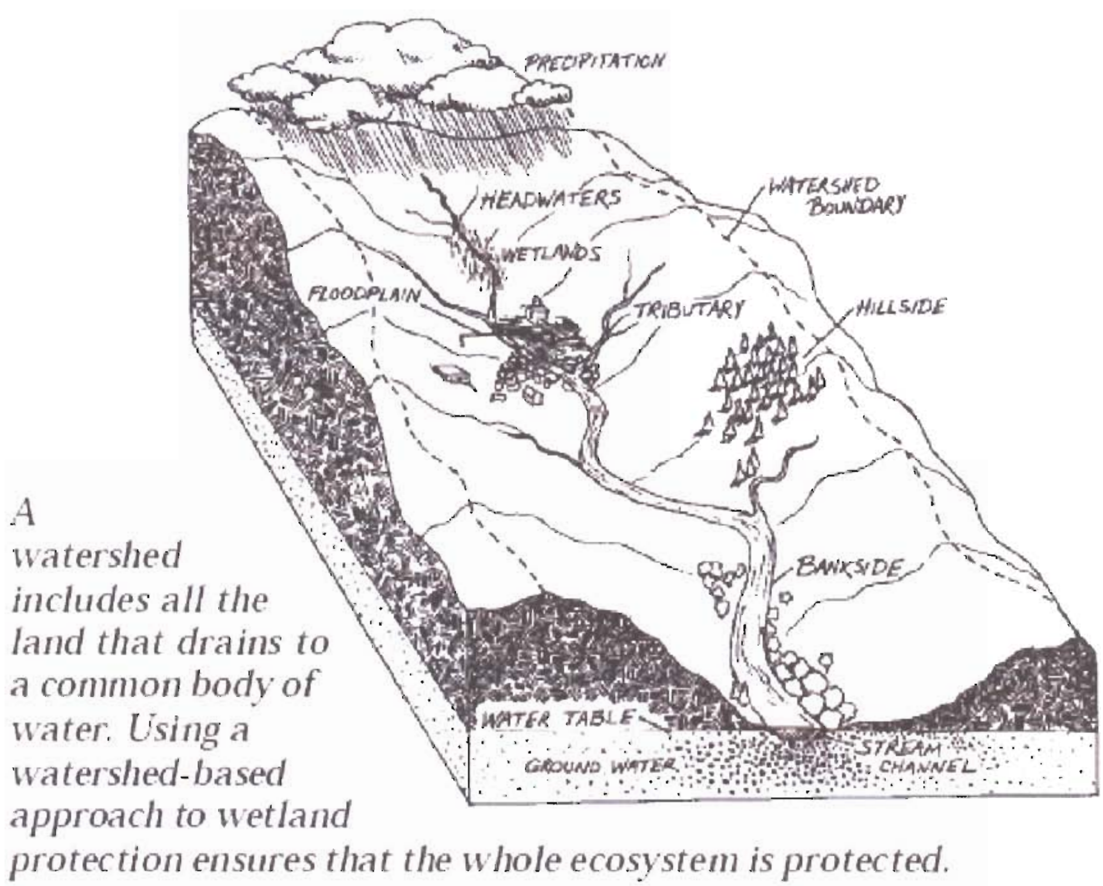



Figure 5-2. Wetlands and Watersheds (EPA, 2006a)

wet meadows are a common form of wetland, and along low gradient valley bottoms wetlands often occur adjacent to the stream channel on floodplain benches where the groundwater table is high or flooding is a common event. Although historically wetlands were often drained, filled, or altered to provide lands for other uses, society now recognizes a variety of benefits that accrue from wetlands. These benefits include fish and wildlife habitats, water quality and quantity improvement, flood storage, and opportunities for recreation and aesthetic appreciation. Functional indicators can be used to inventory the benefits and qualities of wetlands for watershed health, and are important to identifying opportunities for restoration and enhancement (Table 5-2).

**Table 5-2.** Relationship between Watershed Issues and Wetlands (Watershed Professionals Network, 1999)

| Wetland Function | Functional Process | Functional Indicators | Additional Data Needs |
|---|---|---|---|
| Salmonid rearing habitat | Wetlands adjacent and to the channel can provide refuge from predators and increased habitat complexity. | Must have direct passable connection to a stream. | Assess needs for rearing habitat and opportunities for enhancing or constructing wetlands. |
| Flood Control | Wetlands can help to reduce flooding by temporarily retaining water during a high flow event. | Located upstream of areas with high flood hazards; requires a topographic depression or constrained outlet. | Identify wetlands that potentially serve this function. Evaluate possibilities for enhancement or construction of additional flood control wetlands. |
| Low summertime flows/poor water quality | Wetlands can be sites of groundwater discharge and hyporheic flows, and can serve as a filter for pollutants. | Cool water emergence from wetland location and reduction in toxic water chemistry | Assess DEQ Thermal Infrared surface water temperature data to identify and enhance these locations. |
| Turbidity | Wetlands can filter sediment from surface-water runoff and through flow by slowing water velocities and allowing deposition. | Wetlands receive degraded runoff that ultimately enters the channel; wetlands densely vegetated | Identify wetlands adjacent to surface water run-off locations and riverine wetlands that could be enhanced or restored. |

Federal law prohibits the fill, draining, or alteration of wetlands without mitigation. Several federal, state, and local regulations affect activities that alter wetlands. The primary agencies with regulatory jurisdiction over wetlands are the United States Army Corps of Engineers and the Oregon Department of State Lands. Although wetlands are regulated on a site-by-site basis by federal and state authorities, local governments play an important role in wetland management through local land use decisions and natural resource plans. These decisions can take a proactive approach that extends beyond individual sites by planning that protects wetland resources, enhances aesthetic and open space values, and provides the many watershed benefits served by wetlands. Furthermore, local planning to incorporate or construct wetlands as part of a stormwater management plan is an important strategic watershed enhancement tool. While unplanned development can be detrimental to wetlands by altering flows, increasing pollutant loads, and sediment deposition (Center for Watershed Protection, 2006), proactive planning can mitigate these impacts through constructed wetland design and enhance local community values.

The objective of the remainder of this section is to offer a brief overview of wetland areas within the assessment area. This section addresses the general characteristics of wetlands in the assessment area and discusses opportunities that exist to restore and enhance the wetlands.

## 5.8 WETLANDS IN THE ASSESSMENT AREA

Few sources of wetlands data exist for the assessment area. The United States Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) and the *Local Wetlands Inventory: City of Prineville, Crook County, Oregon* (Evans, David & Associates Inc., 1994) are the two most comprehensive identification of wetlands for the assessment area; however, the scale and accuracy of each are limited. Evaluation of historical watershed processes also offers an indication of potential for wetlands in the Lower Crooked River Watershed. Constructed wetlands are increasingly becoming an important component of the wetlands resources in the assessment area.

Historically, the assessment area had more wetlands due to regular flooding, floodplain connectivity, and the natural flow regime (Buckley, 1992; David, 2005). The Crooked River flooded almost annually, and had meandering channels that took up the entire valley floor with stream channels that were well connected to the broad valley bottom floodplains (Buckley, 1992; David, 2005; Elmore and Beschta, 2005). Regular flooding promoted the establishment of wetlands and hydrophytic vegetation.

Historic beaver activity also contributed substantially to wetland development. Beavers build and maintain elaborate dam structures that alter the natural flow regime. The structures dam water behind them providing a number of benefits, including the attenuation of peak flows, reduced flow velocity, deposition of sediments causing the soil profile to build, the filtration of suspended solids, seasonal inundation, the creation of pools and ponds, increases in groundwater recharge and hyorheic flows, increased water availability during dry periods, and the creation of fish and wildlife habitat (Elmore and Beschta, 2005).

Current data for evaluating the extent of wetlands in the assessment area is limited to two sources. The National Wetlands Inventory (NWI) digital map of wetlands only exists for the portion of the study area west of Range 15 East, or roughly the Lower Crooked River – Lower Section study area. The NWI data indicates that approximately 1610 acres of wetlands exist within the assessment area, of which 769 acres are lacustrine wetlands forming a continuous border along the banks of Lake Billy Chinook; 595 acres are palustrine described as marshes, wet meadows, and other isolated wetlands (Figure 5-3);

Figure 5-3. Riverine wetland along the Lower Crooked River (photo credit: A. Cowie).

and 246 acres are riverine and adjacent to a stream or river channel that provided seasonal inundation (Figure 5-4). The median size of palustrine wetland is 0.4 acres, while riverine wetlands tend to be nearly double in size (median =0.8 acres). Riverine wetlands tend to occur in narrow bands along the bank of streams and rivers (connectivity of riverine wetland results in only 14 distinct riverine wetlands), while palustrine wetlands tend to occur in isolation with more variation in shape depending on location and local topography (482 total palustrine wetlands are identified in the NWI). Riverine wetlands tend to dominate the canyon section of the Lower Crooked River, and are occasionally flanked by palustrine emergent shrub-scrub wetlands (Figure 5-5). Palustrine wetlands are most abundant upstream of or on terraces above the canyon section of the Lower Crooked River.

Figure 5-4. Palustrine wetland along the floodplain of the Lower Crooked River (photo credit: A. Cowie).

A second source of wetlands information for the assessment area is City of Prineville *Local Wetlands Inventory* conducted by David Evans & Associates Inc. (1994). The Local Wetlands Inventory analyzed wetlands greater than 0.5 acres, and identified 15 wetlands with a total estimated area of 207 acres. These wetlands varied from small floodplain bench wetlands immediately adjacent to Ochoco Creek and the Crooked River to long broad complex palustrine wetlands located in seasonal drainages and catchments. Given the median size of both palustrine and riverine wetlands identified in the NWI, the local wetlands inventory likely omits the majority of wetland area within the Prineville area.

A final source of wetlands resources are constructed wetlands. Wetlands may be constructed as the result of a mitigation project, or for functional purposes such as

Figure 5-5. Palustrine emergent shrub-scrub wetland near Smith Rock State Park with alder (Alnus Rhombifolia) hardwood community (photo credit: N. Nielsen-Pincus).

stormwater detention. The City of Prineville has recently elected to become the recipient of a wetlands mitigation bank as the recipient of Oregon Department of Transportation (ODOT) mitigation credits (Figure 5-6). ODOT is constructing nearly 15 acres of wetland adjacent to the City's new wastewater treatment facility along the Lower Crooked River, which provide a buffer between the river and the treatment facility. Constructed wetlands are also an opportunity being pursued by several irrigation districts in central Oregon to provide a buffer and filter for irrigation return flows. Other constructed wetlands have been built by private entities, often for mitigation, throughout the assessment area.

Figure 5-6. Constructed wetland at the City of Prineville wastewater treatment facility during excavation (Feb. 2005), and at the end of the first growing season (Sep. 2005)

## 5.9 SUMMARY

Riparian areas and wetlands act as buffer zones between streams and uplands. Vegetative structure in both riparian areas and wetlands can enhance water quality and quantity, recovery of sediment, dissipating energy during floods, stabilizing banks, and providing habitat for aquatic organisms. The majority of the riparian areas in the Lower Crooked River Watershed are lacking a hardwood tree component. Riparian restoration often requires the establishment of a riparian reserve or buffer strip (Kauffman et al. 1997), which can be accomplished through riparian easements, livestock exclusion fences (and off-site watering), and no-harvest corridors. These approaches represent *passive restoration* techniques due to the reliance on natural revegetation. Bank stabilization efforts and planting, sometimes referred to as bio-engineering, are *active restoration* techniques that can effectively accelerate the natural recovery process. Active restoration techniques are most needed in locations where bank erosion prevents riparian establishment.

A full inventory of wetlands is needed to comprehensively assess wetlands conditions and needs in the assessment area. Most wetlands in the assessment area are small isolated palustrine wetlands or narrow riverine wetlands. In the Lower Crooked River – Lower Section study area NWI data should be validated and wetland resource quality and needs should be evaluated. Partnerships on constructed wetland projects for highway mitigation or irrigation return flow should be identified as opportunities for watershed enhancement. Wetland resources around the City of Prineville should be surveyed with a resolution less than 0.5 acres, and opportunities for developing constructed wetlands as stormwater mitigation should be assessed.

# CHAPTER 6 – CHANNEL HABITAT

*Sinuosity in the Lower Crooked River (right) and McAllister Slough (left) looking downstream towards Lone Pine (photo credit: M. Nielsen-Pincus).*

## CRITICAL QUESTIONS

- What are the present channel conditions in the assessment area?
- How does the regulation of flows impact the natural channel forming process?
- Are the channels in the assessment area showing evidence of stability?
- What are the primary types of channel classification in the Lower Crooked River Watershed?
- Is there a need for a more in-depth survey to assess and evaluate the watershed condition of the channels within the basin?

## DATA GAPS AND RESEARCH RECOMMENDATIONS

- Data characterizing the dimensions and hydrologic impact of waterbody crossing structures identified in this assessment should be collected to analyze the impact of the structures on peak flow event hydrology.
- Historical aerial photos, field photos, and land surveys should be collected to inventory and map major channel modifications.

## KEY FINDINGS

- Several channel spanning dams on the Crooked River, Ochoco Creek, and McKay Creek exist. These dams impact the flow regime and modify channel forming processes.
- Numerous road crossings, irrigation diversions and adjacent roads modify channels throughout the assessment area.
- Approximately 50% of the tax lots that encompass the 100 year floodplain in the assessment area have been developed for residential, commercial, or industrial purposes. In the City of Prineville 55% are developed, and within the Crook County portion of the assessment area 49% are developed.
- Floodplain development, especially in Prineville and along Ochoco Creek, continues even following events such as the 1998 Ochoco Creek flood.
- Hydrological analysis indicates that Channel Habitat Types within the assessment area are outside of their historical range.

## ACTION ITEMS

- Continue to work with landowners to implement stream and river channel enhancement projects within the assessment area.
- Engage both City and County officials regarding protection of riparian buffers on the Crooked River, Ochoco Creek, and Mckay Creek.
- Assist in community forums regarding the operations of the Bowman and Ochoco dams and reallocation of the Prineville Reservoir.
- Continue to work with landowners to increase floodplain connectivity and capacity, and increase riparian vegetation through stream corridors.
- Prioritize dams and diversions with USFWS, BLM, ODFW, and NOAA officials to develop an action plan for the restoration of fish passage or removal of channel spanning barriers.
- Assist ODFW and USFS in researching stream habitat typing data collection.
- Identify strategies and techniques for slowing channel incision and speeding recovery of stream channels in transition phases.

## 6.1 INTRODUCTION

Stream channels are dynamic systems that modify themselves in response to changes in physical watershed features (Watershed Professionals Network, 1999). Natural channel forming processes, such as floods, modify the morphology of streams based on water quantity, timing, duration, and sediment transport. Development of wetlands, floodplains, and distribution of spawning material rely upon the fluctuations of streamflow.

Several factors can inhibit the natural morphology of streams by modifying the shape, form, and ability to transport water and sediment. Anthropogenic influences to channel systems include construction of channel spanning dams, irrigation structures, road crossings, vegetation alterations, and channelization. Some channel modifications can lead to long term impacts, including lowered water tables, reduction in groundwater discharge, depletion of soils and soil nutrients, reductions in summer flows, streambank erosion, and loss of stabilizing vegetation.

The *Oregon Watershed Assessment Manual* (Watershed Professionals Network, 1999) lists 14 channel modifying activities of which all but three are present in the assessment area:

- Hydroelectric and irrigation dams
- Reservoirs and artificial impoundments
- Small agricultural impoundments, cattle ponds, fire ponds
- Dike, levees (usually for flood control)
- Channelization (channel straightening, hardening, or relocation)
- Dredged channels
- Stream-bank protection (riprap, pilings, bulkheads)
- Roads next to streams
- Extensive fill associated with road crossing
- Tide gates
- Water withdrawals
- Push-up dams
- Sand and gravel mining in/near channels, tailings deposits

.

Dredging, tide gates, and mining tailings or deposits located near channels do not occur in the assessment area; although, anecdotal evidence suggests that historical mining and dredging may have occurred in the Lower Crooked River. Channel conditions in the Lower Crooked River watershed are modified with respect to streamflow, riparian conditions, channel form, and channel spanning barriers (ODFW, 2003). In addition to the eleven modifications from the OWEB list, streams within the assessment area have also been subject to the removal of vegetation from channel banks and the removal of wood from channels.

The Crooked River and many tributary streams were channelized following the 1964 floods. Channelization increases stream gradient, reduced channel roughness, and disconnects streams from floodplains. The result is increased stream energy, which causes many streams to erode vertically and/or laterally. Channel incision (i.e., vertical downcutting) causes the water table to drop, which reduces water availability for riparian vegetation and for vegetation in adjacent meadows, pastures, or range. Agricultural uses and residential developments in valley bottoms have also altered stream morphology and vegetation throughout the basin (ODFW, 1996; WSPE, 1997; USDA USFS, 1998b; McSwain, 2000; CRWC, 2002).

An extensive reservoir and irrigation system regulate flows in much of the assessment area. Regulated flows provide many benefits including reliable irrigation water (decreasing the threat of drought for farmers and ranchers) and a reduced flood risk to the City of Prineville. Flood hazard is an important concern for the City of Prineville, which was declared a disaster area by President Clinton after the 1998 flood on Ochoco Creek. With increasing urban growth centered in and around the City of Prineville and Ochoco Creek, controlling flood hazards is an important objective (ODFW, 1996; WSPE 1997; USDA USFS, 1998b; McSwain, 2000; CRWC, 2002). However, natural cycles of flooding and sediment transport have been altered in the regulated portions of the watershed (e.g., the Crooked River and Ochoco Creek). Channel shape, riverine vegetation, and in-stream aquatic communities have changed as a result of flow regulation. Prior to construction of the two major dams, the assessment area experienced regular flood events that created complex stream channels with a diversity of structure and habitats for native aquatic species.

Natural wetland and riparian areas, particularly within the increasingly urbanized area of Prineville, have been filled, removed, or relocated. This has in turn altered the storage and transport of water through this area of the basin and has increased the flashiness of hydrologic events. In some cases, riparian vegetation also has been systematically removed in an effort to increase water quantity for irrigation. Many streams are also paralleled by roads adding additional impacts to riparian areas and channel morphology (ODFW, 1996; WSPE 1997; USDA USFS, 1998b; McSwain, 2000; CRWC, 2002).

Although the assessment area has been subjected to extensive channel modifications, it is beyond the scope of this assessment to comprehensively inventory the channel modifying events that have led to the current channel conditions in the Lower Crooked River Watershed. The objectives of this chapter are to: (1) identify existing structures such as dams, irrigation diversions, channel crossings, and adjacent roads, (2) identify development within the 100 year floodplain, and (3) perform a hydrologic analysis to compare historic Channel Habitat Types (CHTs) to the CHTs currently found in the assessment area. Objectives 1 and 2 are addressed in Section 4.3. An introduction to CHTs and the CHT analysis is found is Section 4.4 of this chapter.

## 6.2 METHODOLOGY

Dams and irrigation diversions in the assessment area were inventoried by the Oregon Water Resources Department (OWRD). OWRD staff conducted field surveys of all the diversions within the assessment area in 2004 and 2005. This data includes a dam or diversion description, GPS location, and digital photographs. Included in the inventory are diversions that are currently in use and several that have been abandoned. Abandoned diversions are considered as channel modifications for this assessment only if a channel modifying structure remains in place. Channel crossings were compiled using GIS data. Channel crossings are defined as roads, railroads and irrigation canals that cross major watercourses. Adjacent roads are defined as roads and major all-terrain vehicle (ATV) trails located within 200 feet of streams. Available road and ATV trail data were used in GIS for this analysis. Each set of data was input into ArcGIS 9.1 to display the results. A summary of these results is presented below in Section 4.3 – Channel Modifying Structures. A map highlighting these road and trail sections is located in the Maps Section.

Development within the 100-year floodplain was assessed by overlaying the 100 year floodplain delineated by the Federal Emergency Management Agency (FEMA, 1989) with the improved land tax designation in the Crook County tax parcel database. Improved land includes structures, natural resource extraction, and certain farm uses. Improved land is classified by parcel. The overlay of the two datasets indicates that a portion of the parcel classified as improved land is within the 100-year floodplain, but does not directly imply that the development or improved activity actually occurs within the 100-year floodplain. To quantify actual development or improved activities within the 100-year floodplain requires either the interpretation of aerial photographs or field surveys of parcels classified as improved.

## 6.3 CHANNEL MODIFYING STRUCTURES

### 6.3.1 Dams and Diversions

The assessment area comprises a large portion of irrigated agricultural land. Water used for irrigation is stored in the Prineville Reservoir, created by the Bowman Dam, and the Ochoco Reservoir, created by the Ochoco Dam. Irrigation water is also diverted directly from the rivers, streams, and springs by smaller permanent structures, seasonal dams of various types, and pumps.

The Bowman Dam on Crooked River and the Ochoco Dam on Ochoco Creek form the upstream boundaries of the assessment area. The dams are full channel spanning structures that block the natural channel and regulate flows downstream. The dams have multiple effects on the downstream channels, including alteration of the hydrologic regime, and restriction of sediment transfer from the upper watershed to the Lower Crooked River, which is a concern for maintenance and restoration of riparian vegetation and channel conditions on the lower Crooked River (CRWC, 2002; McSwain, 2005). The timing, duration, frequency, and magnitude of flows in the hydrologic system have changed such that in some reaches average flows are higher than the historical flows during the late spring and summer irrigation season when water is released, and are lower during the fall, winter, and early spring when water is stored for the irrigation season. The seasonal timing of flows also impacts the establishment and growth of riparian vegetation that helps to stabilize channel banks (ODFW, 1996).

Storing water and regulating flow through the dams dampens events that historically created peak flows and floods downstream of the dams. Peak flows have been significantly reduced following closure of Bowman Dam on the Crooked River. For the period 1909-1991 for which peak flow data is available, average peak flows fell by half, from approximately 4,000 cubic feet per second (cfs) prior to dam closure to about 1,950 cfs following closure of the dam. This reduction in peak flows has resulted in a reduction in channel capacity below the dam (BLM 2001). In addition, prior to the dam, approximately 44% of peak flows equal or exceeded 4,000 cfs, with some years reaching as high as 8,400 cfs, whereas peak flows released from the dam have never exceeded 3,300 cfs. Following the construction of the Bowman Dam peak flows have generally occurred when the reservoir is at or near storage capacity and an event such as rain on snow, heavy rain, or a temperature change causes a rapid snow pack melt. For example, in the spring of 2006 heavy rains and warm temperatures generated heavy runoff from areas upstream of both dams. As a result, flows out of the dams were increased in order to maintain the reservoirs. The combined average daily discharge out of both the Ochoco and Bowman dams topped 2,000 cfs for five weeks between March and May 2006, with three weeks of 3,000 cfs average daily discharge during April. Discharges of this magnitude for this duration are considered relatively high. However, prior to the closure of the Bowman Dam 2,000 cfs was a common discharge and is below the peak flow for most of the pre-dam period of record (i.e. peak flows for the period 1909-1960 exceeded 2,000 cfs 85% of the time). As a result, the Crooked River and Ochoco Creek do not receive the flushes of water and sediments that occurred historically, and when high-flows do occur, the impact on channel conditions is greater due to decreased channel capacity.

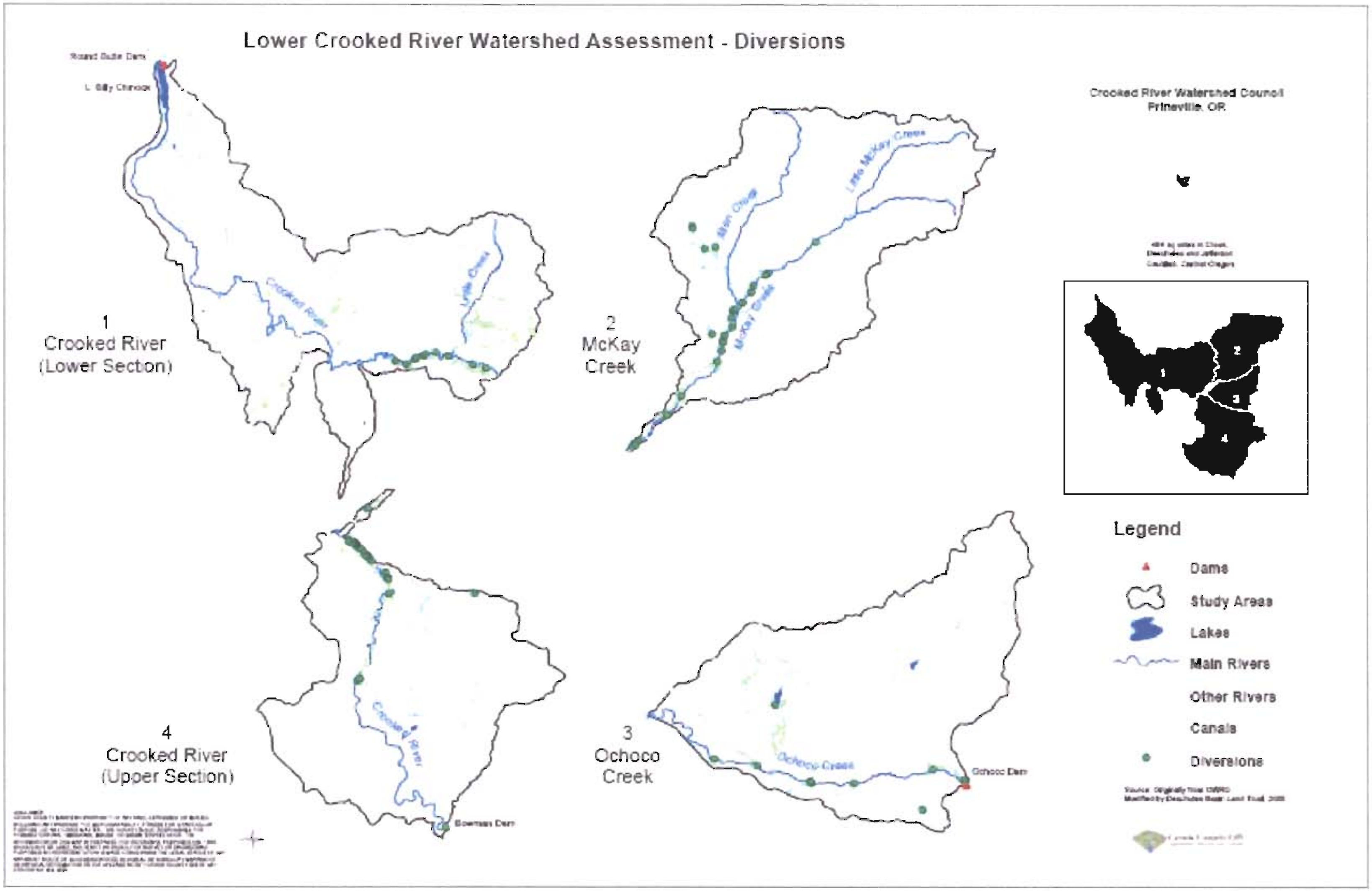
A third large channel spanning dam that impacts channel conditions is the Opal Springs Dam, a hydroelectric facility at Opal Springs operated by the Deschutes Valley Water District. Water from this large concrete diversion structure is used to generate electricity, to deliver drinking water to the City of Madras, and to provide water for a bottling operation. Channel impacts from the Opal Springs dam include the disruption of sediment transport, the diversion of flow, and a barrier to upstream fish passage. The Opal Springs dam is located in a confined canyon and does not have other channel forming impacts.

There are also numerous smaller irrigation dams and diversions, within the assessment area. According to an inventory conducted in 2004-2005 by the OWRD, there are 71 irrigation diversions in the assessment area, 27 of which include channel spanning dams (Map 6-1). Although the inventory does not identify specific channel impacts, each dam effects natural channel processes. Diversions modify the channel directly at the point of the diversion structure, upstream of the diversion in the reservoir pool, and downstream of the diversion where the tailwaters continue down the channel. Diversions modify channels at the location of the diversion by confining channels into narrow widths. Upstream of the diversion, water velocity is reduced in the reservoir pool and can increase water temperatures and sediment deposition. Finally, while diversions are in use, the quantity of tailwater flowing past the diversion structure is reduced again with potential to impact physical parameters such as velocity and sediment transport capacity, as well as water quality parameters such as temperature.

In each of the sub-watersheds, except Ochoco Creek, diversion locations are concentrated. On McKay Creek diversions are primarily concentrated below the confluence with Allen Creek. On the Crooked River diversions are concentrated near the City Of Prineville and below the confluence with Lytle Creek. A concentration of diversions creates concentrated impacts.

### 6.3.2 Channel Crossings and Adjacent Roads

Channel crossings often constrict the channel width and therefore alter natural channel forming processes in two ways. First, structures that constrict the dimensions of the channel can be problematic during high flow events. These crossings can restrict flow on the upstream side and increase velocity downstream resulting in predictable sediment deposition above and increased bank erosion below the structure. Additionally, because of the placement, material type, and velocity through crossings, many channel crossings may impair fish passage at specific life stages and under certain flows. There are



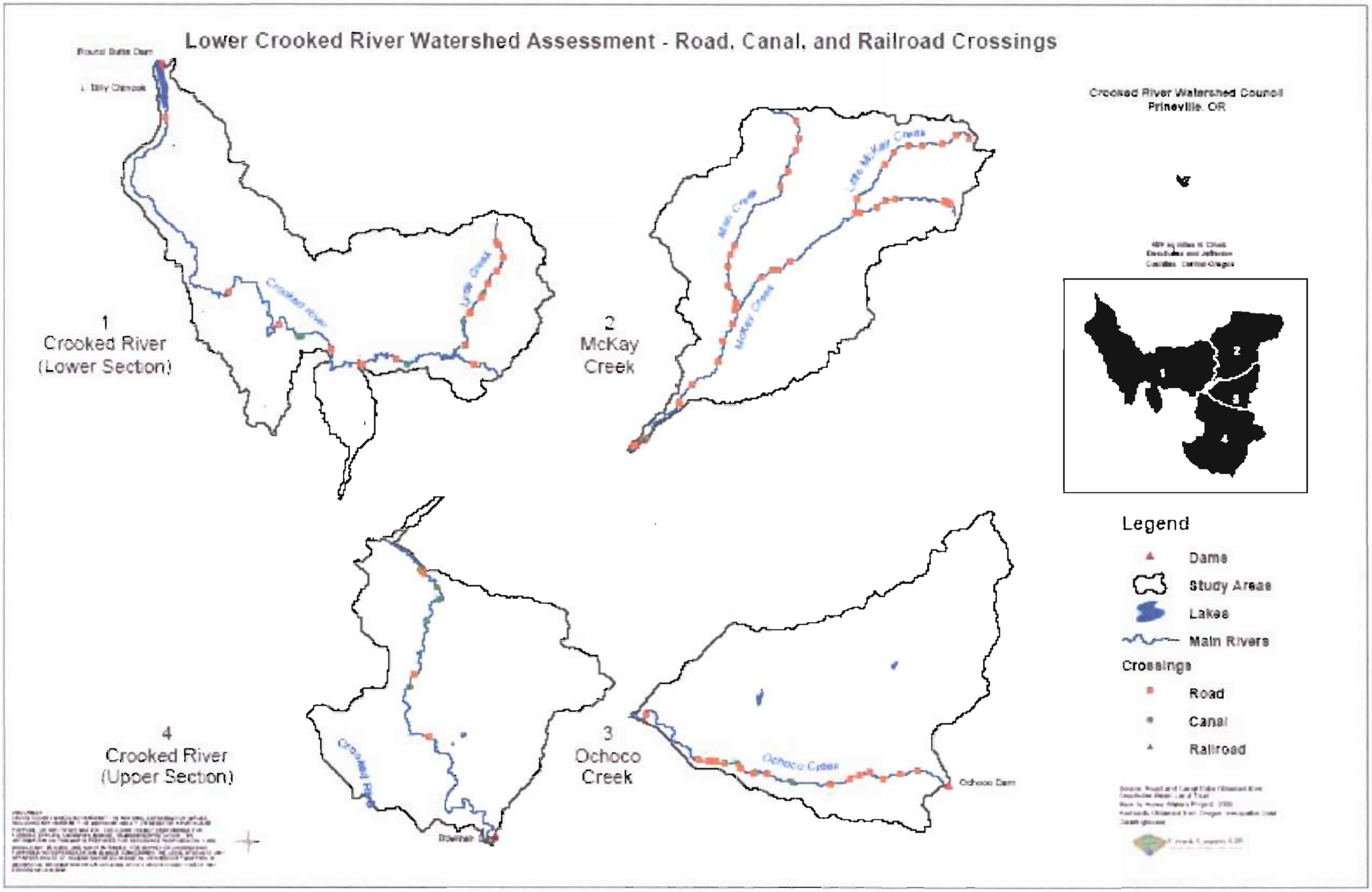

**Map 6-1. Diversions dams in the four main subwatersheds**

approximately 132 miles of major water bodies in the assessment area, and these water bodies are crossed 98 times (Table 6-1). The Crooked River lower section averages 1 crossing every 2.75 miles. The Crooked River upper section averages 1 crossing every 1.6 miles. Ochoco Creek averages 1 crossing every 0.6 miles. Ochoco Creek's crossings are concentrated in the City of Prineville. McKay Creek averages 1 crossing every 0.9 miles.

There are 63 miles of roads within 200 feet of the 132 miles of main watercourses in the assessment area (Table 6-2). The McKay Creek Watershed has the highest road density of the four sub-watersheds (0.23 miles of road within 200 feet of streams per square

Table 6-1. Crossing by Study Areas (Crook County GIS, 2005)

| Type of Crossing | Number of Crossings |
|---|---|
| **Crooked River Lower Section** | |
| Road | 17 |
| Canal | 5 |
| Railroad | 2 |
| **Crooked River Upper Section** | |
| Road | 3 |
| Canal | 7 |
| Railroad | 0 |
| **Ochoco Creek** | |
| Road | 16 |
| Canal | 3 |
| Railroad | 1 |
| **McKay Creek** | |
| Road | 40 |
| Canal | 3 |
| Railroad | 1 |
| **Assessment Area Total** | **98** |




**Map 6-2. Road, canal, and railroad crossings of the four main subwatersheds**

Table 6-2. Riparian Road Density (Crook County GIS, 2005)

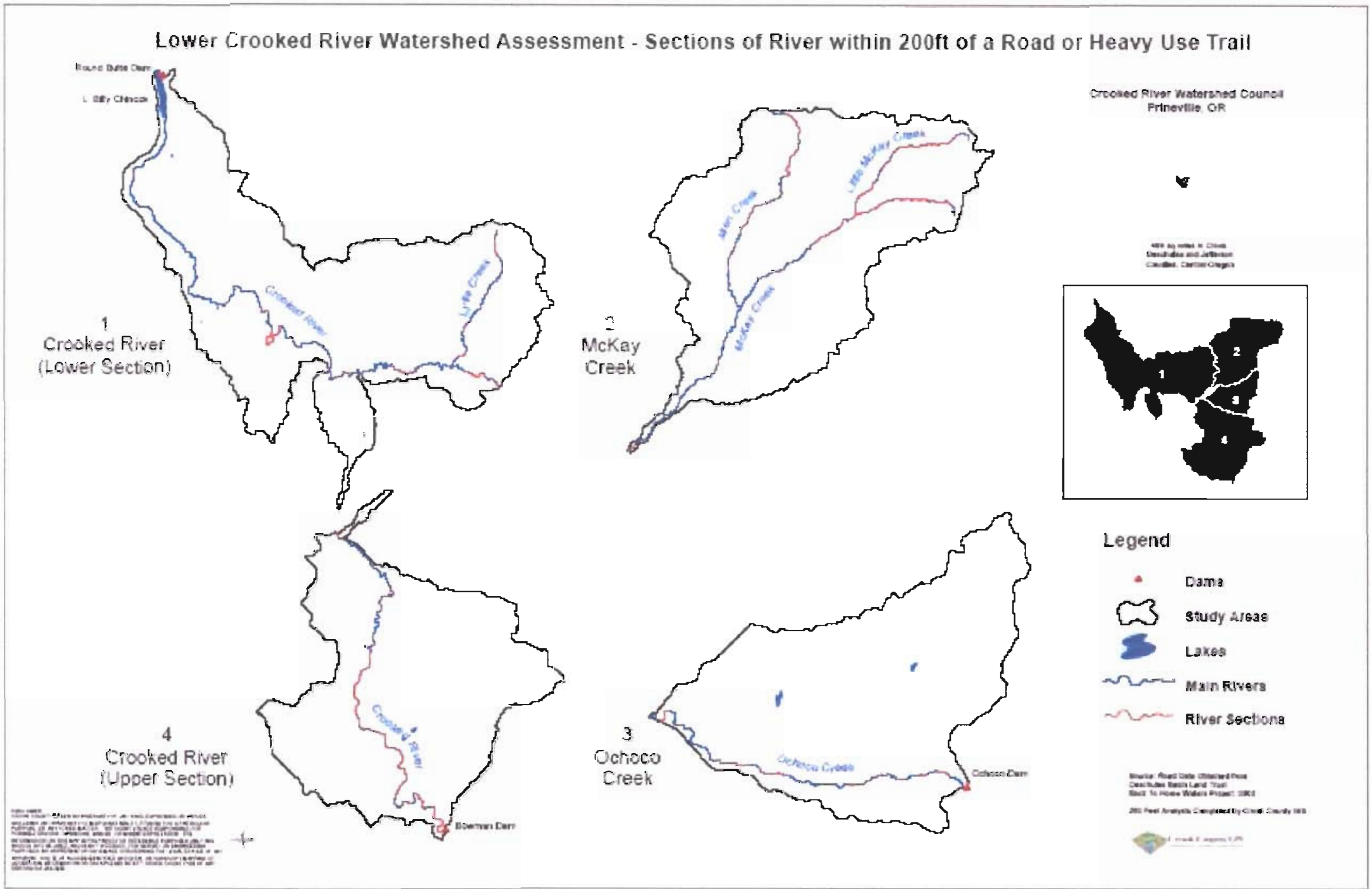
| Study Area | Study area ($mi^2$) | Roads within 200ft of streams (mi) | Road density ($mi/mi^2$) |
|---|---|---|---|
| Crooked River Lower Section | 202 | 15 | 0.07 |
| Crooked River Upper Section | 127 | 20 | 0.16 |
| McKay Creek | 99 | 23 | 0.23 |
| Ochoco Creek | 40 | 5 | 0.13 |
| **Total** | **469** | **63** | **0.13** |

mile). While the road density for Ochoco Creek is relatively low, the data used for this analysis does not include driveways and established trails that run along the creek, which occur in greater proportion on Ochoco Creek than in any of the other sub-watersheds due to the urban influence of Prineville.

### 6.3.3 Floodplain Development

Floodplain modification within the assessment area has occurred mainly to accommodate urban and residential development. In other cases, floodplain modification has been for agricultural land uses. Within the Crook County portion of the assessment area (including Prineville UGB), the Crook County tax parcel map identifies tax parcels comprising 3093 of 6278 acres (49%) of the 100-year floodplain as improved land. The improved land designation is for parcels with residential, commercial, or industrial structures, approved natural resource extractions, and certain farm uses.

In the City of Prineville, tax parcels comprising 184 of the 336 acres (55%) of the 100-year floodplain are designated as improved parcels. While the extent of floodplain development is notable, especially given the history of flooding on Ochoco Creek, the GIS analysis does not identify whether the actual improved use is within the 100-year floodplain. In some cases the parcel may include portions in the floodplain while the improved use may be outside the extent of the floodplain.




Map 6-3. Sections of River within 200ft of a Road or Heavy Use Trail

Regardless of any ambiguity in the above analysis, floodplain development is a concern, especially on Ochoco Creek. In 1998 the combination of a rain event and reservoir management created a flood along Ochoco Creek. On May 30, 1998 approximately 2,050 cfs was discharged from Ochoco Dam, and an addition 350 cfs entered Ochoco Creek at Hidden Falls. Several irrigation diversions on Ochoco Creek backed approximately 580 cfs into farm fields above Prineville, resulting in a total of approximately 1,770 cfs flowing past Combs Flat Road on the east edge of Prineville. The flood resulted in approximately eleven million dollars in property damage, impacting 300 homes, destroying 50 homes, and contaminating over 60 private wells. Nonetheless, according to research done by the Crook County Natural Resources Planning Committee (CCNRPC) development within the floodplain has continued since the 1998 flood, despite recommendations against continued floodplain development from FEMA and the National Riparian Service Team (FEMA, 1998; National Riparian Service Team, 1998; CCNRPC, 2005). Furthermore, the several irrigation diversions on Ochoco Creek that backed 580 cfs into adjacent farm and ranch fields have been replaced with pump and other diversions that will not store water in future flood events.

## *6.4 CHANNEL HABITAT TYPE CLASSIFICATION*

### 6.4.1 Introduction

The classification of Channel Habitat Types (CHT) is used to determine which reaches of the stream network have a high potential for fish production and which are sensitive to disturbance. Classification also helps determine problematic reaches and assist in development of restoration designs (Watershed Professionals, 1999). There are a number of different methodologies used to classify channel habitat types and most methodologies are based on a combination of gradient, width, and other stream channel parameters (Table 6-3). David Rosgen, a professional hydrologist, developed a method that is commonly utilized by government and non-government agencies performing stream analysis. For the purpose of the assessment, the Rosgen method of channel classification

Table 6-3. Summary of CHT Classification Systems (Watershed Professionals Network, 1999)

| Basic Stream Classification Diagnostic Features | Frissell et al. (1986) Seg/Reach Systems[1] | Cupp (1989)[2] | Paustian et al. (1992)[3] | Montgomery & Buffington (1993) Levels II, III, IV | Rosgen (1996) Levels I, II | Moore et al. (1997) ODFW hab. Survey[4] |
|---|---|---|---|---|---|---|
| Valley bottom shape[5] | Qualitative | X | X | Implied | X | X |
| Valley bottom slope and/or stream gradient[5] | X | X | X | X | X | X |
| Side-slope gradient[5] | Qualitative | X | X | | | X |
| Incision depth or entrenchment | | | X | | X | X |
| Bankfull width | | | X | | X | X |
| Active channel width/depth ratio | | | | | X | |
| Valley bottom width: active channel width ratio | | X | | Qualitative confinement | Uses entrenchment | X |
| Position in the drainage network, stream order, or drainage area[5] | X | X | X | Implied | X | X |
| Bed features, channel morphology | X | | | X | Measured | X |
| Plan view channel pattern[5] | X | X | X | | X | Unconstrained channels only |
| Stream-adjacent landforms | | X | | | X | X |
| Other criteria | Lithology, riparian veg., soil assoc., bank composition | | Dominant substrate, bank composition | Sediment supply/sources, substrate; defines reach types | Sinuosity | Substrate, bank composition, riparian data, LWD, other |
| Initial delineation | | Maps | Aerial photographs | | I-remote sensing, existing inventories; II-field measurements | Field surveys |
| Number of basic channel groups[7] | | 5 | 9 | 8 | 9 | Habitat unit level |

1 Oriented to small mountain streams in forested environments; provides theoretical framework rather than specific categories.

2 Developed for forested lands in Washington State.

3 Developed for Tongass National Forest, Alaska.

4 Method is more of a habitat survey than channel classification system.

5 Those criteria identifiable from maps.

6 Montgomery and Buffington (1993) believe stream order inappropriate as a foundation for geomorphic channel classification due to differences in mapping detail, drainage density differences between basins, discharge, and landscape controlling factors.

7 Basic Channel Groups: F - flat cross-section profile, M - moderate gradient sideslopes, V - V-shaped valleys, U - U-shaped valleys, H – headwater tributaries (Cupp 1989), ES - estuarine, PA - palustrine, FP - floodplain, GO - glacial outwash, AF - alluvial fan, LC – large contained, MM - moderate gradient mixed control, MC - moderate gradient contained, HC - high gradient contained (Paustian et al. 1992) braided, regime, pool-riffle, plane bed, step-pool, cascade, bedrock, colluvial (Montgomery and Buffington 1993).

was used. Other classifications systems used in the assessment area include the Moore et al. (1997) system used by ODFW and the Oregon Watershed Enhancement Board's (OWEB) Assessment Manual's system (Walter, 2000).

Rosgen (1996) outlines four levels of assessment. A level I assessment was selected as the appropriate level of assessment for this assessment. The Rosgen level I classification examines channel patterns relative to the surrounding valley, the gradient of the channel, and the cross sectional channel shape to assign a type to each respective stream reach. A Level I assessment provides a geomorphic characterization of the stream. Four primary factors are analyzed in the Level 1 assessment: (1) the stream entrenchment ratio, which is the ratio of the flood-prone width to the bankfull channel width, (2) the bankfull channel width to bankfull depth ratio, (3) channel sinuosity, and (4) channel gradient or slope.

### 6.4.2 Channel Habitat Types (CHTs)

Rosgen (1996) describes nine different channel types in his classification system: Aa+, A, B, C, D, DA, E, F and G (Table 6-4). Of these, B, C, E, F and G types are found within the assessment area; however, it became evident during the field surveying process that many of the reaches cannot be simply classified using one channel type. For example, in many locations C channels were forming within the incised walls of an F channel.

Another channel classification is the ditch channel type, which is taken from the Upper Williamson Watershed Assessment (Draft, 2004). Use of the ditch channel in this assessment was justified by the extensive human influence on the channel of Lytle Creek. The Upper Williamson Assessment (Draft, 2004) states "during the course of the assessment it became apparent that there is a small but significant group of channels that are so highly modified that it would be impossible to place them within any of the Rosgen channel types" (Evans, 2004). The findings of the CHT field analysis are presented below. Additionally, the CHT Map and corresponding table are located in the Maps Appendix. The Map includes numbered stream reaches that correspond to CHTs in the accompanying table.

Table 6-4. Channel Type Descriptions (Rosgen, 1996; Watershed Professionals Network, 1999)

| Rosgen Stream Type | Comparable OWEB Stream Type(s) | General Description | Entrenchment Ratio | W/D Ratio | Sinuosity | Slope | Landform/soils/features |
|---|---|---|---|---|---|---|---|
| Aa+ | VH<br>SV | Very steep, deeply entrenched, debris transport streams. | < 1.4 | < 12 | 1.0 – 1.1 | > 0.10 | Very high relief. Erosional bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls. |
| A | SV<br>BC<br>MV<br>MH | Steep, entrenched cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel. | < 1.4 | < 12 | 1.0 - 1.2 | 0.40 – 0.10 | High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools associated step-pool bed morphology. |
| B | MH<br>MM | Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks. | 1.4 – 2.2 | > 12 | > 1.2 | 0.02 – 0.04 | Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with occasional pools. |
| C | LM<br>FP1<br>FP3 | Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad well defined floodplains. | > 2.2 | > 12 | > 1.4 | < 0.02 | Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology. |
| D | AF<br>FP2 | Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks. | N/A | > 40 | N/A | < 0.04 | Broad valleys with alluvial and colluvial fans. Glacial debris and depositional features. Active lateral adjustment, with abundance of sediment supply. |

| Rosgen Stream Type | Comparable OWEB Stream Type(s) | General Description | Entrenchment Ratio | W/D Ratio | Sinuosity | Slope | Landform/soils/features |
|---|---|---|---|---|---|---|---|
| DA | LM<br>LC | Anastomosing (multiple channels) narrow and deep with expansive well vegetated floodplain and associated wetlands. Very gentle relief with highly variable sinuosities. Stable streambanks. | > 4.0 | < 40 | Variable | < 0.005 | Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastamosed (multiple channels) geologic control creating fine deposition with well-vegetated bars that are laterally stable with broad wetland floodplains. |
| E | FP1 | Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander ratio. | > 2.2 | < 12 | > 1.5 | < 0.02 | Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well vegetated banks. Riffle-pool morphology with very low width/depth ratio. |
| F | | Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio. | < 1.4 | > 12 | > 1.4 | < 0.02 | Entrenched highly weathered material. Gentle gradients, with a high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology. |
| G | | Entrenched "gully" step/pool and low width/depth ratio on moderate gradients. | < 1.4 | < 12 | > 1.2 | 0.02 to 0.04 | Gully, step-pool morphology with moderate slopes and low W/D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials; i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates. |

### 6.4.3 Methods for Delineating Channel Habitat Types

Channel gradient can be estimated using GIS data; while the rest of the parameters must be determined by field measurement. Using the parameters outlined above, the Crooked River and Ochoco, McKay, Allen, Little McKay and Lytle Creeks were assessed and divided into reaches according to Rosgen's stream types. A variety of different channel habitat type analyses for the portions of the assessment area already exist, and summaries of each are presented below. However, different methods are employed by different agencies and many of the existing assessments have missing reaches due to limited access in some areas of the watershed. A comprehensive analysis of the Lower Crooked River Watershed has not been done. Therefore, this assessment includes a level I Rosgen (1996) assessment of channel habitat types for the entire assessment area, and a review of existing channel habitat assessments.

The delineation of CHTs for this assessment employed the following data sources:

- A gradient map was created using a 10-meter Digital Elevation Models (DEM) data in ArcGIS 9.0.
- High quality topographic maps generated by the Deschutes Land Trust using National Geographic Topo 2004.
- Field data gathered by the Watershed Council hydrologist and assessment coordinator.
- Aerial imagery and experience of local watershed professionals was used when access for field surveys was limited or restricted.

The assessment area channel network was initially categorized into similar types based on channel gradient class using the gradient map. The gradient map differentiated stream segments in the assessment area according to the six gradient classes. These gradient classes are <1%, 1-2%, 2-4%, 4-8%, 8-16% and >16%. Channel confinement and valley types were classified using topographic maps to offer an initial prediction of the type of channel that might exist (i.e., confined channels and narrow valley types tend to be occupied by low sinuosity channels). The topographic maps were also used to identify channel patterns that could be single thread, multiple thread, and anastamosed. Channel threads refer to the number of channels associated with an individual stream with multiple threads being separated by land forms or sediment bars.

Channel entrenchment is the ratio of the bankfull width to the width of the current floodplain, where bankfull width is the width of the channel at which overbank flooding begins. Such flooding commonly occurs at 1.5-year intervals. The current floodplain is defined as the flood-prone area, but may or may not correspond to the 100-year floodplain (Rosgen, 1996; Watershed Professionals Network, 1999). Although data limitations prevented the estimation of channel entrenchment, new high resolution data (i.e., LiDAR data available for the Ochoco Creek and the Lower Crooked River) is now available and should be used in the future to estimate channel entrenchment. Estimation of channel entrenchment at the watershed scale may help to prioritize restoration efforts.

### 6.4.4 Preexisting CHT Assessment Summaries:

Ochoco National Forest – McKay Creek (USDA FS, 1997)

*Survey Site:* The Forest Service survey was conducted from the Forest boundary to the headwaters of McKay Creek. A short reach below the confluence with Little McKay Creek was not surveyed because it is on private land. Total length surveyed was 6.3 miles.

*Methodology:* Rosgen Level II Stream Inventory with Wolman pebble count technique used, flow reading taken at reach 1 using Marsh-McBirney meter, stream temperature reading taken with hobo XT's, riparian conditions assessment and fish presence/habitat noted.

*Channel Characteristics:* Overall the inventory assigns McKay a Rosgen B Channel Type Classification. By reach the inventory indicates reach 1 is Rosgen type B3, reaches 3 and 4 are type B4, reach 5 is B3, and reach 6 is typed E3b.

*Bank Stability Summary:* 100% stable for reaches 1 and 3, 98% for reach 4, 92% for reach 5 and no bank stability rating given for reach 6.

Ochoco National Forest – Crooked River (USDA FS, 2003)

*Survey Site:* The Forest Service survey was conducted on the lower reaches of the Crooked River from Lake Billy Chinook to the upper end of the grassland boundary at river mile 17.

*Methodology:* Level II Stream Inventory Region 6 protocol (United States Forest Service, Pacific Northwest Region 2003) including CHT classification, riparian conditions assessment and fish presence/habitat noted.

*Channel Characteristics:* Overall the inventory assigns this section of the Crooked River a Rosgen G 2/3 channel type with all three surveyed reaches having this same type.

Oregon Department of Fish and Wildlife – McKay Creek (ODFW, 1997c)

*Survey Site:* ODFW's McKay Creek survey was conducted on the lower reaches, from its confluence with the Crooked River to the USFS boundary. Not all reaches were included due to access.

*Methodology:* Oregon Department of Fish and Wildlife Stream Habitat Survey (Moore et al., 1997).

*Channel Characteristics:* Overall channel type is broad valley floor. Stream channel constrained by terraces in all reaches. Stream channel in reach one constrained by land use (berms).

*Bank Stability Summary:* 50% vegetatively stable, 50% actively eroding banks.

Oregon Department of Fish and Wildlife – Lower Crooked River (ODFW, 1997b)

*Survey Site:* Lake Billy Chinook Confluence to Smith Rock State Park

*Methodology:* Oregon Department of Fish and Wildlife Stream Habitat Survey (Moore et al., 1997).

*Channel Characteristics:* Channel type is a steep v-shaped, narrow valley floor for the lower reaches and a broad valley floor with constraining terraces in the upper reaches.

*Bank Stability Summary:* 40% non-eroding bedrock banks in lower reaches. Of potentially eroding sections (upper reaches) approximately 80% are vegetatively stable and 20% actively eroding.

Oregon Department of Fish and Wildlife – Lower Crooked River (ODFW, 1997b)

*Survey Site:* Stearns Dam to Bowman Dam

*Methodology:* Oregon Department of Fish and Wildlife Stream Habitat Survey, Moore et al. (1997).

*Channel Characteristics:* Channel conditions for the three reaches are described as: moderate v-shape narrow valley floor, multiple terraces broad valley floor, and steep v-shaped narrow valley floor, from lower to upper reaches.

*Bank Stability Summary:* 90% Vegetatively stabilized, 10% actively eroding.

<u>Ochoco Creek Flood Assessment – Ochoco Creek</u> (National Riparian Service Team, 1998)

*Survey Site:* Lower Ochoco Creek, from Ochoco Dam through the City of Prineville to the confluence with the Crooked River.

*Methodology:* The assessment team (NRST, ODFW, USFS, BLM) walked the creek at the request of City and County officials following the May 1998 flood event, looking specifically at channel stability, channel capacity, fish and wildlife habitat, flood damage and riparian management opportunities.

*Channel Characteristics:* Channel was engineered to be straighter than expected given valley size and gradient. Flood flow energy, failure of a diversion dam and subsequent redistribution of bedload behind the dam caused dramatic erosion of the streambank and terrace, widening of the channel, and formation of new gravel bars. Event began to recreate a more natural meander pattern. Channel capacity not changed through town from flood event.

<u>Crooked River Watershed Council – McKay Creek Assessment</u> (Walter, 2000)

*Survey Site:* Entire creek, 37.7 miles

*Methodology:* OWEB methodology (Walter, 2000). Based on 1996 and 1998 aerial photos and field verification in 2000.

*Channel Characteristics:* McKay Creek has a variety of channel habitat types. Predominant channel habitat types on McKay Creek include low gradient large floodplain channel, followed by moderate gradient moderate to confined channels. Less common channel habitat types include: low gradient moderately confined, low gradient confined, and moderate gradient headwater channels. Channel sensitivity is rated as high for 74% of McKay Creek, moderate for 19% and low for 7%.

Crooked River Watershed Council – Little McKay Creek Assessment (Walter, 2000)

*Survey Site:* Entire creek, 12.5 miles

*Methodology:* OWEB methodology (Walter, 2000). Based on 1996 and 1998 aerial photos and field verification in 2000.

*Channel Characteristics:* The predominant channel habitat type is moderate gradient, confined channel. Channel sensitivity for Little McKay Creek is rated as moderate for 56% and low for 44%.

Crooked River Watershed Council – Ochoco Creek Assessment (Walter, 2000)

*Survey Site:* Entire creek, 48.8 miles (includes area above the dam outside of assessment area)

*Methodology:* OWEB methodology (Walter, 2000). Based on 1996 and 1998 aerial photos and field verification in 2000.

*Channel Characteristics:* The predominant channel habitat type is a large floodplain channel, followed by low to moderate gradient, moderately confined channel. Channel sensitivity is rated as high for 84% of the creek, moderate for 5% and low for 2.7%.

### 6.4.5 CHTs in the Assessment Area

Channel Habitat Types found within the assessment area are described below and summarized in Table 6-5 and Maps 6-4 and 6-5.

Type B Channels

Type B channels are moderately entrenched, have moderate gradient and are riffle dominated channels with infrequently spaced pools. Type B channels are characterized as having a very stable plan and profile, and stable banks (Rosgen, 1996). The B channel type applies to the greatest length of stream channel in the assessment area at approximately 47 miles. These channels are primarily located in the headwaters areas of Allen, McKay and Lytle Creeks, as well as on sections of the Crooked River where the stream gradient is greater. Furthermore, the entire length of Little McKay Creek is a B channel. Ochoco Creek, on the other hand, was found to have no B channel type reaches.

### Type C Channels

Type C channels have low gradient, and are meandering, point-bar, riffle/pool, alluvial channels with broad well-defined floodplains (Rosgen, 1996). Many of the historic C channels in the assessment area are incised, and although they are forming new floodplains within the incised channel they are more accurately classified as a C/F channel. True type C channels are found in all the major waterbodies except for Lytle and Little McKay Creeks. Approximately 32 miles of streams in the assessment area are classified as C channels.

### Type E Channels

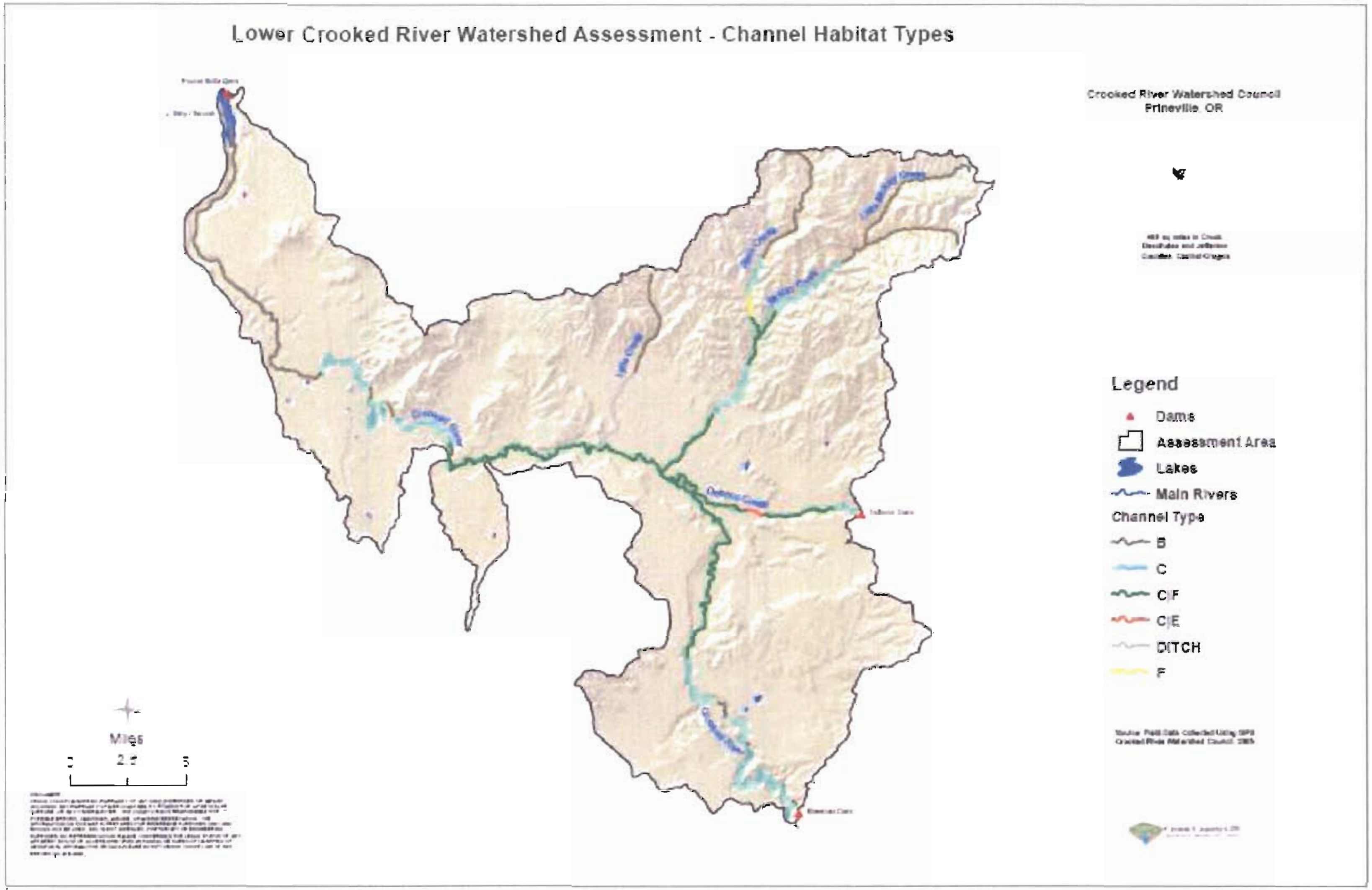
Type E channels are characterized by low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. They are very efficient and stable with high meander to width/length ratio (Rosgen, 1996). There are no stand alone E channels in the assessment area; however, there is a small section of C/E on Ochoco Creek for approximately 1 mile.

### Type F Channels

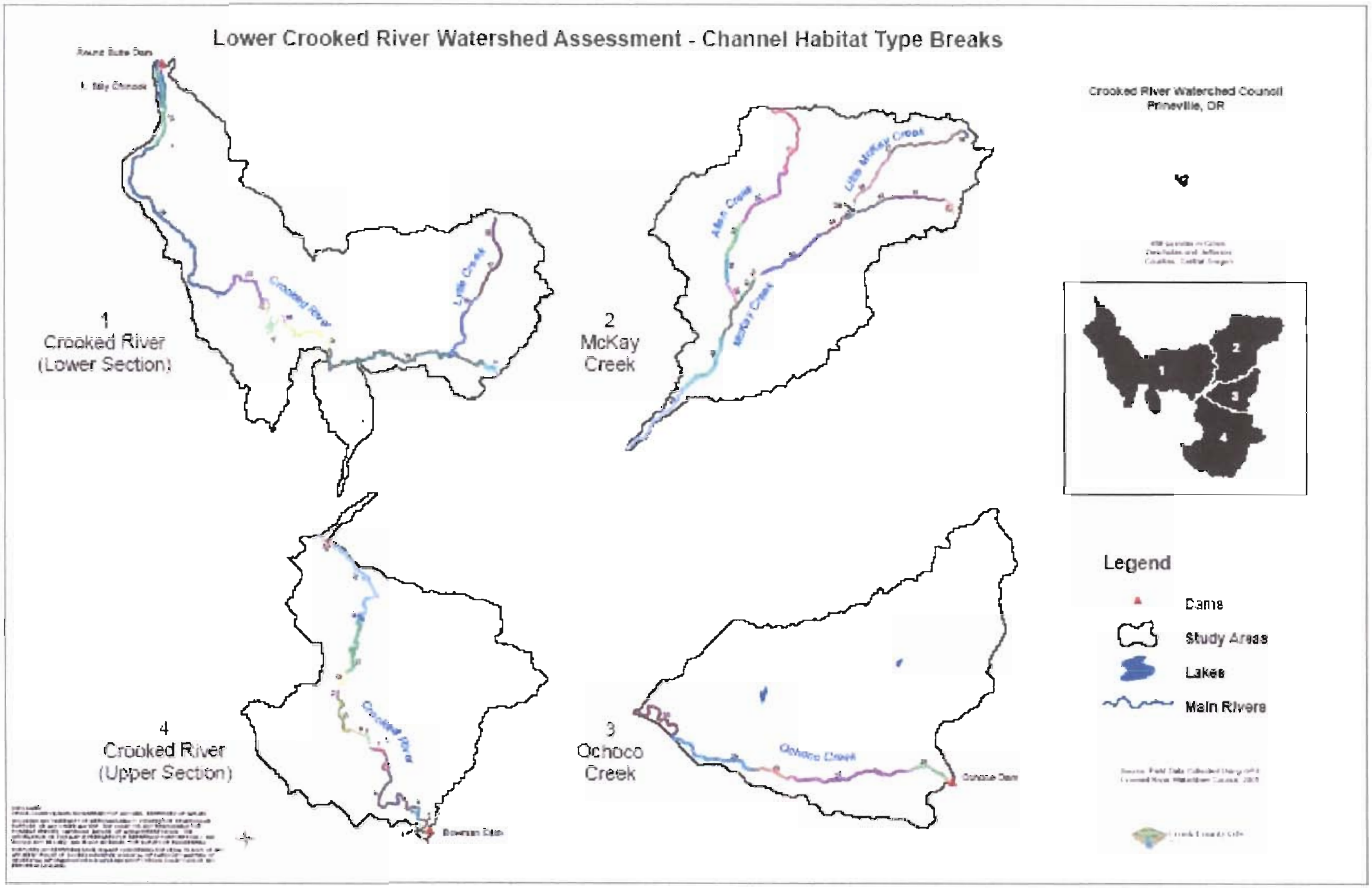
Type F channels are entrenched meandering riffle/pool channels on low gradients with high width/depth ratio. Many of the channels within the assessment area can be characterized as another channel type within a wider F channel. Although the majority of the channel types found in the assessment area have some F channel type features, there is only one small section of true F channel type. This section is approximately 1 mile of Allen Creek where the channel is entrenched by an engineered berm.

### Type G and C|F Channels

This class of channels indicates some type of active transition in channel morphology. Type G channels are entrenched to the point of being a "gully." G channels have a step/pool morphology with a low width/depth ratio on moderate gradient channels (Rosgen, 1996). A previous Rosgen Level III survey from 2003 conducted by the Ochoco National Forest classified a portion of the




**Map 6-4. Channel Habitat Types**




Map 6-5. Channel Habitat Types by Reach (numbers indicate reach ID referenced in Appendix 6-1.

Lower Crooked River as a G type channel. Portions of Lytle Creek could also be classified as a G channel; however, a ditch channel type was determined to be a more accurate description. G channels are a transition phase between other channels types and wider incised F channels that may be naturally rebuilt into B, C, or E channels. Even though no G channels have been identified during the present survey, some stream reaches in the assessment area have transitioned through the G channel type at some point in the past. These stream reaches are classified in Table 6-5 as C|F, indicating that they have, at some recent point, downcut into a G channel, then widened into an F channel, and may be beginning a recovery process back to a C channel. C|F channels are incised channels with a reforming floodplain at the base of the incised bank. While transitioning channels may be in a recovery process that includes recruitment of new vegetation at the bottom of the incised bank and aggradation of sediment that over time may rebuild the floodplain, transitioning channels tend to have lower channel capacity and are less stable than the original channel morphology.

Ditch Channels

Much of the lower portion of Lytle Creek is deeply entrenched and functions as a ditch for irrigation water return flows. The lower portion of Lytle Creek could be classified as a G channel; however, the channel more accurately resembles a ditch in form and function. There are some springs in the lower portion of the creek that contribute to flow, but during the irrigation season (April to October) the majority of the flow comes from irrigation water (Rhoden, 2005). The channel lacks riparian vegetation, and has deep cutbanks and low bank stability throughout the lower portions of the creek. Lytle Creek has 4.43 miles of ditch channel. This channel type was not found in any other portions of the assessment area.

### 6.4.6 Historical CHT Analysis

Comparing current channel habitat types (CHT) to probable historical CHTs provides an estimation of the amount of channel modification present in the assessment area. No baseline empirical data exists for the development of historical CHTs. Instead probable historical CHTs were developed by the expert opinion of several watershed professionals in the assessment area. CHTs are based on a Rosgen (1996) channel type classification system. Typically A type stream channels are located in the highly confined steep gradients

Table 6-5. Channel Habitat Type by Waterbodies

| Waterbody | CHT | Miles | Percentage |
|---|---|---|---|
| Allen Creek | B | 7.25 | 63.6% |
| | C | 1.69 | 14.9% |
| | C\|F | 1.34 | 11.8% |
| | F | 1.11 | 9.7% |
| | **Total** | **11.39** | |
| Crooked River | B | 21.13 | 29.4% |
| | C | 21.91 | 30.5% |
| | C\|F | 28.76 | 40.1% |
| | **Total** | **71.8** | |
| Little McKay Creek | B | 7.06 | 100.0% |
| | **Total** | **7.06** | |
| Lytle Creek | B | 5.14 | 53.7% |
| | DITCH | 4.43 | 46.3% |
| | **Total** | **9.57** | |
| McKay Creek | B | 6.51 | 31.7% |
| | C | 6.93 | 33.8% |
| | C\|F | 7.07 | 34.5% |
| | **Total** | **20.51** | |
| Ochoco Creek | C | 1.35 | 11.8% |
| | C\|E | 1.05 | 9.2% |
| | C\|F | 9.02 | 79.0% |
| | **Total** | **11.42** | |
| Assessment Area | B | 47.09 | 35.7% |
| | C\|E | 1.05 | 0.8% |
| | C\|F | 46.20 | 35.1% |
| | C | 31.87 | 24.2% |
| | DITCH | 4.43 | 3.4% |
| | F | 1.11 | 0.8% |
| | **Total** | **131.75** | |

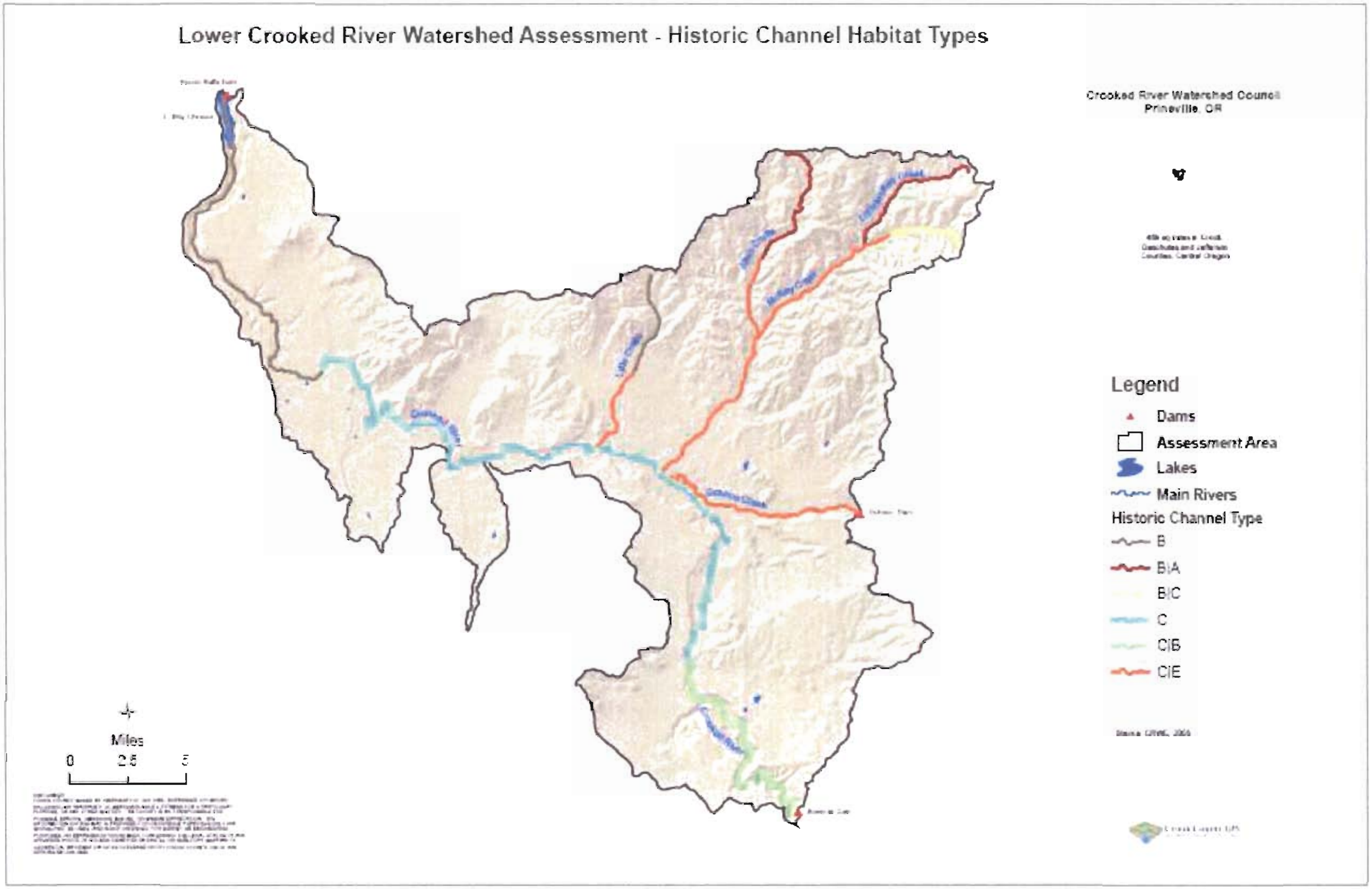
reaches. Moving downstream in a drainage network confinement and gradient tend to decrease, stream channels typically grade to B and then C and E stream channel categories. The tendency for valley type to be associated with stream channel type is an important relationship for identifying probable historical CHT. In this analysis valley type was used as one indicator of historical channel types.

The analysis indicates that major changes in channel habitat types throughout the assessment area have occurred over time (Table 6-6). In the Crooked River Lower Section study area, a large percentage of both C and E types have been lost and replaced by C|F, F, and ditch channels, with C|F and F channels indicating a lower water table and channel incision. B channels exist primarily in the canyons below the Prineville Valley, and are mostly stable. In the Crooked River Upper Section study area C and B channels have been replaced by C within F channels. In the McKay Creek study area A and C channels have been replaced by B, C within F, and F

Table 6-6. Comparison of Current to Historical CHTs (Crook County GIS, 2006)

| **STUDY AREA** | **CHTs** | **Historical (Miles)** | **Current (Miles)** | **% Change**[1] |
|---|---|---|---|---|
| CROOKED RIVER LS | B | 23.2 | 24.7 | + 6.7% |
| | C or E | 31.7 | 10.0 | - 68.5% |
| | C\|F | 0 | 16.1 | – |
| | DITCH | 0 | 4.4 | – |
| CROOKED RIVER US | B | 0 | 1.6 | – |
| | C | 12.9 | 12.0 | - 7.5% |
| | C or B | 13.5 | 0 | - 100.0% |
| | C\|F | 0 | 12.7 | – |
| MCKAY CREEK | A | 14.3 | 0 | - 100.0% |
| | B | 3.7 | 20.8 | + 462% |
| | C | 21.0 | 8.6 | - 59.0% |
| | C\|F | 0 | 8.4 | – |
| | F | 0 | 1.1 | – |
| OCHOCO CREEK | C or E | 11.4 | 2.4 | - 80.0% |
| | C\|F | 0 | 9.0 | – |

[1] A "–" in the percent change column indicates a channel type that probably did not exist historically.




**Map 6-6. Historic Channel Habitat Types**

channels. In the Ochoco Creek study area approximately 80% of the C and E channel types have been replaced by F channels. Although this analysis is based on probable historical CHTs, the results indicate that large scale changes in CHTs have taken place over time.

## 6.5 SUMMARY

Many factors contribute to the current channel conditions within the assessment area. This assessment identified a concentrated number of channel spanning diversions on McKay Creek, Ochoco Creek, and the Crooked River. These diversions modify the hydrology of the assessment area and impact channel morphology. Road density in proximity to the watercourses in the assessment area varies, but is relatively high on McKay Creek. Roads in proximity to streams and rivers may constrain channel movement and be a source of sediment and other pollutants. The level of actual development within the 100-year floodplain in the assessment area is difficult to assess from the data used in the chapter for two reasons. First, although the data suggests that over 55% of floodplain within the City of Prineville urban growth boundary is classified as improved, it is not clear whether the improved activity actually exists within the floodplain, or whether the floodplain portion of the parcel is unutilized. Second, due to growth and changes in land management since 1989 it is not clear whether the 1989 FEMA mapped 100-year floodplain is still accurate in 2007.

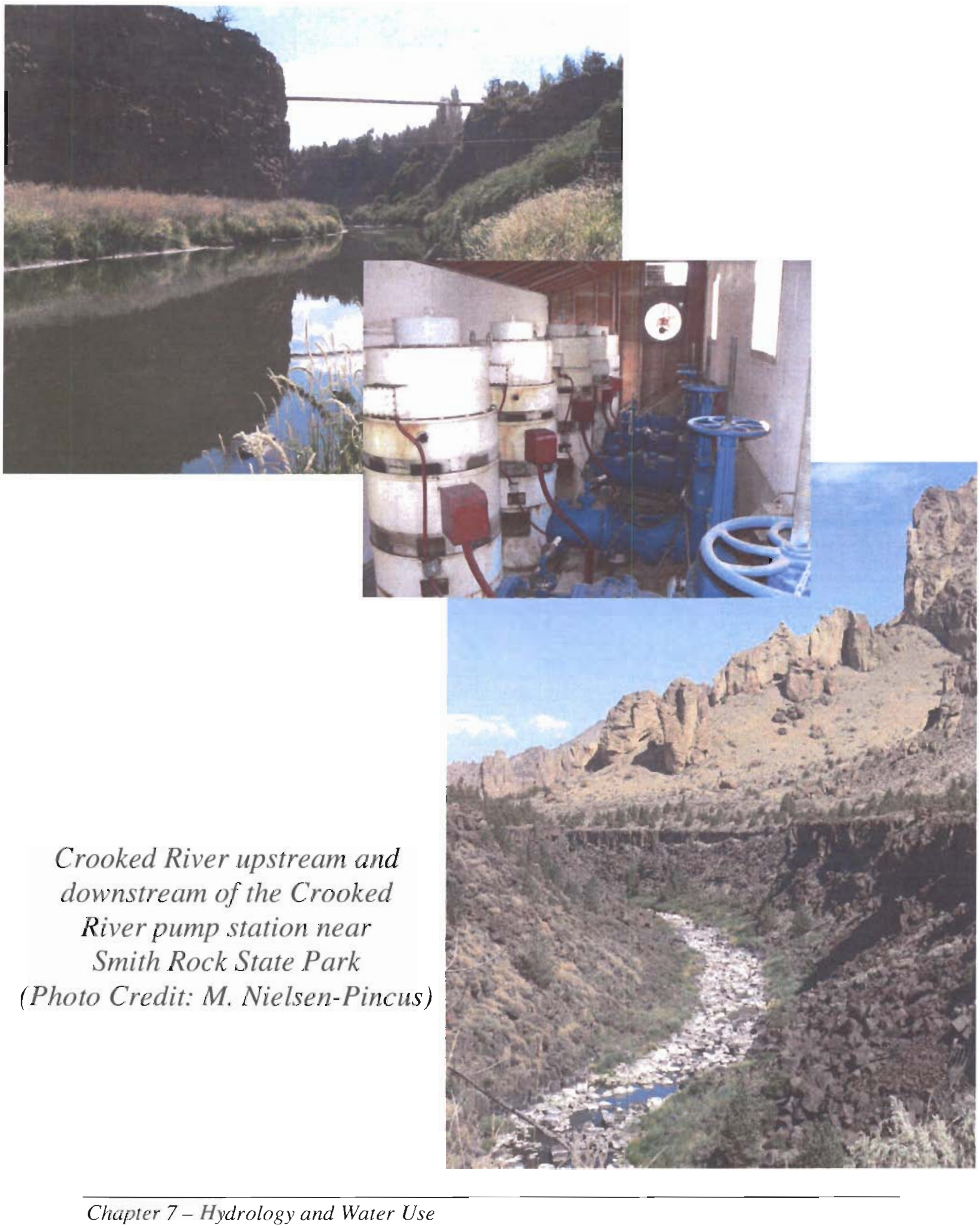
Finally, field surveys and data review suggest that channel habitat types within the assessment area have changed substantially from the probable historic conditions. Much of the Channel habitat in the assessment area is unstable and undergoing transition. Throughout the Lower Crooked River Watershed low gradient valley bottoms have incised, causing lateral erosion that widens the stream channel, changes in riparian and wetland vegetation, and a lowered water table. While many lower gradient reaches have incised into wide, deep F channels, various stages of recovery, revegetation, and aggradation are occurring. Identifying restoration techniques and strategies to arrest the downcutting process while speeding the recovery process is a critical need for the watershed.

Appendix 6-1. Field notes of channel habitat types by reach (Reach IDs correspond to reach numbers on Map 6-5)

| Channel Habitat | | | | |
|---|---|---|---|---|
| **Id** | **Channel Type** | **Notes** | **Feet** | **Miles** |
| **Crooked River** | | | | |
| 1 | C | Dam at top of reach | 5,290 | 1.0 |
| 2 | B | Some C\|B | 1,399 | 0.3 |
| 3 | C | Some C\|B | 4,837 | 0.9 |
| 4 | B | Short riffle section | 1,052 | 0.2 |
| 5 | C | Longer C section | 27,110 | 5.1 |
| 6 | B | Higher gradient & larger substrate | 1,135 | 0.2 |
| 7 | C | Straight C | 9,869 | 1.9 |
| 8 | B | Gradient and substrate change | 4,770 | 0.9 |
| 9 | C | C\|F, entrenched | 3,243 | 0.6 |
| 10 | C | Straight C | 12,775 | 2.4 |
| 11 | C\|F | C\|F, Cutbank, no floodplain on left side | 1,640 | 0.3 |
| 12 | C\|F | Back to C | 5,731 | 1.1 |
| 13 | C\|F | C\|F, cutbank | 20,464 | 3.9 |
| 14 | C\|F | Less entrenched | 3,472 | 0.7 |
| 15 | C\|F | C\|F, incised | 32,389 | 6.1 |
| 16 | C\|F | C\|F, good floodplain, city site, future wetlands | 3,107 | 0.6 |
| 17 | C\|F | C\|F, less incised, good floodplain | 7,382 | 1.4 |
| 18 | C\|F | C\|F, more incised | 77,670 | 14.7 |
| 19 | C | Canyon wall, some floodplain | 16,705 | 3.2 |
| 20 | B | Above Smith Rock, deep canyon | 4,413 | 0.8 |
| 21 | C | Smith Rock C | 16,519 | 3.1 |
| 22 | B | | 3,666 | 0.7 |
| 23 | C | C, down from Smith Rock | 19,329 | 3.7 |
| 24 | B | | 68,860 | 13.0 |
| 25 | B | Slack water, Lake Billy Chinook | 26,246 | 5.0 |
| | | **Total** | **379,072** | **71.8** |
| **Ochoco Creek** | | | | |
| 26 | C | Minimal Cutbank, dam at top of reach | 7,125 | 1.3 |
| 27 | C\|F | C\|F, after bridge, good veg & shade | 20,530 | 3.9 |
| 28 | C\|E | C\|E, narrow deep channel, low W/D ratio good veg | 5,554 | 1.1 |
| 29 | C\|F | C\|F, low W/D ratio, good veg & shade | 14,040 | 2.7 |
| 30 | C\|F | C\|F, through city, areas of E w/o sinuousity | 13,081 | 2.5 |
| | | **Total** | **60,330** | **11.4** |
| **Allen Creek** | | | | |
| 31 | B | Not field checked, headwater area | 19,174 | 3.6 |
| 32 | B | Big substrate, confluence, valley | 19,091 | 3.6 |
| 33 | C | Wide valley type, cannot see channel | 8,929 | 1.7 |
| 34 | F | Bermed w/little veg | 5,846 | 1.1 |
| 35 | C\|F | C\|F, more veg, berms | 7,087 | 1.3 |
| | | **Total** | **60,127** | **11.4** |

| Id | Channel Type | Notes | Feet | Miles |
|---|---|---|---|---|
| **Little McKay Creek** | | | | |
| 36 | B | More of a swale than a channel | 2,607 | 0.5 |
| 37 | B | Confined by valley type, headwater area | 18,273 | 3.5 |
| 38 | B | Current restoration attempting to add sinuosity to C channel | 14,235 | 2.7 |
| 39 | B | B\|C, mostly B w/some short C | 2,177 | 0.4 |
| | | **Total** | **37,292** | **7.1** |
| **McKay Creek** | | | | |
| 40 | B | B all the way down to confluence, some good veg | 4,950 | 0.9 |
| 41 | B | Above more of swale, becomes channel below this point | 13,397 | 2.5 |
| 42 | B | Top of enclosure, very good veg, big cottonwoods | 1,214 | 0.2 |
| 43 | B | B\|C, less gradient, wider valley | 9,591 | 1.8 |
| 44 | B | Back to B | 5,227 | 1.0 |
| 45 | C | Partially entrenched | 18,895 | 3.6 |
| 46 | C | Entrenched | 2,007 | 0.4 |
| 47 | C\|F | Some B, cottonwoods | 16,691 | 3.2 |
| 48 | C | C to bridge | 15,666 | 3.0 |
| 49 | C\|F | Entrenched in F | 20,656 | 3.9 |
| | | **Total** | **108,294** | **20.5** |
| **Lytle Creek** | | | | |
| 50 | B | No Access | 14,733 | 2.8 |
| 51 | B | No Access | 12,422 | 2.4 |
| 52 | Ditch | Irrigation Return Flow Canal | 23,369 | 4.4 |
| | | **Total** | **50,525** | **9.6** |

# Chapter 7 – Hydrology and Water Use



*Crooked River upstream and downstream of the Crooked River pump station near Smith Rock State Park (Photo Credit: M. Nielsen-Pincus)*

## Critical Questions

1. What impact does flow regulation from the Bowman and Ochoco Dams have on the hydrology of the assessment area?
2. What are the hydrological drivers on McKay Creek, a mostly unregulated stream?
3. What are the main water uses and impacts of those uses on the hydrology of the assessment area?
4. How does the hydrology of the Lower Crooked River change downstream of Smith Rock State Park?

## Data Gaps and Research Recommendations

- Stream flow data is lacking on the Lower Crooked River between the OID Feed Canal and Smith Rock State Park, where the majority of water use in the assessment area occurs. A stream flow monitoring program for this reach is needed to better understand the hydrological drivers in the reach and to better plan and design restoration projects
- Stream flow data is lacking on McKay Creek; however, recently installed gauges on McKay Creek will resolve this gap. A comprehensive study on the relationship between water quality and flow should be undertaken to better understand the impacts of flow restoration opportunities.
- Groundwater –surface water interactions in the assessment area are not well understood, and not addressed in this assessment. A baseline (synoptic) model of surface water will help identify groundwater-surface water interactions.

## Key Findings

- The regulation of flow at the Bowman and Ochoco Dams has reduced peak flows on the Lower Crooked River and Ochoco Creek by nearly half.
- On average, annual flows on the Lower Crooked River are less now than prior to the construction of the Bowman Dam; however, summertime flows are increased.
- Historically 80% of annual flow occurred between February and April; now only about 55% occurs during these months.

- Springtime peak flow events tend to stay at bankfull levels in the Prineville Valley rather than accessing the floodplain, causing a long duration of erosive stress on stream banks.
- Hydrology in McKay Creek is largely driven by upland processes. Baseflow in McKay Creek at the National Forest boundary is critically low by the beginning of summer in most years.
- Springs in the lower canyon section of Crooked River contribute significant amounts of cold water in the gaining reach.

## Action Items

- Identify flow monitoring stations and develop rating curves on of the Lower Crooked River between the OID Feed Canal and Smith Rock State Park.
- Initiate relationships with local irrigation districts to better understand water use and its impacts on hydrology in the assessment area.
- Participate in efforts to reallocate Prineville Reservoir water for in-stream uses.
- Initiate a study of the relationship between flow and water quality on McKay Creek.
- Support actions taken by the Ochoco National Forest and private landowners in the McKay Creek watershed to improve stream flow through water conservation and leasing in the short term and forest and rangeland health improvements in the long term.
- Continue to collaborate with the Bureau of Land Management and others to understand the functioning of the Lower Crooked River in the canyons below Smith Rock State Park.

## 7.1 Introduction

The Lower Crooked River Watershed is located in an area characterized by a high desert climate with limited annual precipitation (ranging from less than 10 inches in the low elevations to approximately 25 inches annually at higher elevations). Geology of the assessment area is primarily characterized by the ancient sedimentary and tuffaceous formations of the John Day Ecological Province (Anderson et al., 1998). These finely textured soils are easily eroded and much less permeable than the recent volcanic soils of the Cascades to the West. The geology of the assessment area impacts the hydrology of the assessment area by favoring a surface water-driven system rather than a groundwater system. Capturing and storing the limited precipitation in this geological context is therefore a critically important function of the watershed for both ecological and socioeconomic health. The watershed captures, stores, and releases water in at least three different ways:

- Interception by vegetation, followed by evaporation back to the atmosphere.
- Overland flow or shallow soil infiltration leading to plant respiration or streamflow.
- Storage in snowpack, ponds, pools, wetlands, reservoirs, or groundwater.

In each case water is eventually released from the watershed either through outflow into the Deschutes River, evaporation, or transpiration (Figure 7-1).

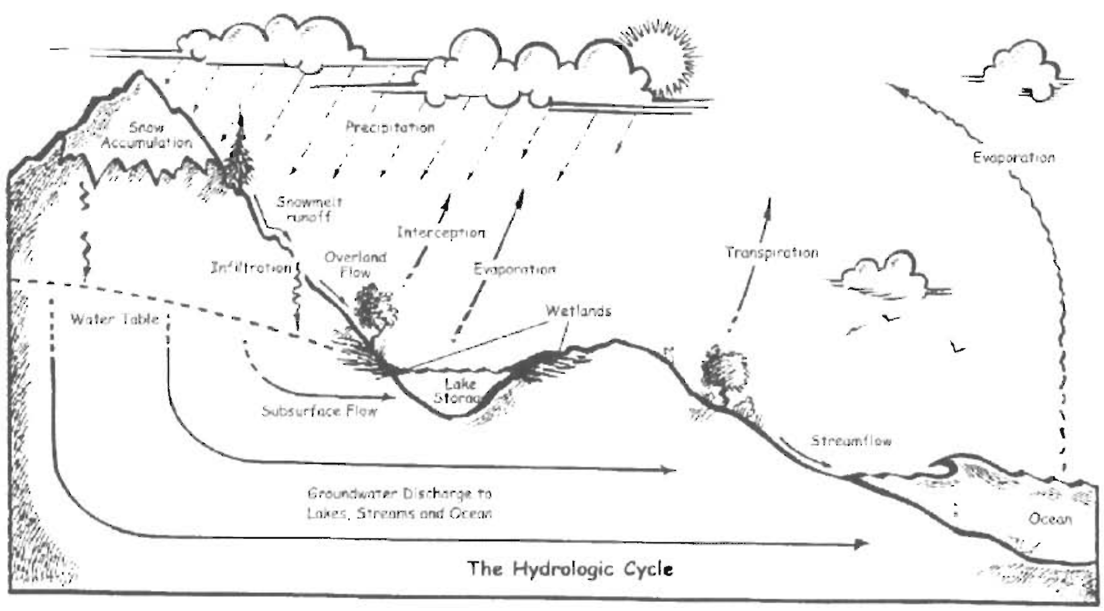



Figure 7-1. The hydrologic cycle describes the circulation of water around the earth. (Watershed Professionals Network, 1999)

The assessment area captures and stores water from approximately 300,277 acres (469 square miles) of the hydrologically active hydrologic unit classified by the US Geological Survey as the Lower Crooked River Subbasin. The upper boundaries of the assessment area are formed by dams that regulate the hydrology of the mainstem of the Crooked River (Bowman Dam) and Ochoco Creek (Ochoco Dam). These dams discharge water into the assessment area at varying levels throughout the year. As a result the assessment area is actually nested at the bottom of drainage network of the larger Crooked River Watershed, and drainage for the assessment area encompasses the approximately 3 million acres of the entire Crooked River Watershed. All water flowing through the Crooked River Watershed's stream network passes through the assessment area before it is discharged into Lake Billy Chinook. The quality and quantity of the water discharging through the assessment area is therefore tightly related to water management within the larger Crooked River Watershed.

There are six major dynamic waterbodies in the assessment area: the Crooked River, McKay Creek, Ochoco Creek, Allen Creek, Lytle Creek and Little McKay Creek (Table 7-1). This chapter focuses on the Crooked River, the largest waterbody, and its primary tributaries, Ochoco Creek and McKay Creek. There are also approximately 304 miles of tributary creeks within the assessment area. Most of these are intermittent and are

Table 7-1. Major Waterbody Miles

| Waterbody | Miles | Percent of Total Miles |
|---|---|---|
| Crooked River | 72 | 54 |
| McKay Creek | 21 | 16 |
| Ochoco Creek | 11 | 9 |
| Allen Creek | 11 | 9 |
| Lytle Creek | 10 | 7 |
| Little McKay Creek | 7 | 5 |
| Total | 132 | 100 |

(Crook County GIS, 2004)

usually dry during the summer and fall. Water use is a critically important socioeconomic factor in the assessment area that impacts the hydrology of watershed. The importance of water use is demonstrated by the fact that in addition to the 132 stream miles existing in the watershed, there are also approximately 131 miles of main irrigation canals and an unknown mileage of small secondary canals associated with small irrigation districts and individual properties. Average annual discharge of the Crooked River is 1,131,000-acre feet or approximately 1,560 cfs per day at Lake Billy Chinook.

Generally, the surface hydrology of the watershed includes major and minor streams, perennial and intermittent streams, wetland areas, an extensive system of irrigation canals, numerous small reservoirs, and an extensive network of springs near the confluence with Lake Billy Chinook (i.e., the Deschutes and Metolius Rivers). Spring water, which makes up a large proportion of the flow in the lower reaches of the river, likely flows from underground aquifers more connected to the hydrologic cycle of the Cascade Mountains than any hydrologic cycle occurring within the watershed.

The objectives of this chapter are to quantify and characterize the flows released into the watershed by the two major dams, describe the impact of water management on water quantity and geomorphological processes in the watershed, explore the hydrology of McKay Creek, and describe the changes in hydrology in the lower canyon below Smith Rock State Park.

## 7.2 Water Use, Infrastructure, and Availability

The capture and storage of naturally occurring flows in the Lower Crooked River Watershed was one of the first economic development opportunities seized by early settlers to the assessment area. The People's Irrigation District formed in 1890, and by 1912 irrigation was so widespread throughout the assessment area that many perennial streams had become seasonally intermittent; sections of the Lower Crooked River and Ochoco Creek were dewatered during the dry seasons. The construction of the Bowman Dam in the 1960s allowed more utilization of water and the amount of irrigated cropland has increased since. The assessment area's irrigation infrastructure affects the basin's natural hydrologic processes by changing the timing and magnitude of flows throughout the irrigated portions of the basin (ONF 1998b, McSwain 1999, ODFW 1996).

Two main storage reservoirs form the boundary of the assessment area. The Prineville Reservoir, created by the Bowman Dam and built by the Bureau of Reclamation (BOR) in 1960, is congressionally authorized for flood control and irrigation. The reservoir is capable of storing up to 148,633 acre-feet, and serves as a supplemental water supply for the Ochoco Irrigation District (OID). The required minimum discharge from the Bowman Dam is 10 cfs measured at the gaging station 0.4 miles downstream from the reservoir. For over a decade, BOR, OID, ODFW and OWRD have agreed to release 75 cfs in the winter when water is available to enhance flows and support the trout fishery below the dam. Approximately 80,000 acre-feet of storage in the Prineville Reservoir remains uncontracted, and could be allocated for new uses such as instream flow enhancement or current uses such as irrigation given congressional authorization.

Ochoco Reservoir is created by the Ochoco Dam, which was built by private interests for irrigation in 1922. BOR has completed extensive maintenance work to the dam and reservoir in the 1940s, 1950s, and 1990s. The reservoir holds up to 44,000 acre-feet of water and is fully allocated to OID irrigation. The reservoir also provides flood control for Ochoco Creek and the City of Prineville.

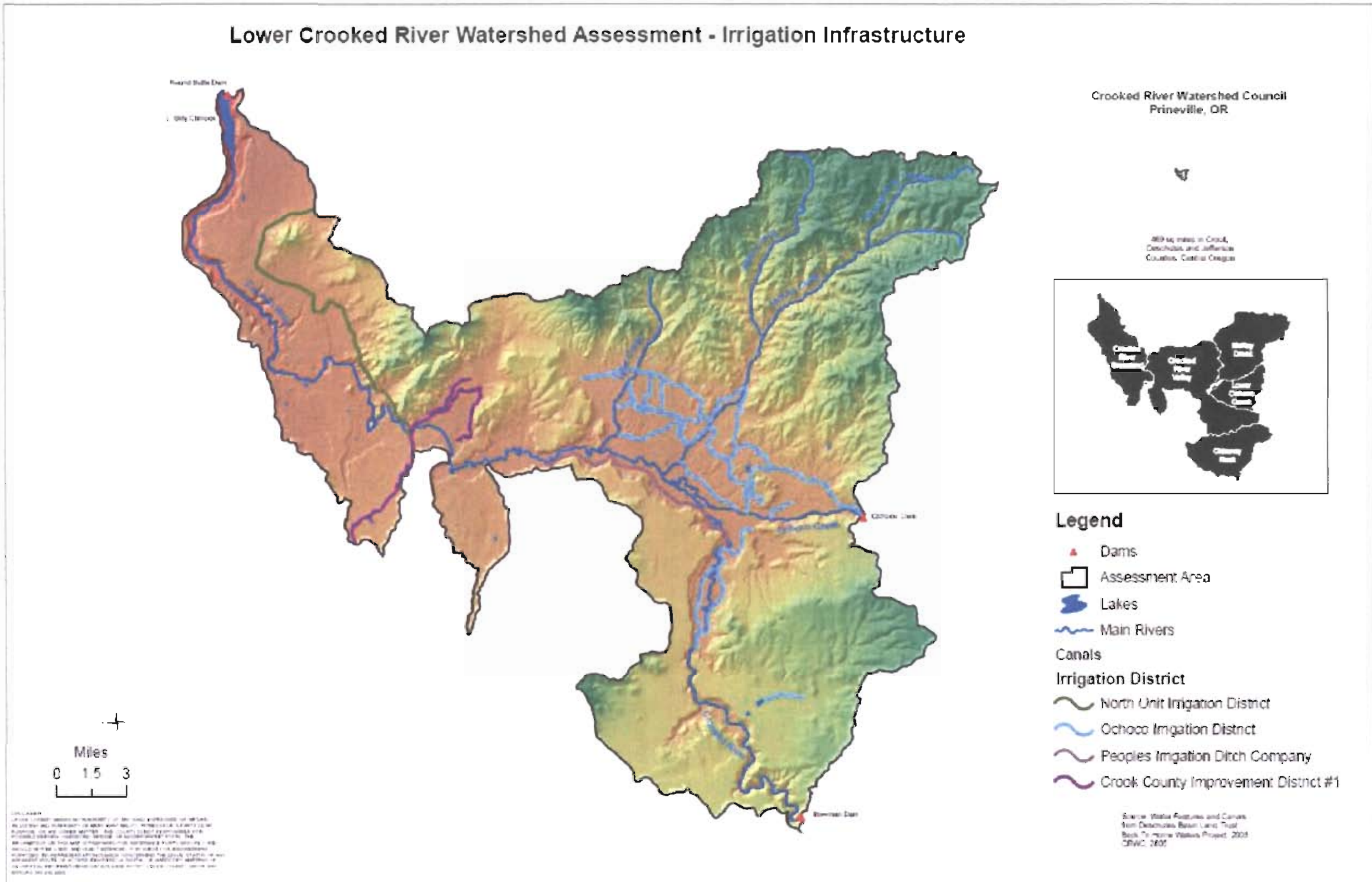
Surface water resources are overallocated in the Lower Crooked River Watershed. The Lower Crooked River Watershed has the largest number of water rights and the largest allocation of water rights in the entire Crooked River Watershed (CRWC, 2002). Consumptive water uses often exceed streamflow (based on 80% exceedance) in the assessment area, particularly in the period from April to October (OWRD 1999). When in-stream rights are added to consumptive uses, water availability is often negative, indicating that some uses, often instream uses, are restricted. Groundwater resources in the Lower Crooked River Watershed are not well understood. A recent collaborative effort between the Oregon Water Resources Department and the United State Geological Survey to study groundwater resources in the Upper Deschutes Basin demonstrates that the Lower Crooked River Watershed is marginally, at best, connected to the groundwater resources stemming from the volcanic soils and precipitation in the Cascades. This connection is greatest in the lower canyons where springs add approximately 1000cfs to the flow of the Lower Crooked River. A weaker connection may occur along the southwestern edges of the assessment area near Dry Canyon and Smith Rock State Park. Surface water – groundwater interactions in the majority of the assessment area is not well understood, but likely to be minimal given the geology of the area.

The diversion and storage of natural flows for the purposes of irrigation has a major influence on the hydrology of most of the Lower Crooked River Watershed (Map 7-1). The system of storage reservoirs, irrigation delivery structures, and canals is extensive and contributes significant return flows to surface waterbodies and infiltration and recharge to the groundwater system.

The Ochoco Irrigation District services water users in the Lower Crooked River watershed above Ochoco Creek, the Ochoco Creek watershed, the lower portion of the McKay Creek Watershed, and the upper portions of the Prineville Valley including those along Lytle Creek where tailwaters are returned to the Lower Crooked River. Ochoco Irrigation District water originates at the Ochoco and Bowman Dams.

Several smaller irrigation districts service water users along the Lower Crooked River between Prineville and Lone Pine, including the People's Irrigation District, Crooked River Central, and the Lowline Ditch Company. Each of these districts diverts water directly from the Lower Crooked River into a canal system or allows users to pump directly from the river.

Irrigation water from outside the assessment area is also routed to the assessment area from the Deschutes River. At Dry Canyon, the Central Oregon Irrigation District returns irrigation tailwaters originally from the Deschutes River to the Crooked River. The Crook County Improvement District #1 (Lone Pine) services water users in the Lone Pine area. Lone Pine irrigation water is also Deschutes River water, and is returned to the




**Map 7-1. Irrigation canals of the major irrigation districts in the assessment area. Several other smaller irrigation districts also deliver water through a network of smaller canals and ditches that are not shown here.**

Crooked River near where the Crooked River enters a canyon above Smith Rock State Park. In the canyon, the North Unit Irrigation District (NUID), which services water users primarily in the Madras area, operates a pump station that consists of 9-450 horsepower pumps that have the capacity to pump 153 cfs from the Lower Crooked River directly to the top of the canyon wall and into the NUID main canal. The NUID Crooked River Pump station, when at or near full operations, withdraws the majority of the water from the Crooked River directly above Smith Rock State Park, leading to critically low flows through the park. NUID is required by stipulation to leave 10 cfs in the river below the pumps. Currently, federal water management legislation is pending that will allow NUID to conserve water and return up to about 75 cfs to the Crooked River.

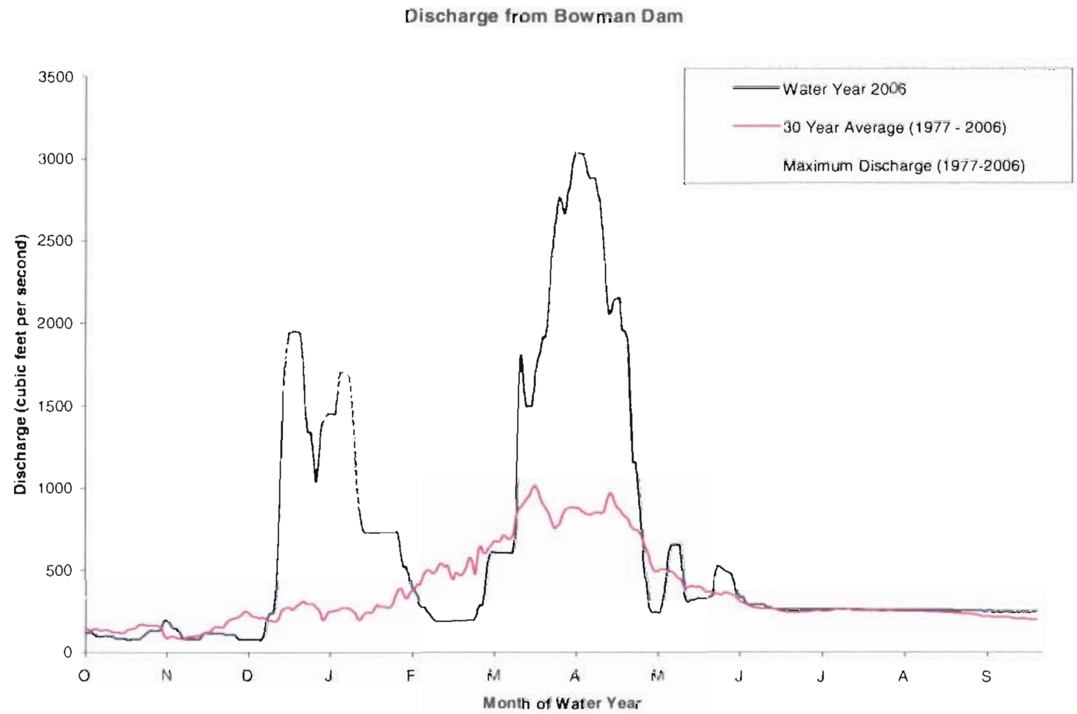
## 7.3 Data Sources

The analysis of hydrology for the Lower Crooked River Watershed is based primarily on secondary data sources. These sources include flow data from Bureau of Reclamation (BOR) and United States Geologic Survey (USGS), analysis from local hydrologists, data obtained from the Ochoco National Forest, and review of documents containing relevant hydrologic information. Currently, the BOR and USGS maintain five monitoring gauges within the assessment area. These include four gauges on the Crooked River (below the Bowman Dam, at OID's main diversion, near Smith Rock State Park, and below the Opal Springs Dam) and one site on Ochoco Creek (below the Ochoco Dam). However, with extensive flow diversion for irrigation, the existing gauges leave substantial gaps in the understanding of the hydrology of the assessment area through the Prineville Valley, Lone Pine, and the McKay Creek watershed. Below Smith Rock State Park the Crooked River is a gaining stream that grows through inputs from groundwater springs. The irrigation system of the assessment area is also described based primarily on document review and interviews with experts on the local water use.

## 7.4 Regulated Hydrology– The Crooked River and Ochoco Creek

The Bowman Dam and Ochoco Dams regulate flow in the mainstem of the Crooked River and Ochoco Creek. The dams, being such substantial hydrologic features, form the boundary of the assessment area. The dams restrict sediment transport and alter the hydrology of the Crooked River and Ochoco Creek, transforming riparian and geomorphological processes downstream (CRWC, 2002; McSwain, 2005). Discharge from the dams is elevated during the late spring and summer when irrigation needs are greatest, and is lower during the fall, winter, and early spring when water is stored for the upcoming irrigation season (Figure 7-2). The timing, frequency, duration, and magnitude of flows in the Lower Crooked River and Ochoco Creek have changed since the construction of the dams, and the natural seasonal flow patterns are largely dependent on irrigation needs (ODFW, 1996; CRWC, 2002; McSwain, 2005). The seasonal timing of flows also impacts the establishment and growth of riparian vegetation that helps to stabilize channel banks (ODFW, 1996).

Peak flows occur in the winter and spring on both waterbodies. Winter and Spring management of the reservoirs follows a flood curve that requires a preset volume of open reservoir space by specific dates to allow managers a predictable reservoir filling. Peak flows happen when the reservoirs are at or near the flood curve storage target and an event such as rain on snow, heavy rain, or a temperature change causes a rapid snow pack melt. For example, in December 2005 and January 2006 and again in March and April 2006 heavy rains generated heavy runoff from areas upstream of both dams. As a result, flows out of the dams were increased in order to manage storage capacity over the course of the reservoir filling season. Discharge from the dams peaked at approximately 3000 cubic feet per second (cfs) on the Crooked River and approximately 400 cfs on Ochoco Creek. While these flows are above average for both waterbodies, the 2006 flows are well within the range of regulated flows over the last 30 years for the season. Before closure of the dam, nearly 80% of the average flow of the Crooked River occurred in the months of February, March, April, and May (Figure 7-3). Currently, peak flows still occur in the winter or spring when the reservoir is at or near storage capacity and a large volume of runoff occurs; however, only about 55% of average annual runoff now occurs in the months of February, March, April, and May. Peak flow on the Lower Crooked River historically tended to be approximately twice the magnitude currently reached (Figure 7-3). In the 15-year period between 1942 and 1956, prior to the construction of the Bowman Dam, average peak flow was approximately 3400 cfs and ranged from



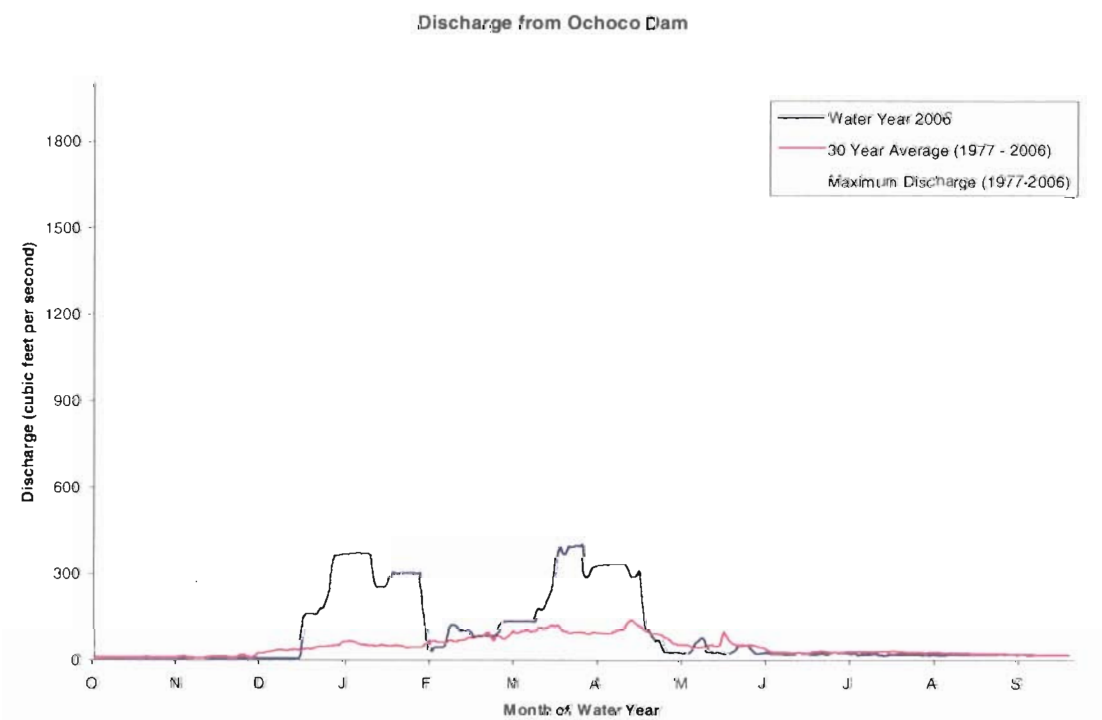




Figure 7-2. Discharge from the Bowman (top) and Ochoco (bottom) dams (USBOR, 2007)

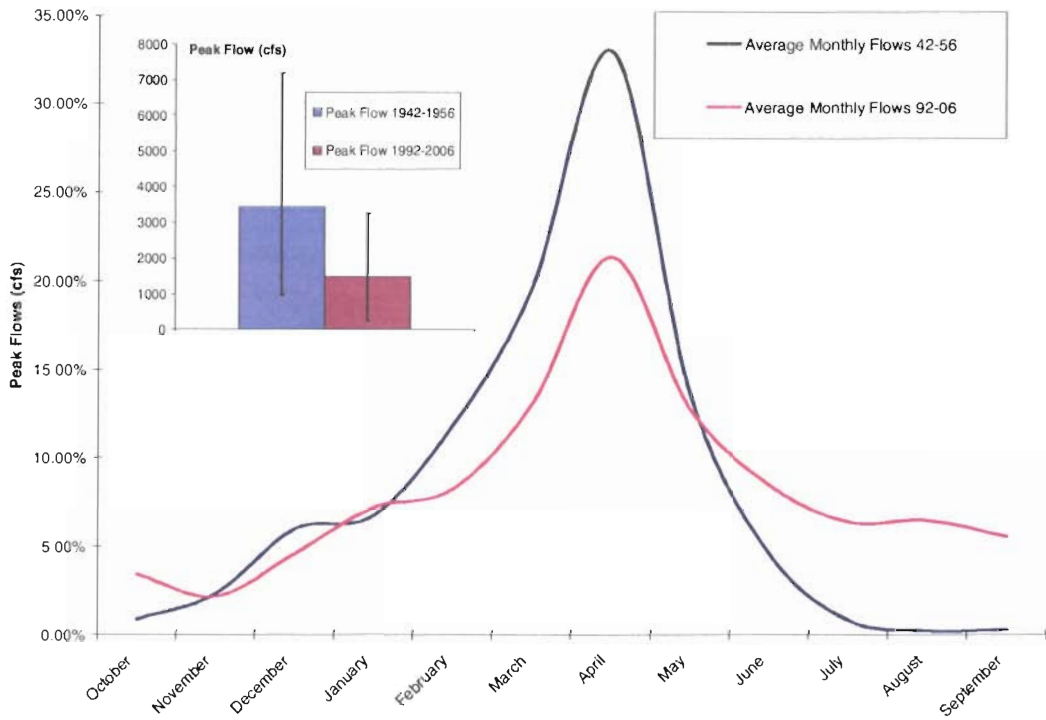



Figure 7-3. Percent of annual flow for the periods 1942-1956 and 1992-2006, with average peak flow for the same two periods with error bars representing the range of peak flow events over each period.

approximately 1000 cfs to 7200 cfs. In the 15-year period between 1992 and 2006, peak flow averaged 1500 cfs and ranged from approximately 200 cfs to 3250 cfs. The reduction of peak flow events limits channel morphology processes caused by large floods, and needed for riparian rejuvenation (ODFW, 1996; McSwain, 2005). Peak flows that historically occurred every 2.5 years (i.e~4,000cfs) now occur on an approximate 50year cycle (McSwain, 2005). Peak flows experienced prior to the construction of the dams occur rarely if ever. In most cases, the storing of water and management of flow through the dams mitigates events that would create floods downstream of the dams.

Unregulated peak flow events tend to occur as overbank flooding in which eroded sediments are deposited to the floodplain or moved downstream to depositional areas. Regulated high flow events tend to keep flows within the bankfull channel exerting stress on streambanks for an extended duration that can lead to excessive bank erosion and channel incision. The regulated nature of flows in the Lower Crooked River Watershed alters the processes of erosion and deposition, contributing to the transition in channel types towards wide and incised channels. The form and function of channels presently found on the Crooked River and Ochoco Creek are directly related to the managed flows from the dams.

Average flows below the Bowman Dam have also been reduced to approximately half of their historic spring-time levels, and are artificially increased for the summer-time irrigation season (Figure 7-4). This *reverse* hydrology occurs primarily in the Bowman tailrace, a 12 mile reach below the dam before irrigation water is diverted at the Ochoco Irrigation District feed canal diversion. The altered flows have improved habitat conditions for the fishery in the reach, but have impacted the growth potential of riparian

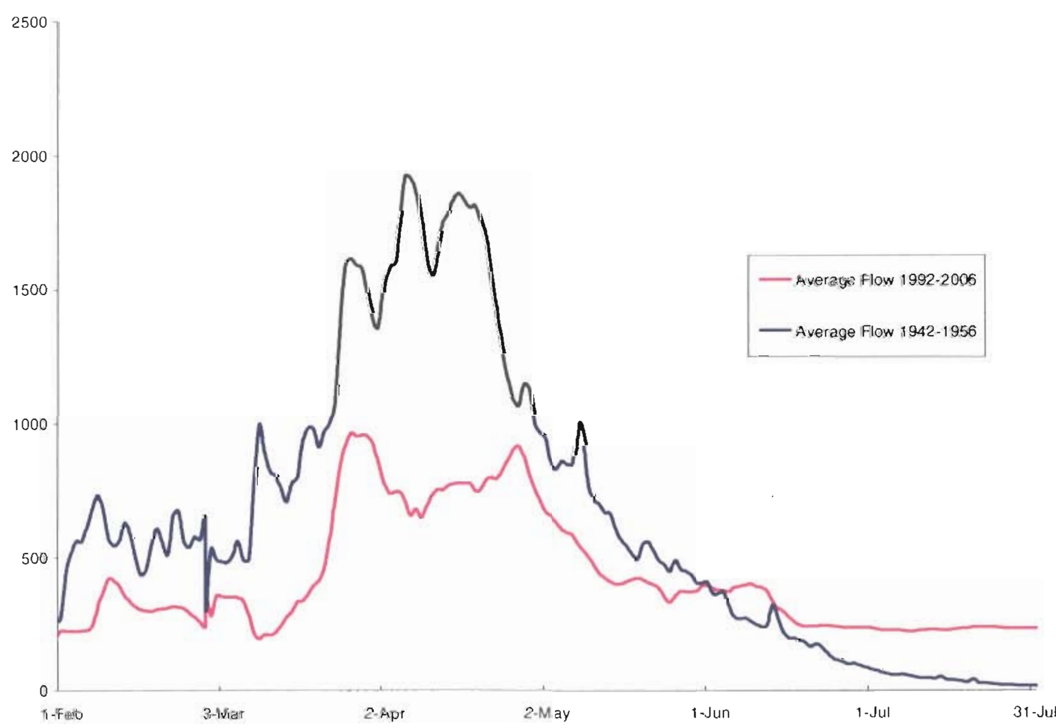



Figure 7-4. Average annual springtime and summer flow at the Bowman Dam for the periods 1942-1956 and 1992-2006.

vegetation during the growing season and the channel forming processes caused by the natural hydrograph (ODFW 1996).

## 7.5 Hydrology and Water Use – McKay Creek

Quantitative data on McKay Creek flows is limited due to the lack of permanent measurement stations in the watershed. A permanent stream gauge was operated on McKay Creek from 1925 to 1932 by the United State Geological Survey (USGS). In 2006 Oregon Water Resources Department installed a permanent stream gauge at the Ochoco National Forest boundary, and in 2007 the Deschutes River Conservancy and the Crooked River Watershed Council financed two additional stream gauges near the confluence with Allen Creek and near the mouth of McKay Creek. These new gauging stations will add substantially to the understanding of the hydrology of McKay Creek. Data collected by the Ochoco National Forest combined with the historical gauge data provides a preliminary understanding the hydrology of McKay Creek.

McKay Creek is a mostly unregulated stream. A large portion of the McKay Creek watershed is managed by the Ochoco National Forest. The Forest Service analysis of the hydrology of the McKay Creek watershed offers an important contribution to the understanding of the dynamics of the least regulated hydrologic system in the assessment area (Ochoco National Forest, 2006). According to Ochoco National Forest, an estimated 61% of the water yield in the McKay Creek watershed comes from Ochoco National Forest lands. Most of this flow is derived from the Upper McKay Creek portion of the watershed (upstream of the Allen Creek confluence), which accounts for about 50% of the flow in the McKay watershed (Table 7-2). Over 95% of this flow comes from Forest Service administered lands.

Peak flows in the McKay Creek watershed result from snowmelt and rain on snow events. About 90 percent of the annual runoff occurs during the months of January through May. High intensity summer rainstorms are also common. In the 7-year period that the USGS operated a stream gauge on McKay Creek (i.e., 1925-1932) peak flows varied from 36cfs to 441cfs and occurred between mid-January and mid-March, and

Table 7-2. Water Yield* in McKay Creek Watershed

| **Subwatershed** | **Forest Service Land (acre feet/year)** | **Other Lands (acre feet/year)** | **Total (acre feet/year)** |
|---|---|---|---|
| Lower McKay Creek | 567 | 8,577 | 9,144 |
| Allen Creek | 3,915 | 4,196 | 8,111 |
| Upper McKay Creek | 16,648 | 8,50 | 17,498 |
| **Total** | **21,130** | **13,624** | **34,753** |

* The water yield for McKay Creek was estimated by subtracting 12.64 inches from each precipitation band and multiplying by the area (Ochoco National Forest, 2006).

nearly 30% of all runoff occurred in March (Figure 7-5). Currently, flows follow a snowmelt hydrograph about 70% of the time with the primary peak in April or May, a secondary peak in April or March, and base flows in September; about 30% of the time, runoff follows a rain-on-snow hydrograph with peak flows occurring in February or January (Ochoco National Forest, 2006). Warmer winters may increase the incidence of rain-on-snow events, and are likely to move the peak snowmelt runoff to earlier in the spring. Peak flow estimates were calculated for the McKay Creek watershed above the forest boundary and at the mouth for 2-year to 100-year precipitation events (Table 7-3).

Peak flow modeling indicates that peak flows are most likely to increase when both forest harvest activities and roads interact to reduce the water storage potential of a drainage (Ochoco National Forest, 2006). Road surfaces prevent infiltration and produce overland flow, while forest harvest activities can reduce leaf area and increase soil compaction leading to decreased soil water holding capacity. Road cuts intercept surface and shallow

Table 7-3. McKay Creek Peak Flows

| **Forest Service Boundary (Average Precipitation 22.9"/yr)** | | | **McKay Creek Mouth (Average Precipitation 19.14"/yr)** | |
|---|---|---|---|---|
| **Time Period** | **Flow (cfs)** | | **Time Period** | **Flow (cfs)** |
| 2 Year Flood | 141 cfs | | 2 Year Flood | 279 cfs |
| 5 Year Flood | 303 cfs | | 5 Year Flood | 610 cfs |
| 10 Year Flood | 424 cfs | | 10 Year Flood | 859 cfs |
| 25 Year Flood | 630 cfs | | 25 Year Flood | 1289 cfs |
| 50 Year Flood | 788 cfs | | 50 Year Flood | 1607 cfs |
| 100 Year Flood | 1013 cfs | | 100 Year Flood | 2077 cfs |

(Ochoco National Forest, 2006)

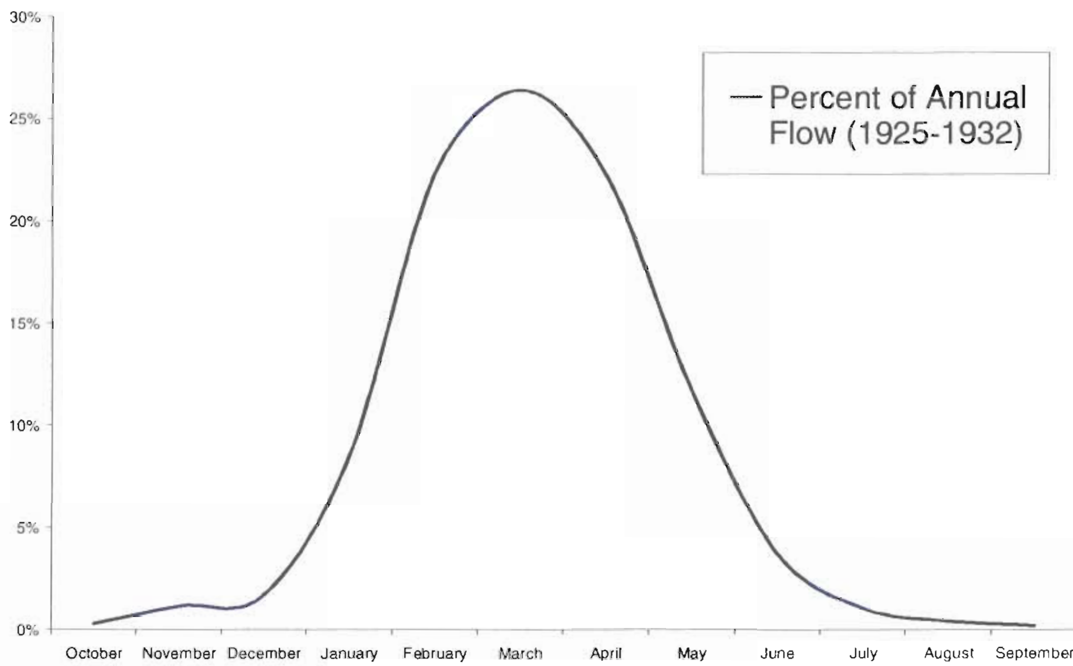



Figure 7-5. Historical flow for McKay Creek by month as a percentage of annual total.

subsurface runoff. Roads then tend to act as continuations of the stream system, funneling overland flow through the road network. The road network in the McKay Creek watershed likely results in increased runoff rates and a flashy response to precipitation events than would otherwise occur in similar unroaded drainages.

The McKay Creek watershed has also experienced a large increase in juniper woodland habitat, especially in the mid-elevations of the watershed. Juniper woodlands tend to reduce the water storage capacity of a drainage due to the impact of juniper encroachment on deep-rooted native bunchgrasses, forbs, and shrubs. The combination of forest harvest activities, roads, and juniper encroachment in the McKay Creek watershed likely has increased the peak flow potential of McKay Creek over time and reduced the water storage capacity of the watershed.

While peak flows generally occur in the spring, base flows normally occur in late summer or early fall (i.e., August or September). A partial hydrograph from 1995 collected at the Ochoco National Forest water quality station on McKay Creek below Little McKay Creek is shown in Figure 7-6. Base flow from this data appears to be about 1.0 cfs at the station, and probably ranges from about 0.1 to 1.5 cfs depending on the amount of moisture during the year.

Base flow can be increased by timber harvest, but with low intensity harvest methods, the increase should be minimal and should decrease to pre-harvest levels rapidly. The greatest increases in water yield from timber harvest are obtained by shelterwood, seed tree, and clear cuts on deep soils in high precipitation zones.

In the McKay Creek watershed the largest factors leading to decreased base flows from pre-settlement days are probably increased forest stand densities, increased juniper woodland, the decrease in beaver dams, the loss of wet meadows and other wetlands, and irrigation diversions in lower McKay Creek.

Although much of the McKay Creek watershed consists of intermittent streams, three main perennial streams exist – McKay, Little McKay, and Allen Creeks (Figure 7-7). Perennial streams are classified by the Forest Service if they are used by fish part of the year. On dry years some reaches of Little McKay Creek and Allen Creek are spatially

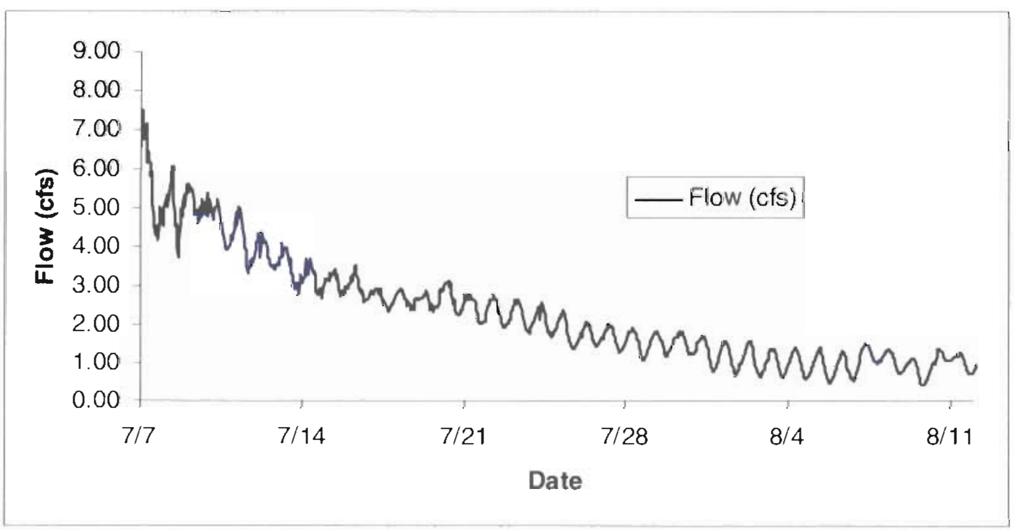



Figure 7-6. McKay Creek summer flows in 1995

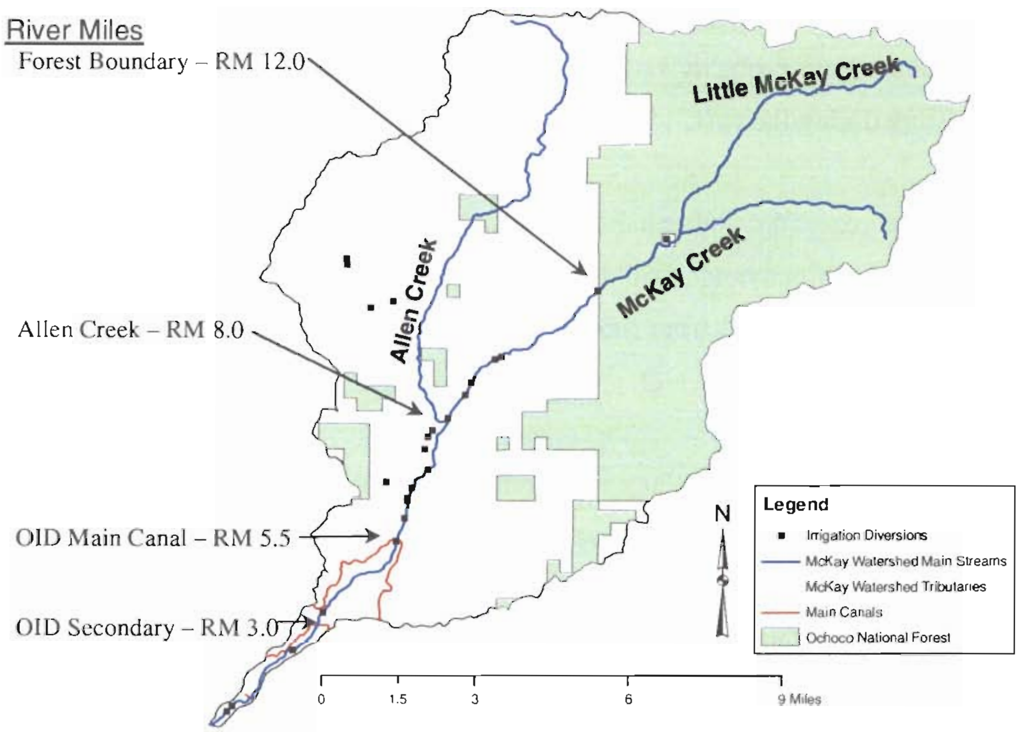



Figure 7-7. McKay watershed drainage network and irrigation diversions

intermittent. The lower portion of McKay Creek (below the National Forest boundary) is often dry by the end of June, or the end of May in dry years. Irrigation withdrawals between the National Forest Boundary and the Ochoco Irrigation District canal contribute to lack of summer water in McKay Creek; however, base flows in McKay Creek at the National Forest boundary indicate that in dry years critical low flows exist naturally. Critical low flows at the National Forest boundary indicate that the water storage capacity in the upper portions of the McKay Creek watershed is not sufficient to maintain adequate flows, and may be related to forest stand conditions such as tree density or wet meadow degradation. Water rights in the McKay Creek watershed date to 1874, and withdrawals for irrigation begin on a National Forest in-holding near the confluence of McKay and Little McKay Creeks (river mile 12). In total certified water rights on McKay Creek account for 8.11 cfs, more than is available most summers. Below the Ochoco Irrigation District main canal (river mile 5.5) base flows are altered by irrigation water deliveries through the stream channel. The Ochoco Irrigation District spills water into the McKay Creek channel as a delivery method for water users along McKay Creek. This water is generally cool water taken from the bottom of the Ochoco Reservoir and creates an artificial flow that is beneficial to in-stream resources. Without this and other irrigation tailwaters McKay Creek would likely be dry from the forest boundary to the confluence with the Crooked River for the majority of the summer months.

Base flows are of great importance between the Forest boundary and the Ochoco Irrigation District canal for irrigation and agriculture. The relative lack of base flows compared to the allocated water rights challenges the productivity of agriculture above the irrigation district boundary. Furthermore, actions to increase base flows (e.g., forest and range management) are not likely to improve actual stream flows below the National Forest boundary for fisheries or other resources because irrigation users have senior water rights. Opportunities to expand the irrigation district boundary and provide McKay Creek in-stream water users with district water may improve agricultural productivity and in-stream resources more than other watershed management activities in the short-term. Working with landowners to conserve water or lease water may also provide opportunities to increase streamflow in this reach. However, long-term strategies to improve forest and range conditions in the McKay Creek watershed are needed to improve both upland and hydrological resources.

## 7.6 The Lower Crooked River below Smith Rock – A Gaining Reach

After McKay Creek joins with the Lower Crooked River, the river flows through the Prineville Valley, where water diversion and irrigation tail water return flows complicate the hydrology of the reach. At Lone Pine the Crooked River enters a steep walled canyon for the remainder of its course to Lake Billy Chinook (approximately 30 miles). Near Smith Rock State Park groundwater springs begin adding flow to the Crooked River. For approximately 20 miles through the increasingly deep walled gorge the spring water additions are mostly small seeps and springs. However, approximately 10 miles upstream from Lake Billy Chinook groundwater additions grow in size to large springs,

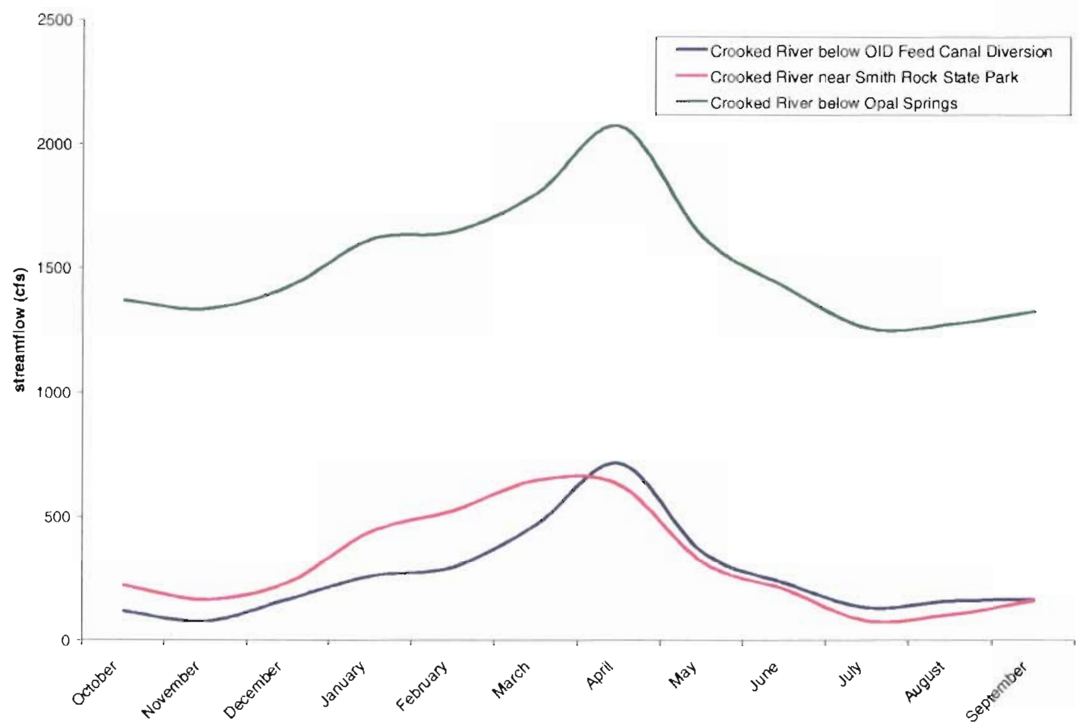



Figure 7-8. Average daily flow on the Crooked River after irrigation water is withdrawn at the OID Feed Canal, near Smith Rock State Park, and below Opal Springs.

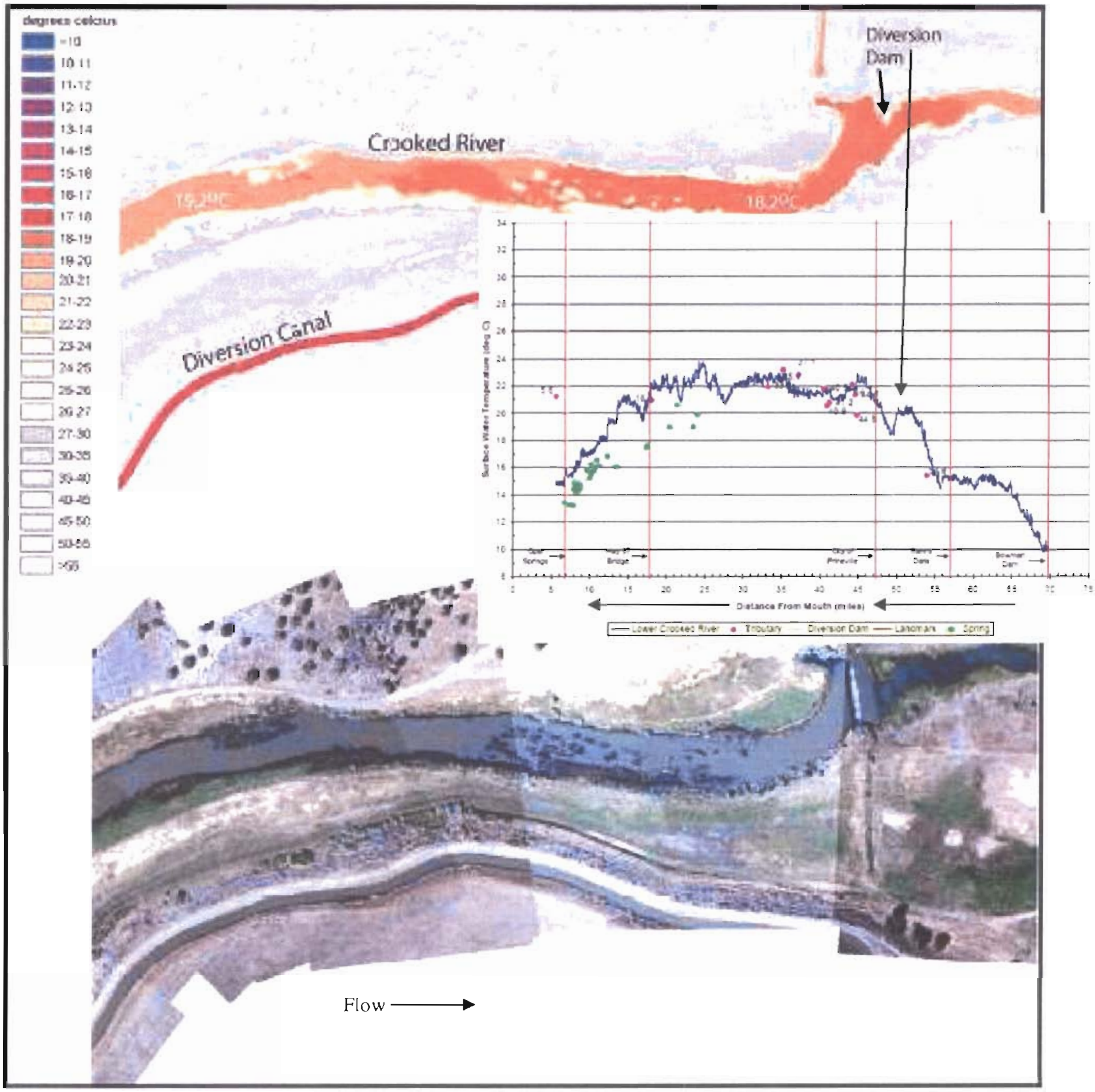
the largest of which is Opal Springs. When combined, these springs and seeps increase the year round flow in the Crooked River by about 1000 cfs (Figure 7-8). Water quality is substantially improved by the addition of cold groundwater that originates from snow melt and rain in the Cascades. This lower section of the Lower Crooked River functions more like the Deschutes River, with its steady groundwater-driven flow, than any other reach of the flashy, surface water-driven Crooked River in the assessment area.

The Deschutes Valley Water District operates the assessment area's only hydroelectric project at the Opal Springs Dam upstream of Opal Springs. The hydroelectric facility was constructed in 1985 and is characterized by a 25 foot concrete dam that sends Crooked River water through two 1500 foot cement conduits to a horizontal turbine. Below Opal Spring the Crooked River flows approximately 2 miles until it hits the slackwater of Lake Billy Chinook. The Crooked River arm of Lake Billy Chinook extends approximately 4 miles until it mixes with the Deschutes and Metolius arms of the reservoir.

## 7.7 Summary

The streams of the Lower Crooked River Watershed are largely surface water-driven streams that respond quickly to snowmelt or precipitation events. Historically, nearly 80% of annual flow occurred between February and May. Currently, the Lower Crooked River Watershed is largely regulated by two dams, the Bowman and Ochoco Dams on the Crooked River and Ochoco Creek, respectively. Directly below the Bowman dam, the hydrograph is characterized by low flows in the winter when water is being stored in the dam, and high flows in summer when water is being released for irrigation use. This *reverse* hydrograph has had a positive impact on the tailrace fishery primarily due to water quality, but likely inhibits channel forming processes and riparian vegetation recruitment in the Bowman tailrace.

The regulation of flows on the Crooked River and Ochoco Creek has also reduced peak flows by about half of their historic levels, and subsequently reduced average flows as well. McKay Creek is the only tributary to the Lower Crooked River that is mostly unregulated. Although numerous irrigation diversions exist on McKay Creek, baseflow from the Ochoco National Forest is critically low most years indicating that forest and rangeland health are the ultimate drivers of surface hydrology in the McKay Creek watershed. A major gap in hydrology data exists from the Ochoco Irrigation diversions on the Crooked River (at the Ochoco Feed Canal) to the gauging station near Smith Rocks, approximately 40 miles downstream. This gap encompasses the majority of all water use, irrigation infrastructure, and tailwater return flow in the assessment area, and therefore represents a critical omission of knowledge in the watershed. Below Smith Rock State Park the Lower Crooked River is characterized by a deep canyon, into which numerous groundwater seeps and springs create a gaining river.




*Thermal infrared and color aerial imagery and longitudinal temperature profiles for the Lower Crooked River at the People's Irrigation Diversion (Watershed Sciences 2006).*

## CRITICAL QUESTIONS

1) What are the designated beneficial uses of water for waterbodies in the assessment area?
2) What Oregon Department of Environmental Quality 303(d) water quality criteria apply to stream reaches in the assessment area?
3) Which stream reaches do not meet water quality standards?
4) What are the causes of water quality limitations?

## DATA GAPS & RESEARCH RECOMMENDATIONS

- The Crooked River Watershed lacks comprehensive ODEQ grade A water quality data. A coordinated interagency water quality monitoring program for the Assessment area is needed.
- Irrigation water return flows and stormwater discharges in the City of Prineville are not well understood, and are an important factor to include in water quality monitoring.
- Stream flows, aside from dam discharges, are also not well understood and improved flow monitoring can help to assess the impacts of flow on water quality.
- Data from the state real estate transaction database indicates that nitrates exist in some residential wells. Further investigation of groundwater chemistry is needed to protect human and watershed health.

## KEY FINDINGS

- Water courses in the assessment area do not meet state water quality standards for a number of parameters requiring the development of a Total Maximum Daily Load (TMDL) models for temperature, pH, total dissolved gas, and possibly bacteria and dissolved oxygen.
- The state also lists flow and habitat modifications as water quality concerns in the assessment area; however, these do not require TMDL development.
- Nitrate in groundwater is an additional water quality concern that requires further investigation.

- The TMDL development process is ongoing. Completed TMDL models will assist in determining actions needed to meet state water quality standards.

## ACTION ITEMS

- Develop an intensive water quality monitoring program that coordinates interagency water quality monitoring in the assessment area and fills the gaps where no monitoring currently exists.
- Work with ODEQ to continue collecting water quality data so that the development of TMDLs for the basin is based on current high quality data.
- Assist local irrigation districts and the Deschutes River Conservancy in developing flow data for mainstem and tributary streams.
- Investigate groundwater contamination in areas with high propensity for contamination and risks to human health.
- Support the City of Prineville to continue developing measures to reduce stormwater discharges.
- Continue to create projects that enhance, preserve, and conserve riparian buffers and wetlands.

## 8.1 INTRODUCTION

The federal Clean Water Act aims "*to protect and maintain the chemical, physical, and biological integrity of the nation's waters.*" The Act establishes the importance of assessing both water quality and the habitat required for maintaining fish and other aquatic organisms. The purpose of this chapter of the watershed assessment is to identify critical water quality issues and what is known about the status of water quality in the assessment area. This chapter includes a screening-level I assessment, which is used to flag obvious areas of water quality impairment to beneficial uses in the watershed.

Because water quality is such a broad topic, some aspects of water quality are addressed in other chapters. Fine sediments (turbidity) and other sources of sediment are addressed in Chapter 6 – Channel Habitat; factors such as shade; that affect temperature are addressed in Chapter 5 – Riparian and Wetland Conditions, and water quantity (flows), which is a critical variable when considering water quality, is discussed in Chapter 7 – Hydrology and Water Use. This chapter focuses on the chemical and physical properties of water quality, including temperature, dissolved oxygen, pH, nutrients, bacteria, and chemical contaminants.

Water quality conditions within the assessment area are highly variable. Higher elevation waterbodies in the Ochoco Mountains generally have better water quality, while lower elevation sites have lower overall water quality (CRWC, 2002). The primary causes of poor water quality are related to flows, the damming and diversion of water for irrigation, resource conditions in uplands and riparian corridors, and stream channels characterized by unstable banks and disconnected floodplains. Land uses including logging, roads, grazing, irrigated and non-irrigated agriculture, recreation, urban and rural residential development, and seasonal sewage treatment plant activities all potentially impact water quality as well (Crooked River Local Advisory Committee, 2006). However, identifying specific relations between land uses and water quality is beyond the scope of this assessment.

## 8.2 BENEFICIAL USES AND WATER QUALITY CRITERIA

The federal Clean Water Act (CWA) requires states to establish water quality standards to protect beneficial uses of the state's waters (Table 8-1). The beneficial uses of water are codified in Oregon Administrative Rules and generally apply basin-wide to all waters of the state. Waters of the state include lakes, bays, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, marshes, inlets, canals, and all other bodies of surface or underground waters, natural or artificial, public or private within Oregon (Crooked River Local Advisory Committee, 2006).

The management of waterbodies, riparian areas, and uplands directly impacts beneficial uses of the water. Salmonids, resident fish, and aquatic life are the most sensitive beneficial uses for a number of water quality parameters (including temperature, sedimentation, turbidity, nutrients, pH, and dissolved oxygen). Because of this sensitivity many of the ODEQ's water quality standards are based on the level at which aquatic life

Table 8-1. Beneficial Uses in Assessment Area (OAR 340-41-0130).

| Beneficial Use | Crooked River Mainstem | All Other Basin Streams |
|---|---|---|
| Public Domestic Water Supply[1] | X | X |
| Private Domestic Water Supply[1] | X | X |
| Industrial Water Supply | X | X |
| Irrigation | X | X |
| Livestock Watering | X | X |
| Fish & Aquatic Life[2] | X | X |
| Wildlife & Hunting | X | X |
| Fishing | X | X |
| Boating | X | X |
| Water Contact Recreation | X | X |
| Aesthetic Quality | X | X |
| Hydropower | X | |

[1]With adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards.

[2] Figures 130A and 130B in OAR 340-41-0130 indicate where specific salmonid Beneficial Uses are designated. All streams in the Crooked River watershed appear to be designated for "Salmon and Trout Rearing and Migration"; no streams are designated for "Salmonid Spawning".

is impacted. An exception to the use of aquatic life to determine the criteria is the bacteria standard, which protects the beneficial use of human water contact recreation.

Section 303(d) of the CWA requires each state to identify those waters for which existing required pollution controls are not stringent enough to achieve that state's water quality standards. These water bodies are considered "water quality limited" or "impaired" and are placed on the State's 303(d) list. The 2004/2006 303 (d) list for the State of Oregon was approved by EPA in February, 2007 (Table 8-2).

Once a water body is identified on the 303(d) list, Section 303(d) requires that a Total Maximum Daily Load (TMDL) plan be developed. TMDLs describe the amount of each pollutant a water body can receive without violating water quality standards. The ODEQ collected TMDL data for the Crooked River Watershed in 2005 and 2006. TMDL plans

Table 8-2. Water Quality Limited Stream Segments in the Lower Crooked Assessment Area

| Stream Segment | Listed Parameters (season) | Criteria |
|---|---|---|
| Little McKay Creek (RM 0-6.7) | Temperature (Year Around) | Salmon and trout rearing & migration 18°C (64.4°F) |
| McKay Creek (RM 0-19.5) | Temperature (Year Around) | Salmon and trout rearing & migration 18°C (64.4°F) |
| Ochoco Creek (RM 0-36.4) | Temperature (summer) | Fish Rearing 17.8° C (64°F) |
| Crooked River (RM 0-51) | pH (year around) | pH range of 6.5-8.5 |
| | Temperature (summer) | Fish Rearing 17.8°C (64°F) |
| Crooked River (RM 51-70) | Total dissolved gas | 110% of Saturation, presence of bubble gas disease in fish |

*(source: DEQ Water Quality Assessment, http://www.deq.state.or.us/wq/assessment/rpt0406.htm)*

for the assessment area are expected to be completed in 2010.

In addition to the listed criteria above, the 303(d) list database includes an evaluation of water quality parameters that don't require a TMDL. These parameters are not included in the impairment list for four possible reasons: 1) they do not require a TMDL since they are not considered a pollutant (e.g., habitat and flow modification), 2) insufficient data existed to determine impairment, 3) the listing criteria changed, or 4) state standards were attained. In the Lower Crooked additional parameters in the database include habitat modification, flow modification, bacteria, sedimentation, turbidity, nutrients, and aquatic weeds and algae.

## 8.3 MONITORING EFFORTS

Water quality monitoring in the assessment area has been conducted by a variety of agencies including the BLM, USFS, DEQ, CRWC, and CTWSRO. However, until recently, little coordination existed among the agencies conducting water quality monitoring leaving the data fragmented without a complete picture of the watershed. These efforts are described below.

1. **DEQ ambient monitoring program.** DEQ conducts bimonthly monitoring at a number of sites around the state. This data is used to assess long-term water quality conditions and trends and to assess compliance with state water quality standards. DEQ has historically maintained three ambient monitoring sites on the Crooked River, although only two are currently included in the DEQ monitoring program. The current sites are the Crooked River at Lone Pine bridge (mid-1960s to the present) and Crooked River at Conant Basin Rd. (1979 to the present). From 1988-1993, data was also collected from the Crooked River at the Hwy 126 bridge in Prineville. Information about the program and results of the trend analyses are available from the DEQ website at: http://www.deq.state.or.us/lab/wqm/ambientmonitoring.htm.

2. **Inter-agency temperature monitoring.** Several agencies have been collecting continuous temperature data from around the Crooked River watershed for a number of years. Agencies that have collected this data include: the Ochoco National Forest, Prineville District of the BLM, the Oregon Department of Fish and Wildlife, Oregon Water Resources Department, Central Oregon Irrigation District, Oregon Department of Environmental Quality, the Confederated Tribes of the Warm Springs Reservation of Oregon, and the CRWC. The CRWC is currently developing an effort to coordinate these many programs for temperature monitoring to ensure the appropriate quality assurance/quality control (QAQC) protocols are followed and minimize duplication of temperature monitoring efforts.

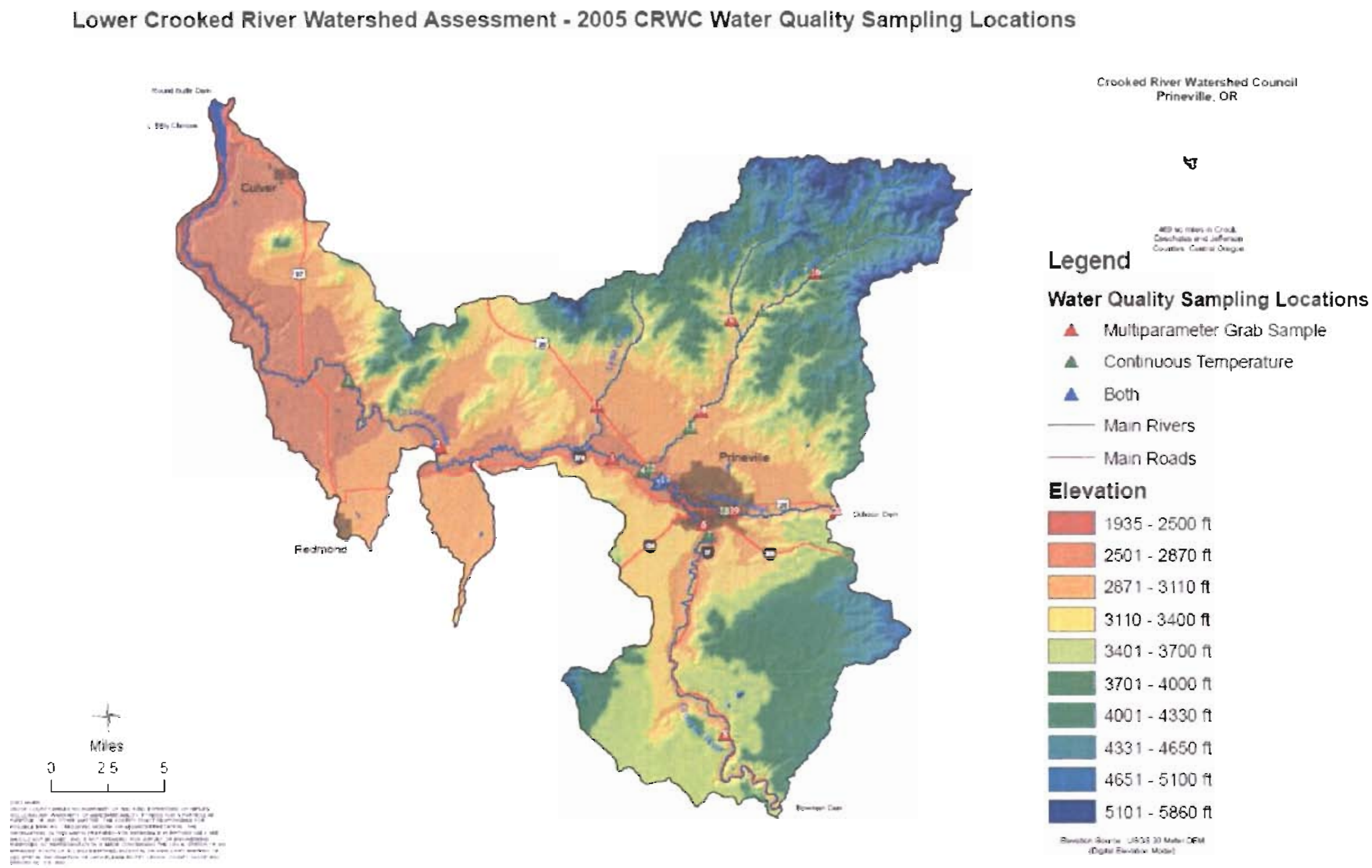
3. **Ochoco National Forest monitoring program.** The Forest Service is required to address water quality in environmental documents (e.g., environmental assessments and environmental impact statements). The Ochoco National Forest

manages a portion of the McKay Creek Watershed and regularly conducts water quality monitoring including temperature, flow, and turbidity measurements.

4. **BLM water quality study of Wild & Scenic River sections.** The BLM conducted a water quality study of the Wild and Scenic river sections of the Crooked River managed by the agency. Reports from these studies includes extensive water quality monitoring including flow data, multi-parameter water quality sampling, continuous temperature monitoring, infrared thermal monitoring to identify cool water spring infiltration to the river, and macroinvertabrate sampling. Results from these studies are available from the BLM at: http://www.blm.gov/or/districts/prineville/files/study%20results/pdo_Agenda-Symposium_05_07_2007.doc.

5. **CRWC Water Quality monitoring program**. The CRWC conducted preliminary water quality monitoring in 2005. This monitoring was designed to provide a general picture of water quality conditions within the assessment area (as well as the larger Crooked River Watershed). The ODEQ has provided funding to the CRWC to continue to develop this program. The initial monitoring data collected in 2005 included continuous temperature monitoring at ten stations and grab sample monitoring at 14 stations (Table 8-3, Map 8-1). Grab sample monitoring included dissolved oxygen, pH, turbidity, and specific conductance.

6. **DEQ TMDL monitoring**. DEQ conducted several different water quality studies in the Crooked River watershed during 2005 and 2006 in preparation for development of TMDLs. Based on the 2002 303(d) list, TMDLs need to be developed for temperature, pH, bacteria, and TDG. The following studies were designed to collect the necessary data.
   - <u>Bacteria</u>: Samples were collected for E. coli analysis for eight consecutive weeks in 2005 (mid-July through late-August) at eight sites distributed throughout the mainstem Crooked River Watershed. All but one of the sites was located in the assessment area.




**Map 8-1. 2005 CRWC Water Quality Sampling Locations**

Table 8-3. CRWC Monitoring Stations and Parameters for 2005.

| ID | Waterbody | Description | Lat | Long | Elev | T | G |
|---|---|---|---|---|---|---|---|
| 0 | Allen Creek | at Allen Bridge Road | 44.42369 | -120.81765 | 3225 | | 1 |
| 1 | Crooked River | at Canyons Ranch | 44.39055 | -121.15888 | 2600 | 1 | |
| 2 | Crooked River | u/s Lone Pine Bridge | 44.34823 | -121.08159 | 2755 | 1 | 1 |
| 3 | Crooked River | Elliot Road Bridge | 44.33673 | -120.92689 | 2820 | | 1 |
| 4 | Crooked River | d/s McKay Creek | 44.32826 | -120.89969 | 2830 | 1 | |
| 5 | Crooked River | Rim Rock Road wastewater lagoon | 44.32000 | -120.88681 | 2830 | 1 | 1 |
| 6 | Crooked River | Les Schwab park u/s footbridge | 44.29283 | -120.84794 | 2855 | | 1 |
| 7 | Crooked River | u/s end Les Schwab park | 44.28600 | -120.84333 | 2860 | 1 | |
| 8 | Crooked River | u/s BLM boundary | 44.15850 | -120.83430 | 2975 | | 1 |
| 9 | Dry Canyon | at Irrigation return flow | 44.33461 | -121.04802 | 2780 | | 1 |
| 10 | Lone Pine Canal | Irrigation return flow | 44.34633 | -121.07982 | 2760 | | 1 |
| 11 | Lytle Creek | u/s Hwy 26 | 44.37073 | -120.93860 | 2880 | | 1 |
| 12 | McKay Creek | d/s Hwy 26 bridge | 44.33000 | -120.89325 | 2845 | 1 | |
| 13 | McKay Creek | d/s Grimes Road bridge | 44.35564 | -120.85704 | 2940 | 1 | |
| 14 | McKay Creek | d/s McKay Creek Road bridge | 44.36555 | -120.84676 | 2980 | | 1 |
| 15 | McKay Creek | u/s Holtzapple bridge | 44.42913 | -120.78990 | 3255 | 1 | |
| 16 | McKay Creek | u/s USFS boundary | 44.45239 | -120.74195 | 3500 | | 1 |
| 17 | Ochoco Creek | d/s Hwy 26 bridge | 44.32272 | -120.88360 | 2840 | 1 | 1 |
| 18 | Ochoco Creek | under RR on Combs Flat Road | 44.30135 | -120.82655 | 2880 | 1 | |
| 19 | Ochoco Creek | d/s Willowdale Road bridge | 44.30114 | -120.82024 | 2890 | | 1 |
| 20 | Ochoco Creek | d/s Ochoco dam | 44.29906 | -120.72899 | 3030 | | 1 |

(T) = continuous temperature monitoring; (G) = grab sample monitoring for dissolved oxygen, pH, turbidity, and specific conductance; u/s = upstream and d/s = downstream.

- Temperature: An aerial Thermal Infrared (TIR) survey was conducted during the first week of August 2005 to better characterize thermal conditions throughout the Crooked River Watershed. In the assessment area, data was collected on the Crooked River and Ochoco Creek, and both true color digital imagery and TIR imagery were acquired (e.g., Figure 8-1). The TIR data is appropriate for identifying sources of thermal cooling within the hydrologic system such as cool water springs or general longitudinal trends in thermal conditions. The final report from the survey can be obtained from the DEQ at the following web location:

http://www.deq.state.or.us/wq/TMDLs/docs/deschutesbasin/crookedriver.pdf.

Water quality intensive surveys: Three week long intensive water quality surveys to collect both continuous diurnal data and instantaneous ambient data were done in August 2005, early-November 2005, and mid-March 2006. Study parameters included water

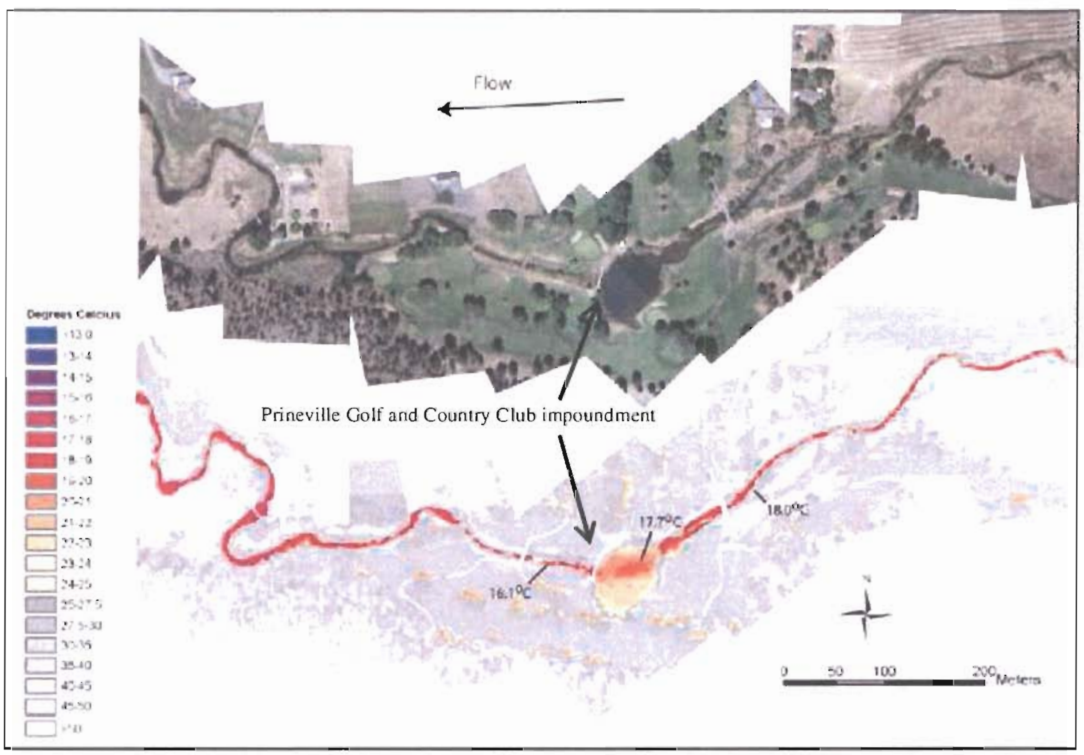



Figure 8-1. Thermal infrared image (bottom) and true color image (top) show Ochoco Creek at mile 8.6. A temperature decrease of 1.6o C was observed just downstream of the Prineville Golf and Country Club impoundment.

temperature, pH, alkalinity, conductivity, dissolved oxygen, turbidity, nutrients, solids, chlorophyll-a, total organic carbon (TOC), and chemical oxygen demand (COD). Monitoring included the following sites within the assessment area on the Crooked River:

- Downstream of Bowman Dam
- Downstream of Castle Rock Campground
- County Park
- Downstream of Waste Water Treatment Plant
- Upstream of Dry Canyon
- Lone Pine Bridge
- Smith Rock

In addition, samples were collected from the mouths of Ochoco Creek, McKay Creek and Dry Canyon.

- Biomonitoring surveys: During September, 2005, macroinvertebrates surveys were conducted at 28 sites in the Crooked River Watershed, with six of these sites located in the assessment area on either McKay Creek or the Crooked River.

## 8.4 SUMMARY OF WATER QUALITY DATA AND CONCERNS

### 8.4.1 Temperature

Water temperatures are critical to fish growth and survival at all life stages. Warm stream temperatures increase stress and disease, raise metabolism, lower growth rates, and enhance conditions for introduced non-native predators. Temperature affects the dissolved oxygen potential in water – the warmer the water, the less dissolved oxygen it can hold. Fish cope with thermal stress and the related water quality impairments by adjusting their behavior during the warmer summer months. Coldwater fish may seek refuge during the heat of the day in nearby cooler waters that are fed by springs or ground water, while others may migrate great distances to seek out cooler headwaters. Coldwater species of fish also adapt their body structure, chemistry and physiology during thermal stress to become more efficient at the metabolic processes that regulate swimming, avoiding predators, etc.

Stream temperatures are influenced primarily by direct solar radiation, air temperature, and movement of groundwater into streams (Moore and Miner, 1997). Basic approaches to minimizing increases in water temperature include: providing shade, maintaining a narrow stream, and maintaining adequate in-stream flows. Water temperature is closely correlated to water quantity, such that more thermal energy is required to increase water temperature under greater flows. Vegetation also affects most of these factors and land use and management often have a direct influence on vegetation.

Oregon's temperature standard (OAR 340-041-0028) is designed to protect the different life stages of fish and aquatic life, and has several different numeric temperature requirements (criteria) based on the type of aquatic use being supported. These numeric criteria are based on a seven-day moving average of daily maximum temperatures. ODEQ's current temperature standard was adopted in March 2004. Under the previous standard, the assessment area was evaluated for both fish spawning (numeric criterion of 55°F) and rearing (numeric criterion of 64°F). This evaluation is reflected in the older 2002 303(d) list. Under the new standard, the spawning criterion was only applied in streams that were identified as supporting salmon and steelhead spawning; no streams in the Crooked River watershed currently meet this criterion. Therefore, streams in the Crooked River watershed were only evaluated against the rearing criterion (64.4°F under the new standard). If the reintroduction of anadromous fish into the assessment area is successful, it is likely that the spawning criterion will be again applied to the assessment area. The standard also allows streams to naturally exceed the temperature criteria; however, human activities may not increase the water temperature beyond the natural level. If a stream exceeds the numeric criterion, agricultural landowners are not in violation as long as their activities are in compliance with the *Crooked River Agricultural Water Quality Management Area Plan* (2004).

Data collected in 2005 show that temperature generally increases in each stream as you progress downstream (Figure 8-2). Thermal stratification of water causes colder more dense water to sink to the bottom of reservoirs and warmer less dense water to remain on

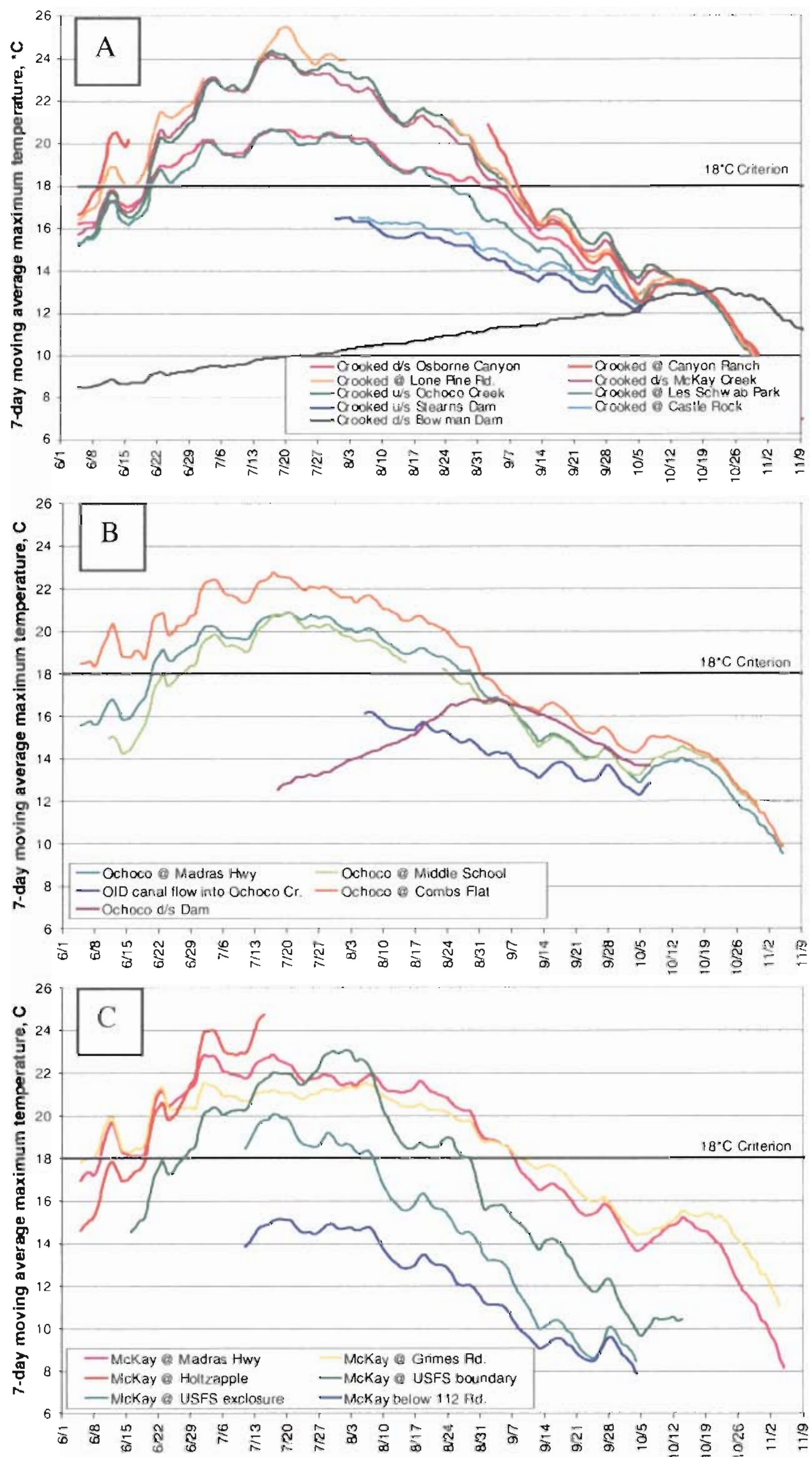



Figure 8-2. 2005 Water Temperature Data: A) Lower Crooked River, B) Ochoco Creek, and C) McKay Creek (data sources: DEQ, CRWC, ODFW, USFS).

the surface. In both the Crooked River and Ochoco Creek, temperatures in the river directly below the dams are cold all summer long since the discharges from the dams are pulled from the bottom of each reservoir where cooler water stratifies. In the Crooked River, temperatures generally increase as you move downstream until the Osborne Canyon site. Colder water from springs causes the cooler temperatures in the lower stretch of the Crooked River. In Ochoco Creek, a cooling trend is observed between Combs Flat Rd. and the Middle School. This decrease in temperature is the result of an Ochoco Irrigation District return flow below Combs Flat Rd. The return flow pipe introduces cooler canal water diverted from the Crooked River into Ochoco Creek.

### 8.4.2 pH

pH is a measure of the hydrogen ion concentration of the waters using a logarithmic scale of 0.0 to 14.0. pH below 7.0 is acidic while pH greater than 7.0 is alkaline. Spawning and rearing of salmonid fish species are the most sensitive beneficial uses affected by pH. Values of pH outside the range in which a species evolved may result in both direct and indirect toxic effects. Elevated pH levels can cause dramatic increases in toxicity of other pollutants, such as metals and ammonia, and cause fish kills.

Like temperature, pH naturally varies both daily and seasonally. Fluctuations in pH are usually the result of the photosynthetic activity of aquatic plants or algae. Algae and aquatic plants become food for aquatic insects and crustaceans, and are an important part of the stream ecosystem. However, over-stimulated plant growth from warm water and high levels of nutrients can cause an increase in pH, a decrease in the available oxygen, and alter aquatic invertebrate and plant communities. Nutrient sources in streams often include septic systems, treated waste water from municipalities, animal feed lots, and fertilizers used in agriculture. These conditions can be exacerbated by low stream flows and lack of riparian cover. pH levels in streams are typically highest late in the afternoon when photosynthesis is at its maximum.

The pH standard for streams in the Deschutes Basin (including the Crooked River watershed) states that pH values should not fall outside the range of 6.5-8.5 (OAR 340-

041-0135). However, the Crooked River drains the Ochoco Mountains, which are more similar geologically to eastern Oregon than the Cascades. Eastern Oregon has a maximum pH criterion of 9.0, and as part of the TMDL analysis, ODEQ may raise the maximum pH criterion for the Crooked River watershed from 8.5 to 9.0, to reflect the local geology.

During the 2005/6 intensive study by DEQ, pH levels exceeded the state criteria of 8.5 in all three sampling months (August 2005, November 2005, March 2006; Table 8-4), with the Castle Rock site having the largest diurnal swings from 7.83 to 9.22. If the upper pH criterion was adjusted to 9.0, then pH criterion would only be exceeded in August based in the 2005-2006 data.

Table 8-4. Range of pH levels by sampling month from ODEQ intensive study.

| | August 2005 | | November 2005 | | March 2006 | |
|---|---|---|---|---|---|---|
| **Stream Name** | **Low** | **High** | **Low** | **High** | **Low** | **High** |
| Crooked River | 7.3 | 9.3 | 8.2 | 8.9 | 8.3 | 8.7 |
| Dry Canyon | 8.0 | 7.7 | 8.0 | 8.3 | 8.0 | 8.5 |
| McKay Creek | 8.0 | 9.0 | 8.7 | 8.7 | 8.2 | 8.4 |
| Ochoco Creek | 7.6 | 8.7 | 7.9 | 8.2 | 8.0 | 8.8 |

CRWC collected data in 2005 to support the TMDL development. The sampling period differed from ODEQ's by sampling primarily during the higher flow periods from February to April. The focus of the study was to assess the pH levels in the tributary streams in relation to the mainstem Crooked River. In the sampling period, Allen and Ochoco Creek exceeded the 8.5 standard for all three months. Only the Crooked River exceeded the 9.0 pH standard in the CRWC high flow data.

pH is also measured at DEQ's ambient monitoring station at Lone Pine Road bridge. pH levels at the Lone Pine Road site have surpassed the 8.5 criteria fairly regularly since the 1960s when data collection began; with March typically having the highest recorded values.

### 8.4.3 Dissolved Oxygen

Adequate concentrations of dissolved oxygen (D.O.) are essential for supporting fish, invertebrates, and other aquatic life. Some aquatic species including salmonids are sensitive to reduced concentrations of D.O., especially during early life stages as eggs and alevins. D.O. concentrations in the water column vary naturally over the course of the day due to temperature changes and photosynthetic processes. D.O. levels in the water are typically at their lowest during the early morning hours when photosynthesis is typically lowest.

Concentration of dissolved oxygen within water also undergoes seasonal fluctuations. Warmer water temperatures increase the amount of plant production and thereby increase dissolved oxygen. However, the decomposition of plants material requires oxygen and leads to decreases in dissolved oxygen. Other factors affecting D.O. include changes in flow patterns that affect the aeration of the water; sewage seepage, urban runoff, and nutrient deposition all increase the amount of organic and inorganic compounds within the water and lead to reduced oxygen levels as nutrients undergo chemical oxidation.

D.O. can be measured either as mg/L of oxygen or as percent of saturation. Percent of saturation is the amount of oxygen that can be held within the water at that temperature and altitude. Cold water holds more dissolved oxygen than warm water, and water at higher altitudes holds less dissolved oxygen than water at lower altitudes.

The water quality standard (OAR 340-041-0016) for dissolved oxygen takes into account the salmonid life stage present, barometric pressure, altitude and temperature. D.O. levels are most stringent during the spawning season. In the Deschutes basins, redband/steelhead trout typically spawn during the spring months from March to May (Zimmerman, 1999). At other times of the year the "cool-water" or "cold-water" criteria apply. For the assessment area, the standard can generally be summarized as follows: (1) during the spawning season (January 1-May 15), the D.O. may not be less than 11.0 mg/L, or if conditions of barometric pressure, altitude and temperature preclude attainment of 11.0 mg/L, then D.O. levels must not be less than 95 percent of saturation;

(2) for water bodies identified as providing cold-water aquatic life, the D.O. must not be less than 8.0 mg/L or 90 percent of saturation; and (3) for water bodies identified as providing cool-water aquatic life, the D.O. may not be less than 6.5 mg/L. The designation of "cool-water" and "cold-water" is determined based on the ecological zone in which the water body is found. In the development of the draft 2004/2006 303(d) list, McKay Creek, Little McKay Creek, and Ochoco Creek were identified as providing cold-water aquatic life and the Crooked River was identified as providing cool-water aquatic life. Other tributaries in the assessment area were not evaluated.

During low flows in August, 2005, DEQ continuous data indicates that there are some reaches within the basin that are D.O. limited (Figure 8-3); however, most reaches in the Crooked River exceed the D.O. criterion for the river. The Crooked River is classified as "cool-water" habitat and falls within the 6.5 mg/l guidelines. The monitoring sites located downstream of the Waste Water Treatment Plant (WWTP), upstream of Dry

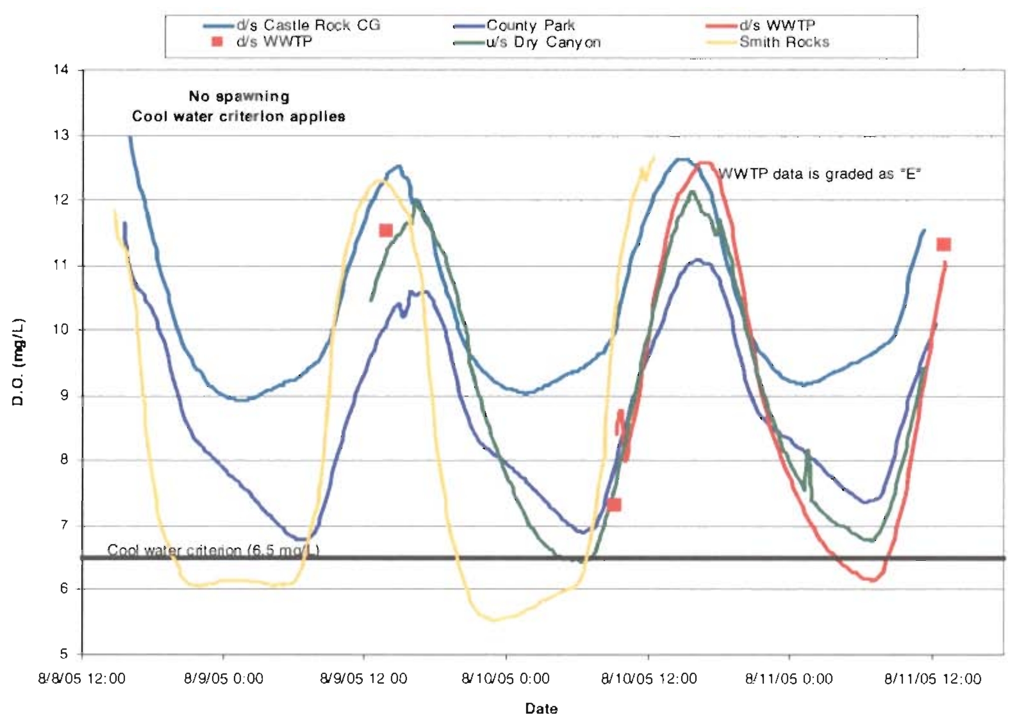



Figure 8-3. D.O. levels for the Crooked River sampling locations in August 2005.

Canyon, and at Smith Rock sites had values that dropped below the 6.5 mg/L standard in August of 2005. Plant photosynthesis, lower instream flow, and water temperature are all factors that contribute to the depletion of dissolved oxygen.

During DEQ's TMDL monitoring in March, 2006, D.O. levels were below the spawning criteria at the monitoring site on the Crooked River at the County Park. D.O. ranged from 10.72 mg/L to 11.43 mg/L, with the lowest levels occurring in the first hours of the day and a median of 10.9 during the sampling period. The only other site where continuous data was available for the Lower Crooked River from the March sampling event was from the Smith Rock site. Data at the Smith Rocks sites was well above 11mg/L (ranging from 12 to 13 mg/L).

### 8.4.4 Bacteria

High levels of bacteria can cause human illnesses. Thus the most sensitive beneficial use protected by the bacteria standard is water contact recreation. Recreation includes activities such as swimming or fishing where people could swallow or have water touch open cuts or sores. The bacteria standard also does not allow bacteria in numbers high enough to interfere with waters used for domestic purposes, livestock watering, irrigation, or other beneficial uses.

Prior to 1996, DEQ's bacteria standard used fecal coliform bacteria as the indicator organism. Based on DEQ's ambient monitoring at Lone Pine Rd., this standard was exceeded in the Crooked River, resulting in an early 303(d) listing of the Crooked River from river mile 0-51 for fecal coliform bacteria. In 1996, DEQ adopted a new water quality standard for bacteria (DEQ, 1995). The new standard (OAR 340-041-0009) uses *Escheria coli* (*E. coli*) as the indicator of the presence of human pathogens in freshwaters, rather than fecal coliform bacteria, and states that: (1) no single sample may exceed 406 *E. coli* organisms per 100 milliliters; and (2) a 30-day log mean may not exceed 126 *E. coli* organisms per 100 milliliters, based on a minimum of 5 samples.

With adoption of the new bacteria standard, DEQ began collecting *E. coli* data in 1996 to evaluate bacteria water quality issues. Data from 1996-2003 was evaluated for the 2004/2006 303(d) list. Because there were no observed violations of the single sample *E. coli* standard (406 organisms/100 ml) at either ambient monitoring site on the Crooked River during this time, the bacteria listings for the Crooked River were removed from the 2004/2006 303(d) list.

As part of the TMDL water quality assessment and data collection, DEQ conducted an 8-week *E. coli* monitoring study during the summer, 2005, to better assess bacteria water quality concerns in the Crooked River. Preliminary results of this study indicate that there were violations of the single sample numeric criterion for *E. coli* at McKay Creek at the Hwy 26 bridge, lower Dry Canyon, and Crooked River at Lone Pine Rd. bridge. These same three sites also exceeded the *E. coli* criterion for the 30-day log mean, as did Ochoco Creek at the Hwy 26 bridge. Further analysis of the bacteria data collected in this study will be done in conjunction with the TMDLs for the Basin.

### 8.4.5 Total Dissolved Gas

High concentrations of dissolved gas can cause gas bubble disease in fish. This disease is characterized by the formation of gas bubbles in the body cavities of fish, such as behind the eyes (causing exophthalmia) or between layers of skin tissue. Small bubbles can form within the vascular system, blocking the flow of blood and causing tissue death. Bubbles can also form in the gill lamellae and block blood flow, occasionally resulting in asphyxiation. The supersaturation of nitrogen gas appears to cause the most problems for fish.

In April 1989, Oregon Department of Fish and Wildlife (ODFW) biologists conducted an extensive fish population inventory on a five mile segment of the Crooked River immediately below Bowman Dam. Gas bubble disease was observed in over 85% of the redband trout captured during this study. Two weeks following the inventory, ODFW biologists measured gas saturation levels at three locations in the river. Saturation levels at 0.5, 3.0, and 5.0 miles below the dam were 109%, 109%, and 108%, respectively. One month after the inventory saturation levels were still 108% at all three locations.

As a result of the 1989 ODFW fish population inventory which documented gas bubble disease in trout, the Crooked River from Bowman Dam to river mile 51 (slightly upstream of Prineville) was included the State's 303(d) list for not meeting the State total dissolved gas (TDG) standard. The standard has both a narrative and numeric criterion:

(1) Waters will be free from dissolved gases, such as carbon dioxide, hydrogen sulfide, or other gases, in sufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life, navigation, recreation, or other reasonable uses made of such water.
(2) Except when stream flow exceeds the ten-year, seven-day average flood, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 110 percent of saturation. However, in hatchery-receiving waters or other waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 105 percent of saturation.

In preparation for development of a TMDL for TDG on the Crooked River, the Bureau of Reclamation (BOR), ODEQ, ODFW and the Ochoco Irrigation District (OID) have been conducting a TDG study on the Crooked River from Bowman Dam down to Stearns Dam (a distance of approximately 12 miles). TDG data was collected during high flows in April and May 2006 and on one day of low flows during June 2006, and again in the spring of 2007. In addition, ODFW conducted a fish survey on April 11, 2006 during the high flows of 2600 cfs to assess the presence of gas bubble disease in fish. The survey was done in several reaches of the first four miles of the river below the dam focused on redband trout and mountain whitefish.

Preliminary results from the 2006 investigation indicate that the numeric criterion of 110% saturation was routinely exceeded along the entire 12-mile length of the study when river flows were greater than 2000 cfs. During high flows TDG levels decreased over the first two miles below the dam, and then increased slightly over the next ten miles. The maximum TDG observed during the study was 123% in the stilling basin with flows around 2600 cfs. Preliminary results from 2007, conducted between flows of 500 and 1000 cfs indicate that TDG decreases along the entire 12-mile length of the study area, and that TDG is generally below the 100% criterion. Preliminary results from the fish survey under these same flows indicate that a substantial percentage of fish show signs of gas bubble disease. Redband trout appeared to be more severely impacted than mountain whitefish in terms of both number of fish affected and severity of the disease. Between 45%-67% of redband caught exhibited signs of gas bubble disease, compared with 47% of the mountain whitefish. The results of the study during high flow conditions indicate that releases from the dam contribute to the TDG problems observed in the river.

During the June 2006 low flow sampling event, TDG levels in the stilling basin were below 110% saturation, however levels increased with distance from the dam. All of the monitoring sites from 2-12 miles downstream of the dam slightly exceeded the 110% criterion. This reverse pattern of TDG suggests that under low flow and warmer conditions that the super-saturation observed in the river may be due to a combination of primary production and increasing water temperature. Further research is needed to better characterize the conditions which cause elevated TDG levels under different flow conditions and the effects of these TDG levels on fish.

### 8.4.6 Turbidity

Turbidity measures the amount of light able to pass through a sample and is reported as nephelometric turbidity units (NTU); with increasing NTU, decreasing light passage and increasing solids are reported. Prolonged exposure to increased turbidity within the water column affects the ability of fish to see and obtain food and to uptake oxygen due to solids in gill tissues. As solids settle, they can cover the aquatic substrate smothering fish eggs and other benthic organisms. Turbidity also reduces the penetration of sunlight into the water column.

Turbidity is related to total suspended solids (TSS), which can include toxins carried in the water column. Once in the water column, some compounds can enter directly into the aquatic food chain through fish and other high trophic-level species. Other toxins make their way into the food chain by adhering to fine sediments, which deposit onto the aquatic substrate and are incorporated into benthic organisms (UDWC, 2006).

Sediment loading occurs from natural and anthropogenic influences and can contribute to the turbidity of an aquatic system. The local geology, soils, slope, health of the riparian zone, precipitation rates, and natural stream flows all can contribute to natural rates of sediment loading and turbidity. Land management practices, storm water discharges, construction, logging, roads, flow regulations, and agricultural activities can increase the sediment load and turbidity above natural levels (UDWC, 2006). Unstable and avulsing stream banks also contribute substantial loads of fine sediment into the water column causing increased turbidity.

The state standard for turbidity (OAR 340-041-0036) states, *"...no more than a ten percent cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity."* This standard is useful when assessing point source discharges (i.e. individual or end-of-pipe), but does not adequately address nonpoint source concerns (i.e., runoff or sediment production from eroding stream banks). The Oregon Watershed Assessment manual recommends an *"evaluation criteria of 50 NTU"* as the level at which salmonid sight is negatively affected for feeding (Watershed Professionals Network, 1999).

Samples collected during both the CRWC and DEQ intensive study in 2005 were largely under the OWEB evaluation criteria (Table 8-5). The highest values for turbidity occur in spring when precipitation carrying small particles enters into the waterways. With the exception of Dry Canyon, the highest values recorded took place from January to April. Since Dry Canyon returns effluent from irrigation in Powell Butte the highest values typically occurred in September when irrigation water increases the volume of flow.

Table 8-5. Range of turbidity values from 2005 CRWC monitoring data (DEQ values in parenthesis).

| Stream | Lowest NTU | Highest NTU |
|---|---|---|
| Allen Creek | 1 | 14 |
| Crooked River | 4 (3) | 48 (45) |
| Dry Canyon | 1 (1) | 6 (3) |
| Lytle Creek | 4 | 20 |
| McKay Creek | 1 (4) | 26 (12) |
| Ochoco Creek | 1 (1) | 14 (91) |

Although during the 2005 sampling, most samples were under the OWEB 50 NTU criteria, the issue of turbidity and its role in water quality is still an area of concern for the assessment area. Continuous monitoring of turbidity levels throughout the year could clarify temporal and spatial discharges of sediment into streams and assist in identifying problematic reaches.

### 8.4.7 Nitrates

Local concern over nitrate contamination in well and groundwater has been voiced by local residents and City of Prineville staff. The Pacific Northwest Water Quality Exchange database assimilates data from a number of sources including when wells are tested as part of real estate transactions. The database confirms that a number of area wells have shown nitrate levels exceeding the EPA's safe drinking water standard of 10 mg/L since approximately 1990. Some of the wells tested indicate nitrate levels as high as 30.6 mg/L in the exchange database (Pacific Northwest Water Quality Exchange, 2005). Concentrations greater than 3 mg/L suggest human influence (Lamb, 2005). Common human sources of nitrates in groundwater and well water include contamination from agricultural fertilizers, livestock waste, wastewater treatment lagoons, industrial waste and septic systems (ODEQ, 2002).

Groundwater in the assessment area is particularly susceptible to nitrates as well as other types of contamination because high water tables exist in the most populated portions of the watershed around Prineville, Lone Pine, and along valley bottoms in general. This is especially a concern where residents are not serviced by the public water and sewer systems. Many residents have shallow wells and septic systems. Nitrates can also be a concern around crop and livestock production areas that are dependent on inputs of high nitrogen fertilizers. Elevated nitrate levels in drinking water can cause serious health problems in infants and pregnant or nursing women. Nitrate exposure may also pose a danger for miscarriages and cancer in adults (ODEQ, 2002). A comprehensive evaluation of nitrogen contamination in groundwater is beyond the scope of this assessment; however, a 2006 DEQ publication specifically focuses on groundwater quality in the Deschutes Basin:

(http://www.deq.state.or.us/lab/techrpts/groundwater/DeschutesBasinGW.htm). A more thorough investigation of groundwater in areas with the propensity for contamination, focusing on nitrates and other harmful contaminants, is needed to better understand human health risks and groundwater concerns in the assessment area.

## 8.5 STORMWATER

Currently, the City of Prineville is not required to have a stormwater discharge permit. However, as the City's population increases, the City's stormwater management may come under greater scrutiny, and there is a greater likelihood that the ODEQ may require a storm-water discharge permit. In response to concerns regarding stormwater and rapid population growth, the City of Prineville and Crook County have recently entered into a regional partnership with other cities and counties in Central Oregon to develop a stormwater management guide. The goal of the partnership and guide is to develop guidelines for managing stormwater runoff in an effort to protect water quality and meet provisions of the federal Clean Water Act and Safe Drinking Water Act.

## 8.6 SUMMARY

An understanding of water quality in the assessment area has been driven by ODEQ's mandate to implement the requirements of the federal Clean Water Act. Intensive data collection has occurred for temperature, pH, dissolved oxygen, total dissolved gas, bacteria, and turbidity. Based on the available data, temperature, pH, and total dissolved gas, and bacteria most consistently limit water quality in the assessment area. Detailed multi-parameter data are mostly limited to the Lower Crooked River and little detail is available for tributaries. There is also some indication that nitrates and dissolved oxygen may be a concern; however, the assertion is based on a limited sample of data and further research is needed to test the validity of the concern. Stormwater run-off is a growing concern as the population and developed area of the assessment area increases. While the City of Prineville and Crook County are taking proactive steps to address stormwater, continued engagement will be required to evolve stormwater management practices to keep pace with continued growth and development.

To keep current with trends in water quality over time and space, a locally driven water quality monitoring program will be needed so that land management practices, regulations, and decision making reflect current needs and limitations rather than those of the past. A vast array of resources exists in the assessment area for understanding and improving water quality. A local effort to coordinate those resources and keep monitoring data current will be an asset to local and state decision makers as water quality will continue to be a priority regulatory concern.

# Chapter 9 – Fish and Fish Habitat

*Redband Trout (photo credit: unknown)*

## CRITICAL QUESTIONS

1) What species of fish were historically present in the assessment area?
2) What is the current status of fish habitat and populations in the assessment area?
3) What factors will affect the anadromous reintroduction effort in the assessment area?

## DATA GAPS AND RESEARCH RECOMMENDATIONS

- Competition between fish species (i.e. redband trout and mountain whitefish) is not well understood.
- Impacts to resident redband trout from total dissolved gas below the Bowman Dam are not well understood.
- Competition between resident and reintroduced anadromous species and the potential for the introduction of disease to resident fish from anadromous fish are unknown factors that may affect fish populations in the assessment area.
- The regulatory impact of reintroducing of steelhead and bull trout into the assessment area is unclear.

## KEY FINDINGS

- Anadromous fish species including Chinook salmon and steelhead trout are native to the assessment area.
- Bull trout are a native species that historically foraged in the lower reaches of the assessment area.
- Modifications to channel structure and riparian areas have contributed to degraded fish habitat, and declines in redband trout populations.
- Stream flow significantly impacts quantity and quality of fish habitat and is leading factor in determining fish populations.
- Water quality, specifically temperature and nitrogen super saturation, affects fish populations and available habitat.

- The Crooked River below Bowman Dam provides a very popular tailrace fishery for redband trout. This generates favorable publicity and economic revenue to Prineville and Crook County.
- Flow releases for irrigation purposes in Ochoco Creek and McKay Creek below the Jones Diversion have created artificially favorable conditions for redband trout.
- Minimum flow targets for salmonids are met in most years in the upper and lower canyon reaches; however, the Prineville Valley is likely habitat limited due to low stream flows.
- Several important irrigation diversions do not currently allow for upstream fish passage or require screening.

## ACTION ITEMS

- Continue to work with landowners to implement stream enhancement projects within the assessment area.
- Engage both the City of Prineville and Crook County regarding the protection of riparian buffers on Crooked River, Ochoco, and McKay Creeks, and search for win-win solutions for habitat and flow restoration to support the anadromous reintroduction effort.
- Work with ODFW in researching interaction between redband trout and mountain whitefish in the tailrace fishery below Bowman Dam.
- Work with ODFW and BOR regarding solutions to nitrogen gas super saturation.
- Support efforts to monitor and evaluate populations of redband trout, steelhead, and Chinook after reintroduction begins.
- Work with landowners and ODFW to provide fish passage at migration barriers.

## 9.1 INTRODUCTION

Fish are a recognized indicator of watershed health. Anadromous and resident fish, and the aquatic life they consume, have predictable sensitivities to water quality parameters including temperature, sedimentation, turbidity, nutrients, pH, and dissolved oxygen. For example, water temperatures are critical to fish growth and survival at all life stages. Warm stream temperatures increase stress and disease, raise metabolism, lower growth rates, and increase competition from introduced non-native species. Coldwater fish cope with thermal stress by adjusting their behavior and seeking refuge during the heat of the day in nearby cooler waters that are fed by springs or ground water or migrating great distances to seek out the cooler headwaters. Because of these sensitivities many of the Oregon Department of Environmental Quality's (ODEQ) water quality criteria are based on the level at which aquatic life is impacted (Crooked River Local Advisory Committee, 2004). The evaluation of fish habitat and populations is a critical part of understanding the in-stream conditions of the watershed.

This component provides a general description of fish populations and their distribution as well as fish habitat conditions within the assessment area. Understanding fish populations and habitat is important for developing future management, conservation, and restoration efforts. Fish are an important indicator of overall watershed health as they live and breathe in the water that is captured, stored, and released by the watershed. While currently no anadromous species exist in the watershed, a reintroduction effort is planned to begin in 2008. The challenges and opportunities of that effort are also addressed in this chapter.

## 9.2 Fish Management and Regulations

There are numerous agencies and regulations that oversee the management and protection of fish resources within the assessment area. ODFW is charged with managing fish populations and harvest within the waters of the State of Oregon. ODFW interacts with federal, state, local partners, and tribal governments. At the federal level, the USFWS is responsible for ESA listed resident inland fish, and the NOAA Fisheries Service is responsible for ESA listed marine and anadromous fish. These agencies administer all federal laws related to fish. In the assessment area the CTWSRO work collaboratively with ODFW to meet the objectives of the Crooked River Basin Plan (1996) and the Anadromous Fish and Bull Trout Management in the Upper Deschutes, Crooked, and Metolious River Plan (ODFW, 2003). CTWSRO are involved in many fish management activities in the Deschutes River basin, including the Pelton-Round Butte anadromous reintroduction. The management objectives adopted within the Crooked River Basin Plan (1996) include to:

- restore anadromous and migratory resident fish to their historic range by improving upstream and downstream passage over artificial barriers, and
- reconnect isolated and fragmented populations of redband trout by restoring and improving passage over manmade barriers.

At the federal level there are numerous laws that impact fish and fish habitat including the Endangered Species Act (ESA) and the Clean Water Act (CWA). The ESA is particularly relevant in the assessment area given the planned reintroduction of Federally Threatened anadromous mid-Columbia summer steelhead (*Ochorynchus mykiss*). The CWA regulates water quality with the objective "to protect and maintain the chemical, physical, and biological integrity of the nation's waters." The Act establishes the importance of assessing both water quality and the habitat required for maintaining fish and other aquatic organisms (Watershed Professionals Network, 1999).

At the state level, the OWRD regulates water use (water rights) throughout the state, and the ODEQ and ODA enforce state water quality standards under ODEQ administrative rules (Chapter 340, Division 41) and Senate Bill 1010. The Oregon Forest Practices Act (ORS 527.610 to 527.730), administered by ODF, contains measures that are intended to protect water quality, fish, and fish habitat from degradation related to timber harvest activities. ODSL administers Oregon's Fill-Removal law, which requires a permit for the removal or filling of more than 50 cubic yards of material below the average high water mark. ODSL collaborates with ODFW to set guidelines for establishing in-water work periods for removal-fill activities within waterways.

## 9.3 FISH HABITAT

Historical accounts of the Crooked River Basin describe an ecosystem characterized, "by dense riparian vegetation [that] supported abundant fish populations." (Lichatowich, 43, 1998; Stuart et al., 2006). In general, historical accounts describe an ecosystem that included resources such as healthy beaver populations, extensive wetland areas, high water tables, lush native grasses, and abundant riparian vegetation. Riparian vegetation included prolific willow, alder, and cottonwood communities that would have provided a variety of habitat enhancing elements such as shade, nutrients, woody debris, channel diversity, and bank stability.

Roads, development, urbanization, recreation, grazing, agriculture, dams, irrigation diversions, and timber harvest have all impacted fish habitat conditions in the assessment area (Nehlsen, 1995; ODFW, 1996; ICBEMP, 1997; Lichatowich, 1998; USDA USFS, 1998b; WSPE, 1999; NWPPC, 2001; CRWC, 2002; Stuart et al., 2006). Intensive grazing in the late 1800's and early 1900's combined with drought had a substantial impact on fish habitat (Buckley, 1992; USDA USFS, 2002; Murphy, 2005). The extensive diversion, damming, and management of natural flows for irrigation purposes has reduced the volume and timing of water available for fish habitat. Land and water use have resulted in lower water quality in the Lower Crooked River Watershed, particularly with respect to temperature, which may limit fish habitat potential (CFTWSRO & PGE, 2001a). Water quality and quantity are closely related, and both are cited as sources of significant impacts to fish habitat (ODFW, 1996; Lichatowich, 1998; USDA USFS, 1998b; WSPE, 1999; NWPPC, 2001; ODFW, 2003, Hodgson, 2005).

In addition to the many current land and water use impacts to riparian and aquatic communities in the Lower Crooked River Watershed, "the depletion of beaver probably had [the] greatest impact on salmonid habitat in … the Crooked River" (Lichatowich, 43, 1998). The removal of the beaver combined with current factors such as grazing and water use effect habitat structure, complexity, and diversity in a variety of ways including (USDA USFS, 1995b; ODFW, 1996; USDA USFS, 1998b; WSPE, 1999; NWPPC, 2001; CRWC, 2002):

- Decreases in pool habitat (frequency and depth)
- Losses of riparian vegetation
- Increases in channel width
- Changes in volume of water flow

- Changes in timing (season) and level of peak flows
- Barriers to fish migration, including low flows
- Entrapment in unscreened irrigation diversions.
- Increases in turbidity and pollutants
- Increases in water temperatures

Declines in stream morphology function, riparian conditions, water quality and quantity, and habitat connectivity have led to severe declines or extirpation of native fish species within the basin (CRWC, 2002). Although management of riparian and aquatic habitats is improving in much of the assessment area, the extent of historical damage and continued pressure on fish habitat has slowed recovery. Degradation levels limit management options as fish populations are currently depressed in much of the assessment area and active restoration efforts are needed throughout the assessment area (ODFW, 1996; USDA USFS, 1998b; WSPE, 1999).

Another water quality issue affecting fish habitat is the presence of dissolved gas (particularly nitrogen) super saturation in waters released from the Bowman Dam. While surveys to date have not quantified the level of impact.(ODFW, 1996; ODEQ, 2002; Lamb, 2005; Hodgson, 2006), high concentrations of dissolved gas can cause gas bubble disease in fish. At 140% saturation and higher, gas bubble disease can cause fish kills, and the presence of gas super saturation between 105-140% can impact fish behavior (Crooked River Local Advisory Committee, 2004). ODFW and Oregon State University plan to implement a cooperative research project in 2008-2009 to identify limiting factors affecting the redband trout population below Bowman Dam and quantify the impacts of total dissolved gas super saturation (TDG).

While gas super saturation is an issue in the Lower Crooked River below the Bowman Dam, discharge from the dam is drawn off the bottom of the reservoir where water is the coolest. Dam discharge has substantially improved temperature conditions in the twelve-mile stretch below the Prineville Reservoir despite high turbidity. This tailrace fishery supports a very popular redband trout fishery in the Lower Crooked River (ODFW, 1996; USDI BLM, 1992a).

Water in the Lower Crooked River below Bowman Dam is turbid, until approximately river mile18 where spring and seep inflows add substantial clear and cold water to the system. The Prineville Valley reach of the Lower Crooked River (downstream of the tailrace reach) is characterized by a wide flood plain and a high proportion of private land used for livestock grazing, crop production, and residential, industrial, and commercial uses near the City of Prineville. Stream channel and aquatic habitat conditions in this reach are typically incised with little habitat structure or ability to access the floodplain. Riparian vegetation is fragmented and mostly composed of woody shrubs or agriculture. Additionally, up to 90% of the flow is diverted for agricultural uses.

In the Lower Crooked River canyon reach downstream of the Highway 97 Bridge, the steep canyon topography has resulted in relatively undisturbed conditions, characterized by native riparian areas and increased flows. Natural springs augment flows beginning at river mile 18 and are responsible for improved flow, cooler water temperatures and improved water quality (Lichatowich, 1998). Habitat conditions are good in this section of the river and it hosts an abundant population of redband trout (Hodgson, 2005). Opal Springs Dam, however, does create and upstream fish migration barrier.

Ochoco Creek runs through agricultural lands above the City of Prineville, through town and confluences with the Lower Crooked River near the City of Prineville urban growth boundary. Ochoco Dam regulates Ochoco Creek flow for irrigation and flood mitigation purposes. Hatchery rainbow trout have been released into Ochoco Creek, and it serves as a popular fishery for local residents, particularly youth. Habitat conditions in Ochoco Creek are impacted from urban land uses in lower reaches and impacts from agricultural and rural residential development in upper reaches. Stormwater from impervious surfaces in the City of Prineville is discharged directly into the creek. Both rural residential and urban growth are impacting riparian habitat and channel form in the upper reaches and through the City of Prineville.

Unlike the Crooked River and Ochoco Creek, McKay Creek has no major dams or diversions. Several smaller diversions exist on McKay Creek between the Ochoco National Forest boundary and the Ochoco Irrigation District canal crossing, and on several smaller tributaries. These diversions reduce flow and McKay Creek is observed to go dry in the middle reaches in summer and early fall. In general, habitat conditions improve in the upstream reaches of McKay Creek and its tributaries. These areas include the Ochoco National Forest and a section of land owned by the Ochoco Lumber Company in the Allen Creek drainage.

## 9.4 FISH POPULATIONS

### 9.4.1 Historical Fish Populations

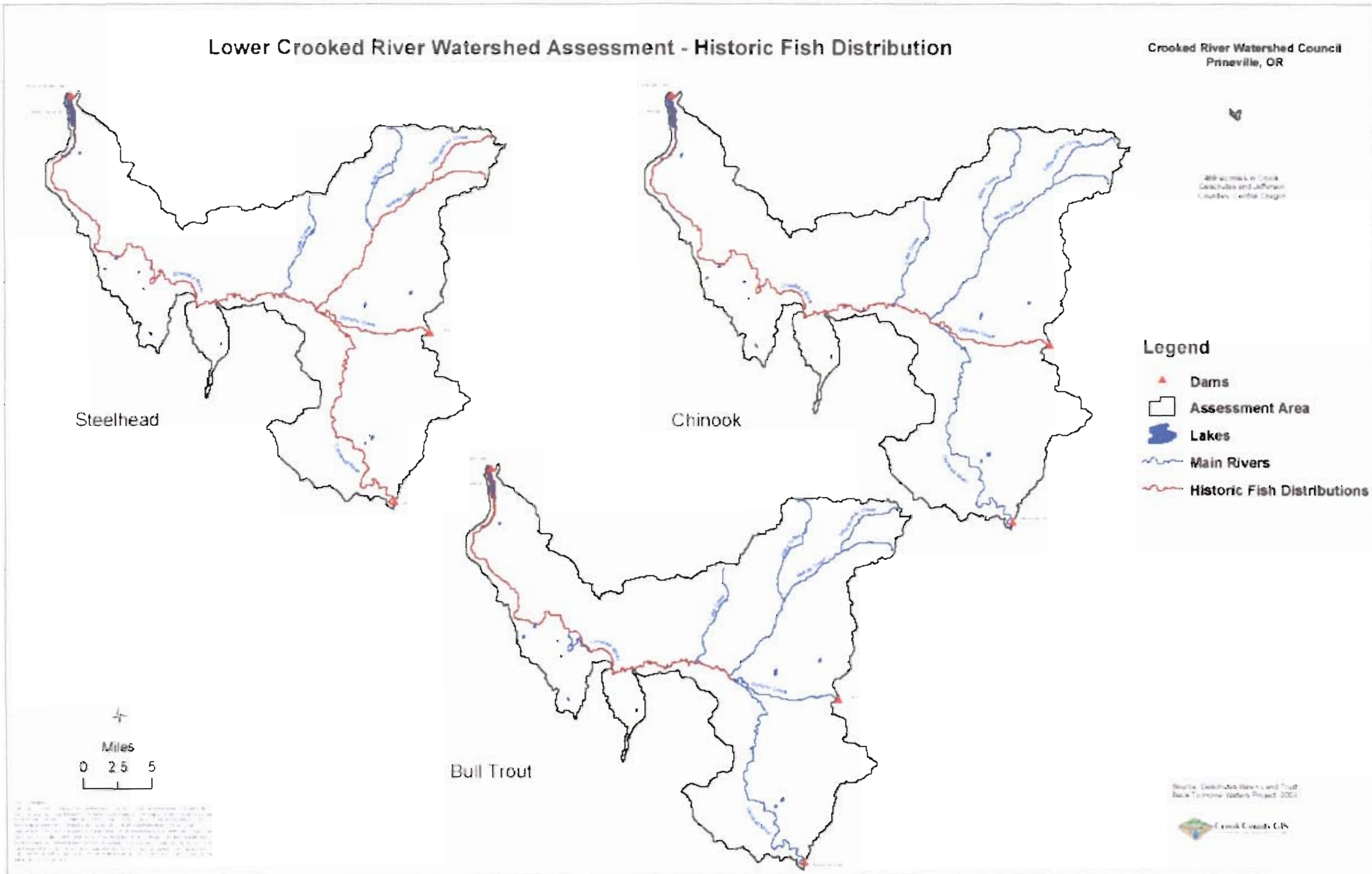
There are many references in the historical record to fish species within the assessment area. Historical records describe the presence of Chinook salmon, steelhead trout, bull trout, Pacific lamprey, and redband trout in the assessment area (Nehlsen, 1995; ODFW, 1996). Some of this documentation identifies areas upstream of the assessment area, which indicates the presence of these fish in the Lower Crooked River Watershed. Some landmarks in the historical documentation are enumerated in Table 9-1.

The first formal fish species surveys in the basin took place in the 1950's. Despite the major habitat changes that had been underway for approximately 75 years, the 1952-54 surveys located steelhead up to 120 miles from the mouth of the Crooked River (Nehlsen, 1995; ODFW, 1996). Historical accounts indicate that most spawning and rearing of salmon and steelhead in the Upper Deschutes Subbasin occurred in the main tributaries, which includes the assessment area. Species documented to be present in the basin in the early 1950's included spring Chinook salmon, summer steelhead, bull trout (in mainstem up to the town of Prineville) and redband trout (ODFW, 1996). The historic distribution of extirpated fish species is presented in Map 9-1. The extirpation of anadromous fish species is a result of a number of factors; most notably the presence of fish passage barriers at the Pelton-Round Butte hydroelectric complex and at the Opal Springs Dam.

Table 9-1. Landmarks in fish presence in the Lower Crooked River Watershed

| Date | Activity |
|---|---|
| 1826 | Peter Skene Ogden noted a native American salmon weir just downstream of the confluence of the North Fork Crooked River and the Mainstem Crooked River. |
| 1892-1902 | Approximate time that Chinook salmon were present in Beaver Creek in the upper watershed as reported by long-time residents in 1942. |
| 1921 | Ochoco dam installed – fish passage barrier. |
| 1921 | Opal Springs dam installed – partial fish passage barrier. |
| 1942 | Reports of steelhead in lower Ochoco Creek and Beaver Creek in the Upper Crooked Watershed. |
| 1948 | Department of Interior (DOI) states that Chinook and steelhead gone from the Crooked River system around 1915. |
| 1951 | Oregon State Game Commission noted that salmonids migrated through entire Crooked River system in late winter-early spring when flows were high. |
| 1952 | Steelhead in Crooked River above Prineville. |
| 1952 | Spent steelhead found in McKay and Ochoco Creeks in the assessment area, and Drakes, Horse Heaven, and Beaver Creeks and the North Fork Crooked River in the Upper Crooked River watershed. |
| 1953 | Steelhead redds are observed in Ochoco Creek and Twelvemile Creek in the upper watershed. |
| 1954 | Steelhead adults observed in Paulina Creek. |
| 1958-64 | Construction of the Pelton Round Butte hydroelectric complex – fish passage are originally structures installed in the original facility; however, major problems with downstream passage of juveniles occurred due to the thermal challenges of Lake Billy Chinook. |
| 1960 | The US Department of Interior notes that steelhead and a few Chinook still exist in the Crooked River System. Chinook reported in Ochoco Creek, Beaver Creek, and the Upper Crooked River. |
| 1961 | Bowman dam installed on the Crooked River and creates a fish passage barrier. |
| 1968 | Upstream passage of fish eliminated at Pelton Round Butte complex. |
| 1980 | Bull Trout caught in Lower Crooked River at Prineville. |
| 1982 | Renovation of the Opal Springs hydroelectric facility occurs and creates a fish passage barrier. |
| 2007 | Reintroduction plan for both steelhead and Chinook is postponed to 2008. |
| 2007 | Construction begins on a fish passage facility at the Pelton Round Butte hydroelectric complex. |

(Crook County Historical Society, 1994; Nehlsen, 1995; ODFW, 1996)




**Map 9-1. Historic distribution of extirpated fish species.**

Nonnative stocks of hatchery rainbow trout fingerlings and yearlings were planted sporadically in streams and reservoirs throughout the basin from the 1920s to the mid-1980s (ODFW, unpublished reports). The combination of chemical treatments, which cause direct mortality, the introduction of foreign species and hatchery rainbow trout, which caused competition or predation, and the degradation of habitat resulted in reductions in redband trout abundance in much of the assessment area (Stuart et al., 2006).

### 9.4.2 Current Fish Populations

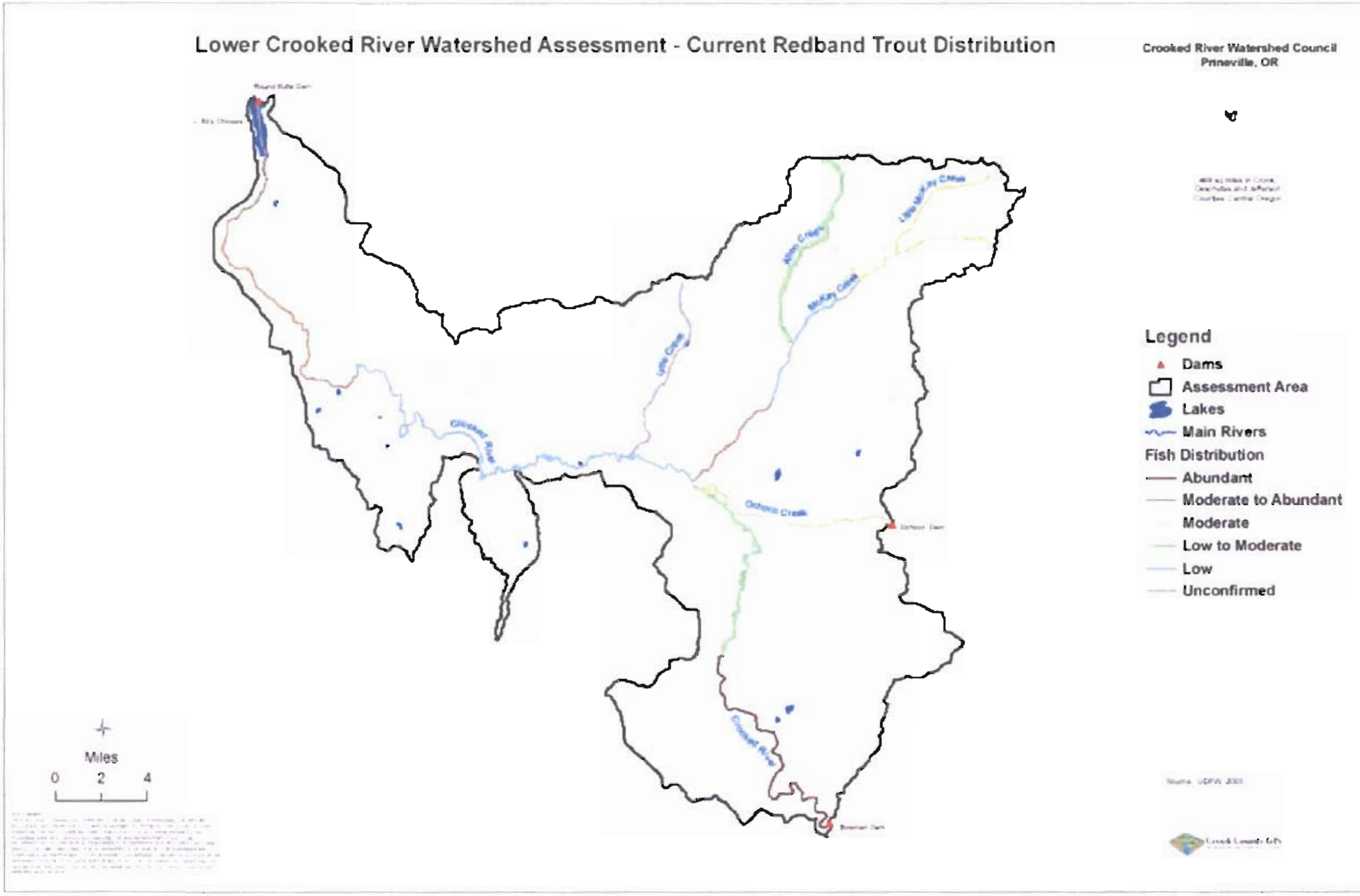
The management philosophy of fish and wildlife managers in the Crooked River basin since the mid-1980s has shifted from supplementation of hatchery rainbow trout to protection and restoration of native fish habitats. The Oregon Fish and Wildlife Commission adopted the 1992 Wild Fish Management Policy, which emphasizes protection and management of wild native fish species over supplimentation. The policy recommended release of hatchery fish for sport and commercial fisheries only where they were compatible with wild fish. Fish managers in the Crooked River basin quickly adopted this policy and stocked hatchery fish in lakes or reservoirs only where intensive recreational fishing occurred and the potential for competing or breeding with native redband trout was limited. In addition, managers emphasized the protection and restoration of native fish habitat. This has included reconnecting fragmented stream reaches through construction of passage facilities at barriers, screening water diversions, and constructing streamside riparian fences and livestock pasture systems that encourage recovery of riparian and upland areas. Current ODFW management is driven by the Crooked River Basin Plan and Native Fish Conservation Policy (Stuart et al., 2006).

A variety of fish species currently occupy the assessment area in varying levels of abundance (Table 9-2). Populations of bull trout, kokanee salmon, and brown trout are currently restricted to the Crooked River arm of Lake Billy Chinook and the Crooked River downstream of the Opal Springs Dam. Redband trout are the primary native game fish in the assessment area, although their abundance varies throughout the assessment area (Map 9-2). All reaches of the mainstem lower Crooked River are managed for native

Table 9-2. Current and Historic Fish Species in the Assessment Area (CRWC, 2005)

| Common Name | Origin | Current Status | Abundance |
|---|---|---|---|
| Pacific Lamprey | Native | Extirpated | None |
| Summer Steelhead | Native | Extirpated | None |
| Redband Trout | Native | Present | Moderate |
| Bull Trout | Native | Present [1] | None |
| Chinook | Native | Extirpated | None |
| Mountain Whitefish | Native | Present | Abundant |
| Rainbow Trout | Introduced | Present | Moderate |
| Brown Bullhead | Introduced | Present | Rare |
| Large Mouth Bass | Introduced | Present | Rare |
| Smallmouth Bass | Introduced | Present | Rare |
| Black Crappie | Introduced | Present | Rare |
| Bluegill | Introduced | Present | Rare |
| Shorthead Sculpin | Native | Present | Unknown |
| Torrent Sculpin | Native | Present | Unknown |
| Paiute Sculpin | Native | Present | Moderate |
| Goldfish | Introduced | Present | Rare |
| Longnose Dace | Native | Present | Moderate |
| Speckled Dace | Native | Present | Very Abundant |
| Chiselmouth | Native | Present | Abundant |
| Largescale Sucker | Native | Present | Very Abundant |
| Bridgelip Sucker | Native | Present | Very Abundant |
| Northern Pikeminnow | Native | Present | Abundant |
| Carp | Introduced | Present | Rare |
| Stickleback | Introduced | Present | Rare |

[1] Bull trout are believed to only be present below the Opal Springs Dam.




Map 9-2. Current redband trout abundance by stream reach.

redband trout, with some hatchery trout emigrating from Prineville Reservoir. Hatchery rainbow trout continue to be stocked in Ochoco Creek to provide youth angling opportunity. (ODFW, 1996). Redband trout are most abundant in the upper and lower reaches of the Crooked River, abundant to moderate in the lower reaches and headwaters ODFW has conducted redband trout surveys to estimate trout density since 1993 (Figure 9-1). Surveys were conducted on the Crooked River below Bowman Dam by electro-fishing from a drift boat and mark-recapture sampling. A survey in 2006 suggests that the redband population in this reach has declined to 581 trout per mile. The cause of this downward trend in redband trout abundance and demographic transition towards younger fish (Figure 11-2; using length as a proxy for age) is unknown; however, several explanations are plausible.

Although mountain whitefish is less desirable to anglers as a game species than redband trout, a high number of this species is reported within the assessment area. Sampling efforts prior to 1997 attempted to monitor the population of mountain whitefish in the Crooked River below Bowman Dam. After 1997, however, extremely high numbers of whitefish precluded attempts to quantify the population. Anecdotal observations made while electro-fishing suggest the whitefish population is extremely abundant, approaching 10 times the number of redband trout. Dynamics between whitefish and trout populations are poorly understood. There appears to some niche and habitat partitioning, with whitefish inhabiting the larger pools and glides while trout frequent higher velocity segments with boulders and "pocket water". It is unknown if trout would enlarge their habitat utilization if whitefish were less abundant. Interspecific competition for food and habitat is also unknown, although anglers certainly note that both redband and whitefish take the same flies and lures. Finally, mountain whitefish appear to be less susceptible to gas super saturation than redband trout.

## 9.5 REINTRODUCTION

The Pelton Round Butte Project is a three-dam complex located between river mile 100 and 110 on the Deschutes River. The confluence of three rivers, the Crooked, the Deschutes and the Metolius, is just above the Project's upper most dam, the Round Butte

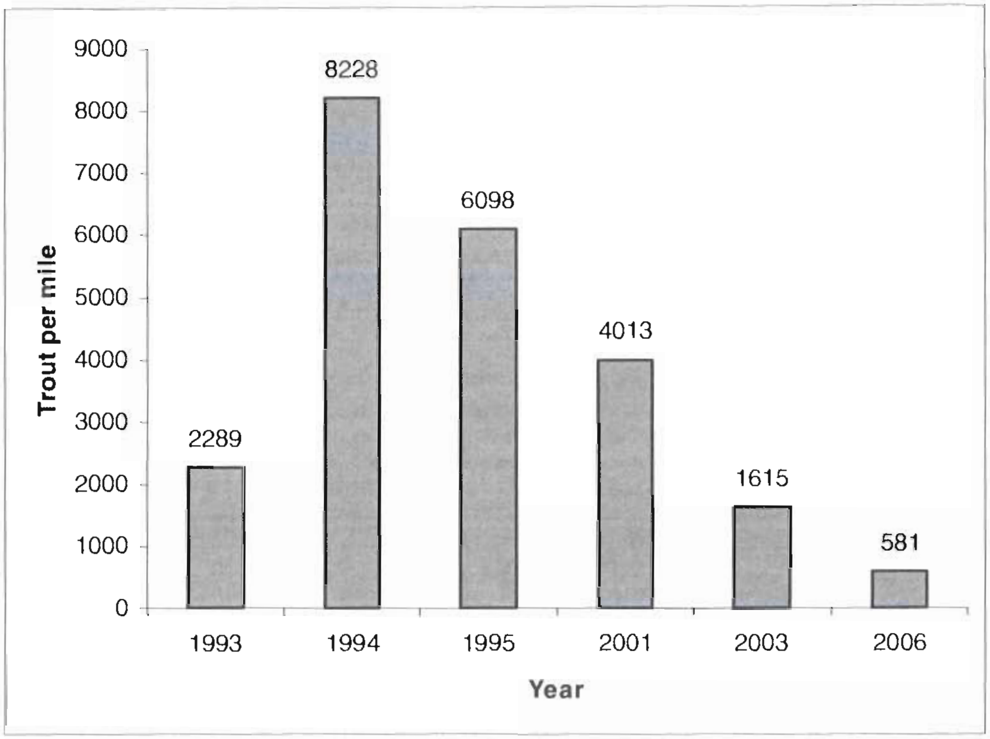



Figure 9-1. Redband trout estimated density on the Crooked River below Bowman Dam (ODFW, 2003). All years are estimated based on 6 survey passes except 2003, which was estimated based on 2 survey passes.

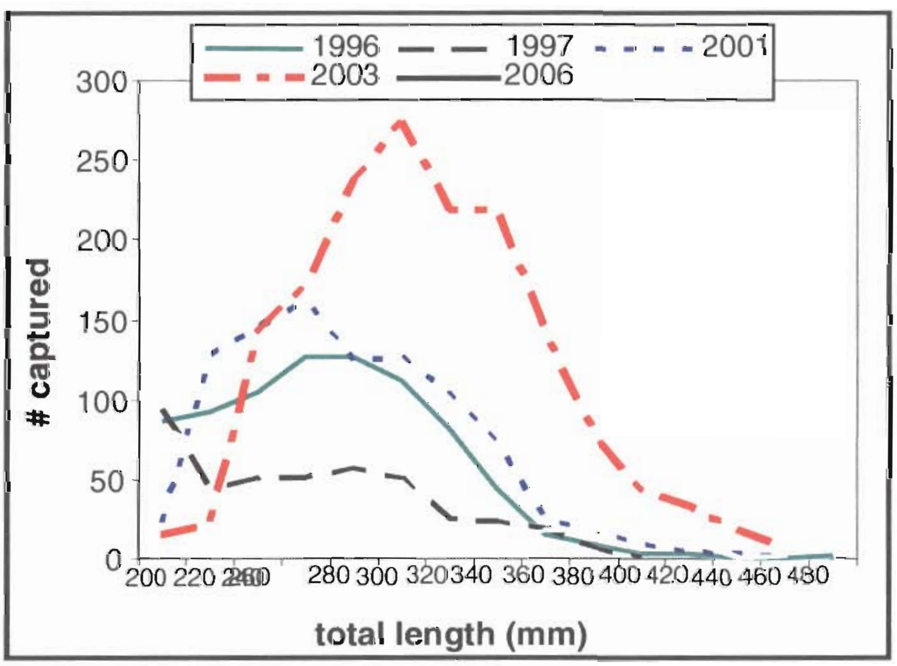



Figure 9-2. Redband trout length frequency Crooked River below Bowman Dam, 1996-2003 (ODFW, 2003).

Dam. The Project was originally owned and operated by Portland General Electric (PGE), but it is partially located on CTWSRO lands, and the tribes have a vested interest in the Project. The tribal interest in the complex was originally as a landlord to PGE. The Tribes became a co-licensee in the 1980's with the addition of a power generation facility at the Reregulating Dam. Non-federal hydroelectric projects such as Pelton Round Butte are licensed by the federal government through the Federal Energy Regulatory Commission (FERC). Licenses are subject to periodic renewal, which subjects the hydroelectric project to a multifaceted evaluation that includes the consideration of environmental impacts of the project and mitigation of these impacts. In the case of the Pelton Round Butte Project, restoration of fish passage and reintroduction of anadromous fish into the Upper Deschutes sub-basin was identified as a priority for mitigating the impacts of the project to fish populations. This priority issue was supported by the co-licensees and owners, PGE and the CTWSRO. The tribes particularly have an interest in restoration of anadromous fish as fish are an important traditional food source and part of tribal culture and heritage. The co-liscencees, PGE and CTWSRO, were issued a new license by the FERC to operate the complex in June 2005 for a 50 year period.

Anadromous fish spawn and hatch in inland fresh water streams, migrate to and live in the ocean, and then return to their fresh water origins to reproduce. Although the construction of the Pelton Round Butte hydroelectric complex originally included measures to facilitate this life cycle, temperature variation in the three rivers converging above Lake Billy Chinook created currents which attracted out-migrating juveniles away from the outlet structure and prevented seaward migration. As a result, state and federal agencies determined passage facilities were ineffective and closed the facilities in 1968. The recent re-licensing of the Pelton Round Butte hydroelectric complex by the Federal Energy Regulatory Commission required that fish passage be constructed at the complex and that anadromous species be reintroduced into the Upper Deschutes sub-basin. The plans for the assessment area include the reintroduction of spring Chinook salmon (*Onchorynchus tshawytschsa*) and summer steelhead trout into the Lower Crooked River Watershed. The reintroduction is planned to start in 2008 with smolt and/or fry releases within the lower mainstem of the Crooked River, McKay, and Ochoco Creeks. The reintroduction will also reconnect populations of bull trout and redband trout populations which are currently disconnected by dams.

Passage will be achieved by construction of a selective water withdrawal tower above the Round Butte Dam. The tower will alter the currents in the reservoir (Lake Billy Chinook) enabling juvenile fish out-migration. Juveniles will then be collected at a facility near the tower and released into the Lower Deschutes River downstream of the Reregulating Dam. The entrance to the existing Pelton Fish Ladder will serve as a trapping location for returning adult fish. These fish will be collected at the Pelton Fish Trap, near the base of the fish ladder and transported above the Round Butte Dam where they will be released into Lake Billy Chinook. The reintroduction effort will increase in intensity over time as the infrastructure and methodology is completed, evaluated and refined.

### 9.5.1 Impacts of Reintroduction

The presence of anadromous species will potentially impact the region in a number of ways. Local citizens and irrigation districts are concerned that the reintroduction will trigger increased regulation of land use practices under the ESA. Currently, Mid-Columbia River summer steelhead and Deschutes River bull trout are listed as threatened under the ESA. Regulatory concerns include the need for fish screens and passage at irrigation water diversions and water quality issues related to temperature as well as other parameters.

Water quantity is also a major concern. The fish carrying capacity of the watershed is largely dependent on water quantity (Hardin-Davis, 2001; ODFW, 2003). Currently, approximately 54% (80,360 acre-feet) of water stored in the Prineville Reservoir is unallocated; the remainder is contracted for irrigation and a mandated 10 cfs minimum streamflow below Bowman Dam (ODFW, 2003). ODFW has a nonbinding agreement with Ochoco Irrigation District (OID) and the Bureau of Reclamation (BOR) to release a mimimum of 75 cfs in years with more precipitation and 50 cfs in years with less precipitation. Water quantity and quality are closely related to suitable fish habitat, and reintroduction of threatened anadromous species may serve as a contributing factor in an attempt to authorize a portion of the unallocated water to other uses.

### 9.5.2 Potential for Anadromous Habitat

Stream flow is a critical factor in the success of the anadromous fish reintroduction (Hardin, 2001). During seasonal spawning and rearing periods stream flows are critical to habitat suitability for anadromous species. Sufficient flows may also mitigate some water quality issues and reduce the impact of smaller fish passage barriers. Habitat area under different flows was estimated for spawning and juvenile steelhead and Chinook Hardin (2001). Estimates were made for three reaches of the Lower Crooked River including the Upper Canyon (Bowman Dam to Stearns Dam), the Prineville Valley (Stearns Dam to the North Unit Irrigation District pumps above Smith Rock State Park), and the Lower Canyon (North Unit pumps to US Highway 97). Usable habitat was not estimated above flows of 130 cfs in the Prineville Valley and Lower Canyon reaches, while flows up to 400 cfs were used to estimate habitat in the Upper Canyon reach. Juvenile rearing habitat for both species is greatest in the upper and lower canyon reaches, while spawning habitat is most extensive in the Prineville Valley and upper canyon reaches (Figure 9-3).

ODFW recommends that for optimum salmonid habitat instream flows between 170 and 335 cfs be released in the Crooked River between Bowman Dam and Lake Billy Chinook. Minimum recommended streamflows to support conservation levels of salmonids range between 75 and 255 cfs (ODFW, 2003). Hardin (2001) estimated flow exceedance for the Crooked River at the Bowman Dam (based on 1980-1999 flows) and near Highway 97 (i.e., Terrabone gauge, based on 1995-1999 flows). In the Upper Canyon reach conservation flow targets are met most years, and optimal flow targets tend to be in the spring, while fall flows tend only to be met in September. In the Lower Canyon reach optimal flows are met in most years in all critical months but November (Figure 9-4). The likelihood of meeting flow targets was not estimated for the Prineville Valley reach because no flow data is available for this reach; however, flow in this reach

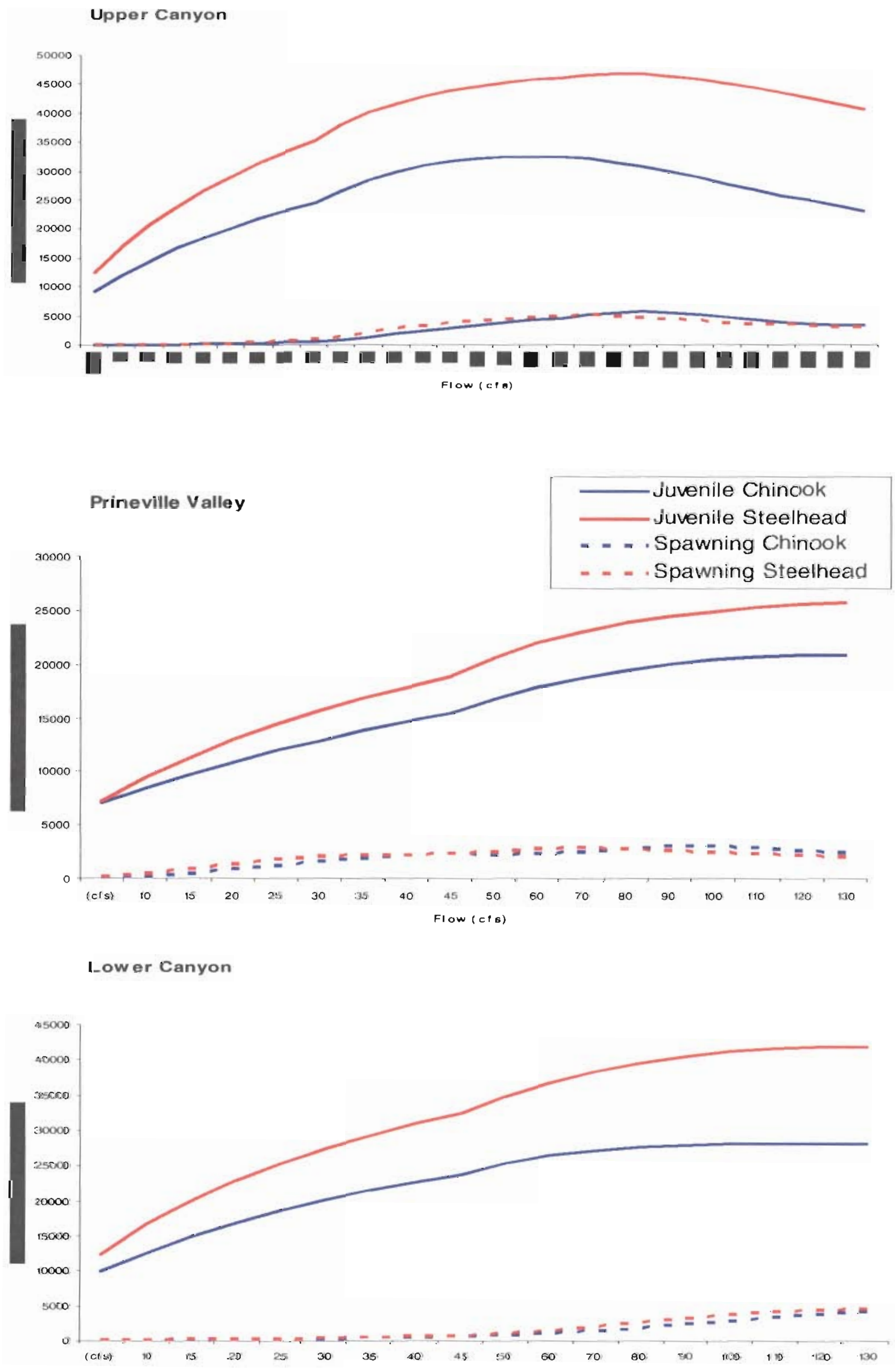



Figure 9-3. The relationship between habitat area and flow for steelhead and Chinook juveniles and spawners in three reaches of the Lower Crooked River.

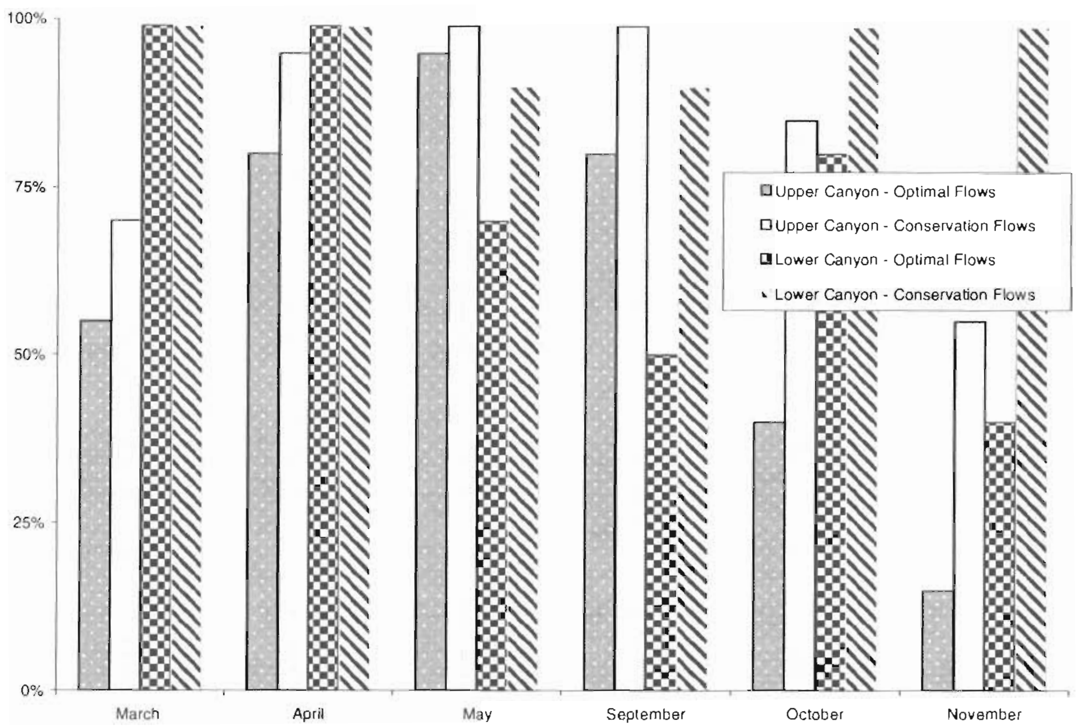
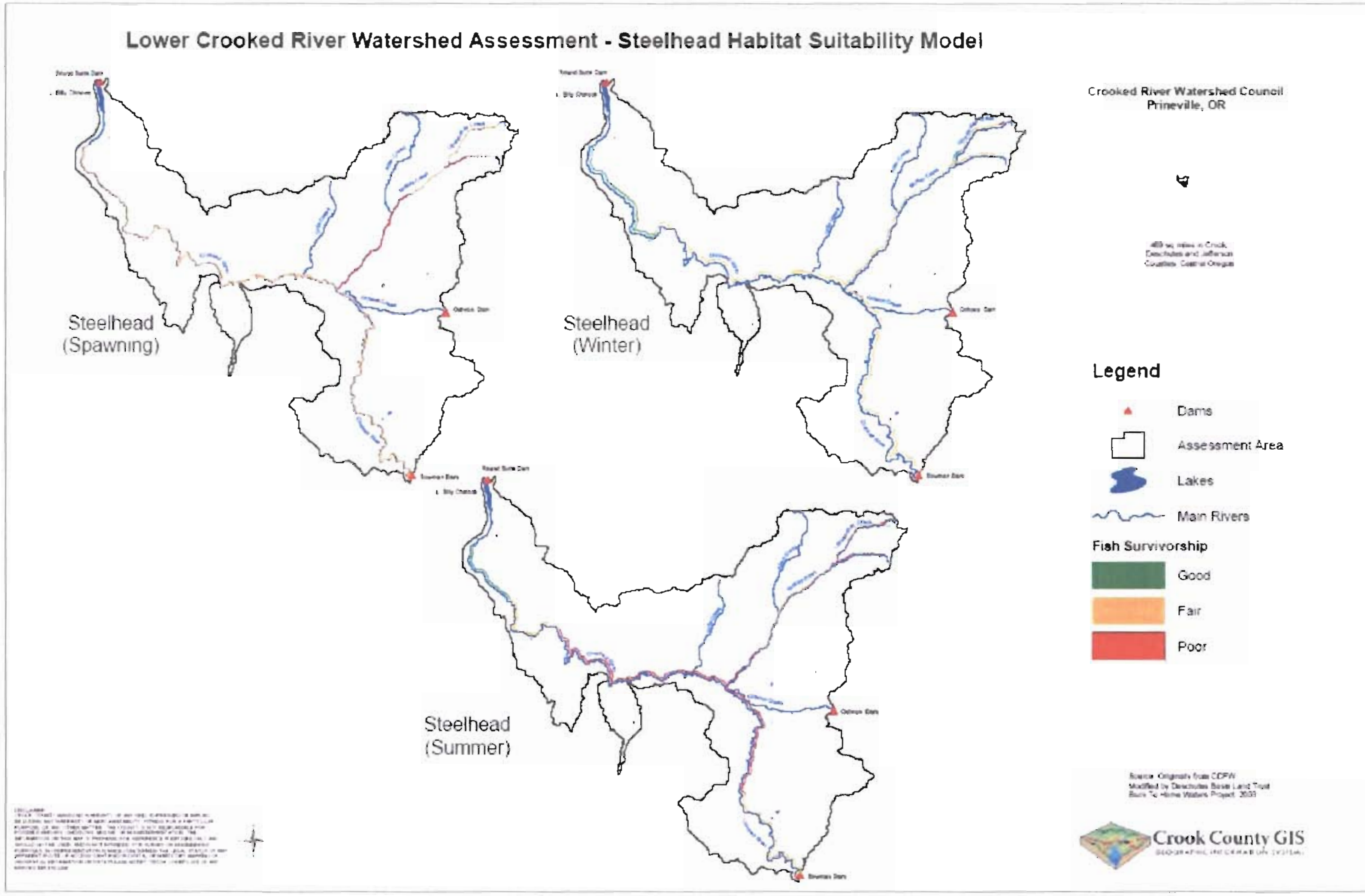


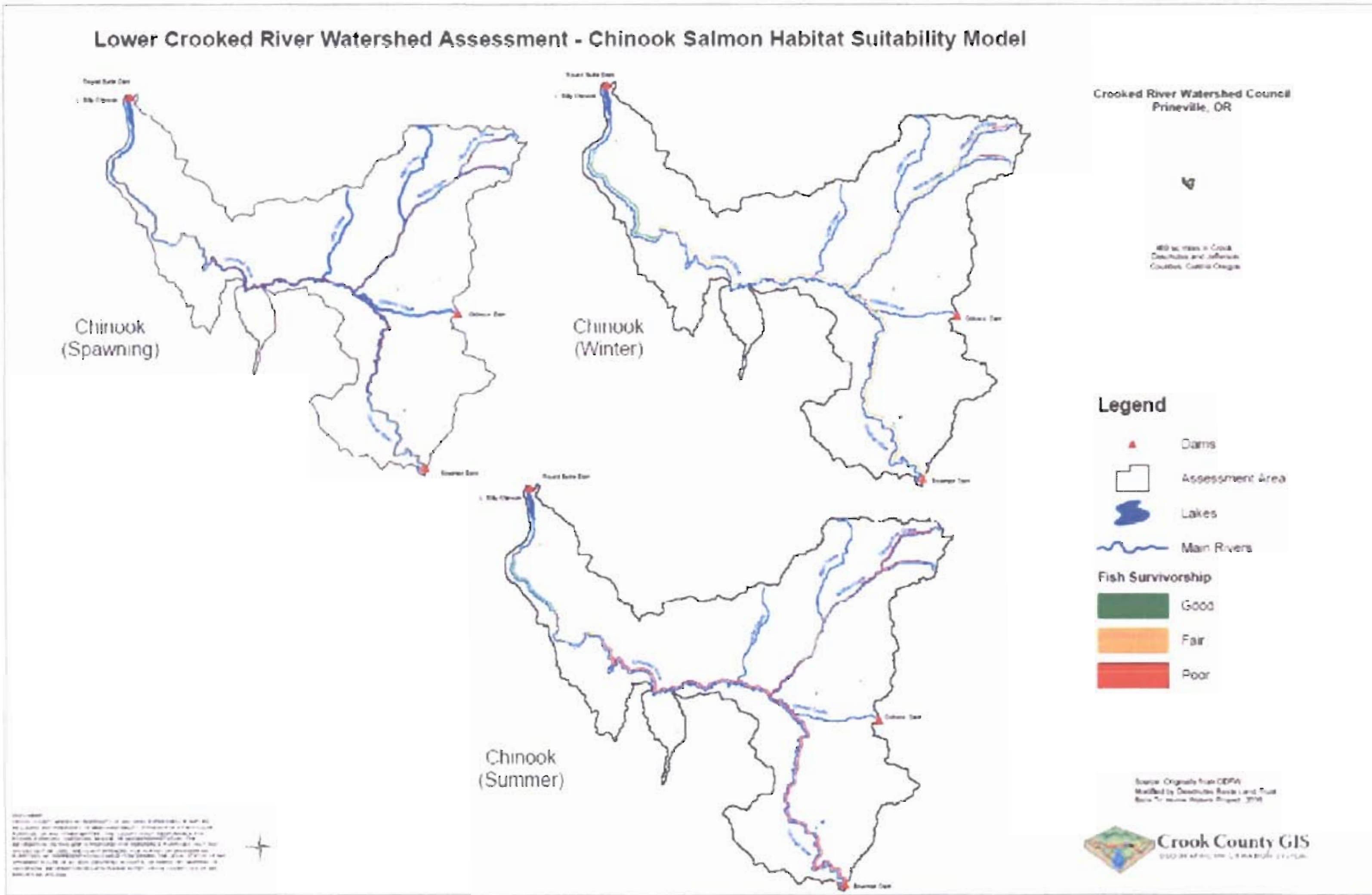

Figure 9-4. Percent of years that flows exceed optimal and conservation flow targets in the Upper and Lower Canyon reaches (adapted from Hardin 2001). Flow data does not exist for the Prineville Valley reach, which likely fails to meet ODFW targets due to water use that can withdraw over 90% of flow in the reach.

likely fails to meet ODFW targets due to the presence of several large irrigation diversions that can withdraw up to 90% of flow from the river.

While flow is a critical component of fish habitat, many other factors are also important for fish habitat, including water quality, substrate, stream structure, riparian conditions, and overall stream habitat. ODFW qualitative assessments of Chinook and steelhead habitat indicate widely varying potential for survivorship of spawners and rearing juvenile fish (Maps 9-3 and 9-4, respectively). For steelhead, winter and spawning habitat is the most favorable to fish survival; however juvenile steelhead must survive challenging summer conditions. For Chinook, habitat is best in the in the lower Canyon




Map 9-3. Steelhead habitat suitability model (adapted from ODFW).




**Map 9-4. Chinook habitat suitability model (adapted from ODFW).**

reaches. Winter habitat is also favorable for Chinook throughout the watershed. Summer appears to be the most challenging to both species due to flow and water quality especially between the upper and lower canyon reaches.

## 9.6 PASSSAGE BARRIERS AND DIVERSION SCREENING

Providing passage for fish at the three dams of the Pelton Round Butte Project is not the only critical passage issue for anadromous fish entering the assessment area. There are five major fish passage barriers on the mainstem of the Lower Crooked River (Table 9-3). Of these five, Opal Springs Dam is a complete barrier for fish moving upstream; however, fish can pass downstream with minimal mortality through turbines and over the dam in high flows. The Opal Springs Dam is located within the canyon section of the Lower Crooked River just upstream of Lake Billy Chinook. This dam is operated as a hydropower generating facility by the Deschutes Valley Water District. Negotiations are ongoing to provide passage at the dam. The other four dams pass fish downstream, but restrict fish movement upstream under lower flow conditions. These passage barriers contribute to fragmentation of resident fish populations within the assessment area and pose a challenge to anadromous migration, specifically returning spawners. The Crooked

Table 9-3. Fish Passage Barriers and Unscreened Diversions in the Assessment Area (ODFW and CRWC, 2006).

| Structure | Location | Owner | Characteristics |
|---|---|---|---|
| Opal Springs (screening not needed) | River Mile 0.5 T12S,R12E,33 | Deschutes Valley Water District | 30 ft. concrete (permanent) |
| Crooked River Central (outdated screen) | River Mile 44 T14S,R15E,22 | Bill Sigman and others | 3 ft, flashboard (seasonal) |
| Peoples Irrigation (unscreened) | River Mile 50 T15S,R16E,7 | People's Irrigation District | 7 ft. concrete (permanent) |
| Rice Baldwin | River Mile 57 T16S,R15E,1 | White Deer, Quail Valley Ranches | 4 ft. concrete (permanent) |
| Stearns Dam (no longer in operation) | River Mile 58 T16S,R15E,1 | Bureau of Land Management | 5 ft. concrete (permanent) |

River Watershed Council is currently developing passage and screening projects at the Crooked River Central and Peoples Irrigation diversions, while the Prineville BLM is developing a passage project for the Stearns Dam.

In addition to the major fish passage barriers on the Lower Crooked River there are approximately 25 unscreened smaller irrigation water diversions and barriers on the mainstem of the Lower Crooked River and its tributaries (OWRD, 2005). Opportunities for funding to screen, build passage over, or remove these diversions may occur once federally threatened fish species are reintroduced into the assessment area. Finally, the Bowman and Ochoco Dams, which create the upper boundaries of the Assessment area, are also major fish passage barriers that fragment habitat between the Lower Crooked River assessment area and it upstream tributaries.

## 9.7 Summary

The Lower Crooked River Watershed historically sustained a diverse population of resident and anadromous fish species. The construction of the Pelton Round Butte hydroelectric complex Deschutes River extirpated the anadromous fish component from the fish assemblage in the watershed. Currently, redband trout are the species of concern for fish habitat and management due to a depressed population that has resulted from degraded habitat and water quality. Redband trout are an important local game fish and icon for assessment area. The major challenges to trout habitat include water quantity, water quality – specifically gas supersaturation below the Bowman Dam, riparian conditions, and stream structure. Redband populations are most abundant in the Canyon reaches below the Bowman Dam and below Highway 97, Ochoco Creek, and portions of McKay Creek.

The reintroduction of anadromous fish into the Lower Crooked River Watershed is expected to begin in 2008. The effort includes releasing juvenile Chinook salmon and Mid-Columbia summer steelhead, and reconnecting bull trout habitat currently disconnected by passage barriers. While the reintroduction introduces a level of uncertainty to landowners and managers due to the currently unknown implications of the presence of ESA listed fish, the effort also brings opportunities to the assessment area in the form of financial resources to improve natural resource conditions that will both improve the potential for a successful reintroduction and assist landowners in implementing best management practices on their lands. The reintroduction may also open other opportunities beneficial to the economy and culture in the assessment area such as the allocation of uncontracted water in the Prineville Reservoir.

## References and Bibliography

Aikens, C.M. 1986. *Archaeology of Oregon*. U.S. Department of Interior, Bureau of Land Management, Oregon State Office.

Anderson, E.W., M.M. Borman and W.C. Krueger. 1998. *The Ecological Provinces of Oregon*. Oregon State Agricultural Extension Special Report 990: Corvallis, Oregon.

Azuma, David, L., Bruce A. Hiserote and Paul A. Dunham. 2005. *The Western Juniper Resource of Eastern Oregon*. United States Department of Agriculture United States Forest Service (USDA USFS). PNW-RB-249. Portland, Oregon

Barrett, S.W. and S.F. Arno. 1982. Indian fires as an ecological influence in the Northern Rockies. *Journal of Forestry*. 80: 647–650.

Boyd, R. (Ed.). 1999. Indians, fire, and the land in the Pacific Northwest. Oregon State University Press. Corvallis, Oregon.

Breese, Doug. 2005. Personal Communication. Local Resident and Rancher. Prineville, Oregon.

Buckley, L. Geoffrey. 1992. Desertification of the Camp Creek Drainage in Central Oregon, 1826-1905. Masters Thesis: University of Oregon. Eugene, Oregon.

Bunch, Debra. 2005. Unpublished: Weed Control Project Narrative (2005). Coordinator: Crook Weed Management Area. Prineville, Oregon.

Business Journal: Portland. 2004. "Brooks Resources Plans Prineville Development". [Cited March, 7 2005] Available from:
http://www.bizjournals.com/portland/stories/2004/12/27/daily18.html

Center for Watershed Protection. 2006. Adapting Watershed Tools to Protect Wetlands [Cited April, 27 2006] Available from: http://www.cwp.org/wetlands/articles/ExecSummaryArt3.pdf

Cerbone, Mike. 2005. Personal Communication. Director of Planning, City of Prineville Planning Department. Prineville, Oregon.

City of Prineville. 2005a. Draft: Comprehensive Plan. Prineville, Oregon.

City of Prineville. 2005b. City Ordinance. American Legal Publishing Corporation, Cincinnati, Ohio. [Cited April 10, 2005] Available from: http://www.amlegal.com/nxt/gateway.dll?f=templates&fn=default.htm&vid=alp:prineville_or.

City of Prineville-Crook County Chamber of Commerce, 1998 Community Profile. Prineville, Oregon.

City of Prineville Planning Department. 1997. Comprehensive Land Use Plan Update. Prineville, Oregon.

City of Prineville Planning Department. 2005. Personal Communication. Prineville, Oregon.

Clarke, Sharon, Liz Dent, Paul Measeles, Tara Nierenberg and John Runyon. 2004. *Oregon Plan for Salmon and Watersheds: Oregon Riparian Assessment Framework.* Oregon Watershed Enhancement Board (OWEB). Salem, Oregon.

Confederated Tribes of the Warm Springs Reservation Oregon (CTWSRO) and Portland General Electric (PGE). 2001. *Final Joint Application Amendment for the Pelton Round Butte Hydroelectric Project.* Warm Springs, Oregon.

Confederated Tribes of the Warm Springs Reservation Oregon (CTWSRO). 2005. *Tribal History and Organization: An Orientation for New Employees with the Confederated Tribes of Warm Springs.* Warm Springs, Oregon.

Cowardin, L.M., V. Carter, F.C. Golet, E.T. LaRoe. 1979. Classification of wetland and deepwater habitats of the United States. US. Department of the Interior Fish and Wildlife Service. Washington D.C.

Cressman, L.S. 1981. *The Sandal and the Cave: Indians of Oregon*. Oregon State Press: Corvallis, Oregon.

Crook County. 1993. Crook County: Periodic Review of Goal 5. Tenneson Engineering Corporation for Crook County. Prineville, Oregon.

Crook County. 2005b. Crook County Code. Code Publishing Company, Seattle, WA. [Cited April 10, 2005] Available from: http://nt5.scbbs.com/cgi-bin/om_isapi.dll?clientID=246383&infobase=crookco.nfo&softpage=PL_frame.

Crook County GIS, 2004. GIS Analysis and Mapping for Lower Crooked River Watershed Assessment. Prineville, Oregon.

Crook County GIS, 2005. GIS Analysis and Mapping for Lower Crooked River Watershed Assessment. Prineville, Oregon.

Crook County GIS, 2006. GIS Analysis and Mapping for Lower Crooked River Watershed Assessment. Prineville, Oregon.

Crook County Historical Society. 1994. *History of Crook County Oregon.* Prineville, Oregon.

Crook County Natural Resources Planning Committee: Water Subcommittee (CCNRPC). 2005. PowerPoint Presentation: Ochoco Creek Development since 1998 Flood. Prineville, Oregon.

Crook County Weed Board. 2000. County Noxious Weed List. Crook County Weed Control and the Crook County Soil and Water Conservation District: Prineville, Oregon.

Crook County Weed Control. 2001. Draft Three-year Plan for the Treatment of Noxious Weeds on Private Lands in Crook County. Prineville, Oregon.

Crook County Wildfire Protection Plan Committee. 2005. *Community Wildfire Protection Plan: Crook County, Oregon.* Prineville, Oregon.

Crook County & City of Prineville, 1997. Projected Population Growth. Prineville, Oregon.

Crooked River Local Advisory Committee. 2004. *Crooked River Agricultural Water Quality Management Area Plan.* Prineville, Oregon.

Crooked River Watershed Council (CRWC) Prepared by Tina Whitman. 2002. *Crooked River Watershed Assessment.* Prineville, Oregon.

Crooked River Watershed Council (CRWC). 2005. Field Work and Data Analysis: Lower Crooked River Watershed Assessment. Prineville, Oregon.

Crooked River Watershed Council (CRWC). 2006. Field Work and Data Analysis: Lower Crooked River Watershed Assessment. Prineville, Oregon.

Cuddy, Paul. 2005. Personal Communication. Environmental Coordinator, Ochoco National Forest. Prineville, Oregon.

David, Jim. 2005. Unpublished: Beaver Research Files. Soil Scientist, Ochoco National Forest. Prineville, Oregon.

Deboodt, Tim. 1989. Unpublished. A Proposal for the Establishment of a Crook County Weed Control Program. OSU Extension Agent. Prineville, Oregon.

Deboodt, Tim. 2005. Personal Communication. Oregon State University Extension Service. Prineville, Oregon.

Donato D. C., J.B. Fontaine, J.L. Campbell, W.D. Robinson, J.B. Kauffman and B.E. Law. 2006. "Post-Wildfire Logging Hinder Regeneration and Increases Fire Risk". *Science*. Vol. 311. no. 5759, p. 352.

Eddleman, Lee. 1989. "Oregon's High Desert –Legacy for Today." Oregon State University Agricultural Experimental Station. Special Report 841. Corvallis, Oregon.

Elmore, Wayne. 2005. Personal Communication. Former Leader, National Riparian Service Team. Prineville, Oregon.

Elmore, Wayne and Robert L. Beschta. 1987. "Riparian Areas: perceptions in Management" *Rangelands*. Vol. 9, No. 6 December.

Elmore, Wayne and Robert L. Beschta. 2005. "Riparian Areas: Perceptions in Management". *Aurora*. [Cited November 27, 2005] Available from: http://www.mtnvisions.com/Aurora/percepmn.html.

Environmental Protection Agency (EPA). 2001. Fact Sheet: Mercury Update. [Cited April 12, 2005] Available from: http://epa.gov/OST/fish.

Environmental Protection Agency (EPA). 2005. Polluted Runoff (Nonpoint Source Pollution). [Cited May 10, 2005] Available from: http://www.epa.gov/OWOW/NPS/qa.html

Environmental Protection Agency (EPA). 2006a. Wetland Definition. [Cited April, 24 2006] Available from: http://www.epa.gov/owow/wetlands/what/definitions.html

Environmental Protection Agency EPA. 2006b. Website: Wetlands Overview [Cited April 24, 2006] Available from: http://www.epa.gov/owow/wetlands/pdf/overview.pdf

Environmental Protection Agency (EPA). 2006c. Website: Wetlands Function [Cited April 24, 2006] Available from: http://www.epa.gov/watertrain/wetlands/

Evans, David & Associates Inc. 1994. *Local Wetlands Inventory: City of Prineville Crook County, Oregon*. Bend, Oregon.

Evans, David & Associates Inc. 2005. Revised Draft: Upper Williamson River Watershed Assessment. Prepared for Klamath Basin Ecosystem Foundation and Upper Williamson River Catchment Group. Portland, Oregon.

Federal Emergency Management Agency (FEMA). 1998. Interagency Hazard Mitigation Team Report fro the Crook County Flood Disaster. FEMA DR-1221. Portland-Oregon.

Frissell, C.A., Liss, F.J., Warren, C.E., & Hurley, M.D. 1986. "A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context". Environmental Management. 10:199-214.

Frost, Courtney. 2006. Personal Communication. Wildlife Biologist and GIS Specialist: Bureau of Land Management. Prineville, Oregon.

Gruell, G.E. 1985. Fire on the early western landscape: An annotated record of wildland fires 1776-1900. Northwest Science **59**:97-107.

Hardin, T. 2001. *Crooked River Instream Flow and Anadromous Habitat Study.* Hardin-Davis. Albany, New York.

Hodgson, Brett. 2005. Personal Communication. Fisheries Biologist, Oregon Department of Fish and Wildlife. Prineville, Oregon.

Hodgson, Brett. 2006. Personal Communication. Fisheries Biologist, Oregon Department of Fish and Wildlife. Prineville, Oregon.

General Land Office (GLO) Became the Bureau of Land Management (BLM). Late 1800's. Township Range and Sections Survey Data for Oregon. Accessed at the BLM Prineville District Office. Prineville, Oregon.

Interior Columbia Basin Ecosystem Management Project (ICBEMP). 1996a. *Integrated Scientific Assessment for Ecosystem Management in the Interior Columbia Basin.* PNW-GTR- 382. Portland, Oregon.

Interior Columbia Basin Ecosystem Management Project (ICBEMP). 1996b. *Status of the Interior Columbia Basin.* PNW-GTR-385. Portland, Oregon.

Interior Columbia Basin Ecosystem Management Project (ICBEMP. 1997. *Highlighted Scientific Findings of the Interior Columbia Basin Ecosystem Management Project.* PNW-GTR-404. Portland, Oregon.

Jackman E. R. and R. A. Long. 1964. *Oregon Desert.* Caxton Press. Caldwell, Idaho.

Kauffman, J.B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. An Ecological Perspective of Riparian and Stream Restoration in the Western United States. Fisheries 22(5):12-24.

Keith, Ed. 2005. Personal Communication. Stewardship Forester, Oregon Department of Forestry. Prineville, Oregon.

Keeley, J.E. 2002. Native American impacts on fire regimes of the California coastal ranges. *Journal of Biogeography* 29:303-320

Kovalchik, B. 1987. *Riparian Zone Associations of the Deschutes, Ochoco, Fremont, and Winema National Forests.* USDA USFS R6 ECOL TP-279-87, Pacific Northwest Region. Portland, Oregon.

Kowalski, Debbie. 2005. Personal Communication. Planner, Crook County Planning Department. Prineville, Oregon.

Kauffman J.B. and D.B. Sapsis. 1989. *The Natural Role of Fire in Oregon's High Desert.* Oregon State University Agricultural Experimental Station. Special Report 841. Corvallis, Oregon.

Lalande, Jeff. 1987. *First over the Siskiyous: Peter Skene Ogden's 1826-1827 Journey Through the Oregon-California Borderlands.* Oregon Historical Society. Portland, Oregon.

Lamb, B. 2005. Personal Communication. Water Quality Specialist, Oregon Department of Environmental Quality. Bend, Oregon.

Lamb, B. 2006. Personal Communication. Water Quality Specialist, Oregon Department of Environmental Quality. Bend, Oregon.

Lent, S. 2006. Images of America: Prineville. Arcadia Publishing. Charleston, South Carolina.

Lichatowich, Jim (Alder Fork Consulting for PGE). 1998. *Conceptual Foundation for the Management of Native Salmonids in the Deschutes River.* Portland, Oregon.

Long Tom Watershed Council (Prepared by Cindy Thieman). 2000. *Long Tom Watershed Assessment.* Eugene, Oregon.

McSwain, M. 2005a. Personal Communication. Hydrologist, Bureau of Land Management. Prineville, Oregon.

McSwain, M. 2005b. Personal Communication. Hydrologist, Bureau of Land Management. Graphs and Analysis of Dams Impact on Hydrology. Prineville, Oregon.

Miller, M. 1974. *Golden Memories of the Paulina Area.* Crook County Historical Society. Prineville, Oregon.

Miller, R.F., J.D. Bates, T.J. Svejcar, F.E. Pierson, L.E. Eddleman. 2005. Biology, ecology, and management of western juniper. Technical Bulletin 152. Oregon State University. Corvallis, OR

Minor, Rick, S.D. Beckham, K.A. Toepel and R. Greenspan. 1987. *Prehistory and History of the Ochoco National Forest, Central Oregon.* Report to Ochoco National Forest. Heritage Research Associates: Eugene, Oregon.

Moore K.M.S., K.K. Jones and J.M. Dambacher. 1997. *Methods for Stream Habitat Surveys: Aquatic Inventory Project.* Oregon Department of Fish and Wildlife, Natural Production Program. Information Report 97-4. Portland, Oregon.

Morgan, P., C.C. Hardy, T.W. Swetnam, M.G. Rollins, and D.G. Long. 2001. Mapping fire regimes across time and space: Understanding coarse and fine scale patterns. International Journal of Wildland Fire **10**:329-342.

Munther, Greg. 1983. *Integration of Beaver into Forest Management.* USDA U.S. Forest Service Lolo National Forest. Missoula, Montana.

Munther, Greg. 1983. *Beaver Management in Grazed Riparian Ecosystem.* USDA U.S. Forest Service Lolo National Forest. Missoula, Montana.

Murphy, Lonnie. 2005. Personal Communication. Fisheries Biologist, Ochoco National Forest. Prineville, Oregon.

Naiman, Robert, J.M. Melillo and J.E. Hobbie. 1986. "Ecosystem Alteration of Boreal Forest Streams by Beaver". *Ecology.* 67 (5), pp. 1254-1269.

National Riparian Service Team. 1998. *Ochoco Creek Flood Assessment.* Bureau of Land Management. Prineville, Oregon.

Nehlsen, W. 1995. *Historical Salmon and Steelhead Runs of the Upper Deschutes River and Their Environments.* Portland General Electric. Portland, Oregon.

Northwest Power and Conservation Council (NWPCC). 2001. *Summary of Conditions for Fish and Wildlife in the Deschutes Basin.* Portland, Oregon.

Olson, Rich and Wayne A. Hubert. 1994. "Beaver: Water Resources and Riparian Habitat Manager." University of Wyoming: Laramie, Wyoming.

Olson, Sigmund. 1961. *The Lonely Land.* Alfred A. Knopf. New York, New York.

Ontko, A.G. 1992. *Trails to Ochoco Valley.* Crook County Historical Society. Prineville, Oregon.

Oregon Climate Service. 2005. Climate Data for Prineville Oregon. Salem, Oregon. [Cited September 15, 2005] Available from: http://www.ocs.oregonstate.edu/index.html.

Ochoco National Forest [ONF]. 2006. McKay Creek Watershed Analysis. United States Department of Agriculture Forest Service. Prineville, OR.

Oregon Department of Environmental Quality (ODEQ). 1996. *Mercury in Oregon Lakes.* Portland, Oregon.

Oregon Department of Environmental Quality (ODEQ). 2002. Nitrate in Drinking Water: Fact Sheet. [Cited April 11, 2005] Available from: http://www.deq.state.or.us/wq/wqfact/nitratefactsheet.pdf.

Oregon Department of Environmental Quality (ODEQ). 2003. Oregon Groundwater Conditions: Fact Sheet. [Cited April 13, 2005] Available from: http://www.deq.state.or.us/pubs/factsheets.asp#WQFS

Oregon Department of Fish and Wildlife (ODFW). 1996. *Crooked River Basin Fish Plan*. Prineville, Oregon

Oregon Department of Fish and Wildlife (ODFW). 1997a. Big Game Statistics. Portland, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 1997c. Stream Report: Crooked River. Aquatic Inventory Project. Corvallis, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 1997b. Stream Report: McKay Creek. Aquatic Inventory Project. Corvallis, Oregon.

Oregon Department of Fish and Wildlife (ODFW). (Prepared by Steve Marx: District Fisheries Biologist). 2003a. *Anadromous Fish and Bull Trout Management in the Upper Deschutes, Crooked, and Metolius River Subbasins*. Bend, Oregon.

Oregon Department of Fish and Wildlife. 2003b. *Crooked River Fish Survey*. Prineville, Oregon.

Oregon Department of Forestry (ODF). 2005. Regional Forest Harvest Data. [Cited March, 10 2005] Available from: http://www.odf.state.or.us/Portal/media.asp

Oregon Department of Land Conservation and Development (ODLCD) and Oregon Department of Environmental Quality (ODEQ). Unpublished. Stormwater Model Code and Guidebook.

Oregon Department of Land Conservation and Development (ODLCD). 2006. Measure 37 Approved by Voters. [Cited March 20, 2006] Available from: http://www.oregon.gov/LCD/measure37.shtml#Measure_37_Approved_by_Voters

Oregon Department of State Lands (ODSL). 2005. Removal-Fill Program. [cited May 15, 2005] Available from: http://www.oregonstatelands.us/r-fintro.htm

Oregon Economic Development Department (OEDD). 2002. Website [Cited February, 2005] Available from: http://www.econ.state.or.us

Oregon Employment Department (OED). 1998. Regional Economic Profile. Salem, Oregon.

Oregon Fish and Wildlife Commission. 1992. *Wild Fish Management Policy*. Portland, Oregon.

Oregon State University Agricultural Experimental Station. 1976. *Soil and Watershed Characteristics in Relation to Turbidity of the Prineville Reservoir*. Corvallis, Oregon.

Oregon State University Agricultural Experimental Station. 2005. *Biology, Ecology and Management of Western Juniper*. Technical Bulletin 152.

Oregon State University Extension Service. 1993. *Western Juniper: Its Impact and Management in Oregon Rangelands*. Corvallis, Oregon.

Oregon Water Resources Department (OWRD). 2005. Crooked River and Tributaries: Diversion Inventory. Bend, Oregon.

Oregon Watershed Enhancement Board (OWEB). Unpublished. Draft Urban Issues Component: *Oregon Watershed Assessment Manual*. Portland, Oregon.

Pacific Northwest Water Quality Exchange. 2005. Real Estate Transactions Well Testing Database. [Cited March 8, 2005] Available from: http://deq12.deq.state.or.us/pnwwqx/

Pollack, Michael and George R. Pess. 1998. *The Current and Historical Influence of Beaver (Castor Canadensis) on Coho (Oncorhynchus kisutch) Smolt Production in the Deschutes Basin: Population Projections*. Portland State University. Portland, Oregon.

Regional Ecosystem Office. 1995. *Ecosystem Analysis at the Watershed Scale: Federal Guide for Watershed Analysis*. Portland, Oregon.

Rhoden, Russell. 2005. Personal Communication. Manager, Ochoco Irrigation District. Prineville, Oregon.

Rosgen, Dave. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, Colorado.

Russell, I. 1905. Preliminary report on the geology and water resources of central Oregon, United States Geological Survey Bulletin 252:1-138.

Sather, Eric. 2005. Personal Communication. Sewer and Water Superintendent, City of Prineville: Public Works Department. Prineville, OR.

Seymour, J. 2005. Personal Communication. Hydrologist: Ochoco National Forest. Prineville, Oregon.

State of Oregon: Water Resources Board. 1961. *Deschutes River Basin*. Salem, Oregon.

Steber, R. 1989. *Ochoco: Big Pine Country*. Bonanza Publications: Prineville, Oregon.

Stuart, Amy, et al., 2006. (Draft) *Historical Background from Redband Trout Investigations in the Crooked River Basin*. Oregon Department of Fish and Wildlife: Fish Biologist. Prineville, Oregon.

Swanson, John. 2006. Personal Communication and Field Site Visit. Range Conservationist: Bureau of Land Management. Prineville, Oregon.

Tanner, Rob. 2005. Personal Communication. Hydrologist, Ochoco National Forest and Crooked River Watershed Council. Prineville, Oregon.

Tanner, Rob. 2006. Personal Communication. Hydrologist, Ochoco National Forest and Crooked River Watershed Council. Prineville, Oregon.

Toepel, K.A., S.D. Beckham and P.E. Lancefield-Steeves. 1980. "Cultural Resource Overview of BLM Lands in North Central Oregon". University of Oregon Anthropological Papers No. 17. University of Oregon. Eugene, Oregon.

Upper Deschutes Watershed Council (UDWC) (Prepared by K. E. Yake). 2003. *Upper Deschutes Subbasin Assessment*. Bend, Oregon.

United States Bureau of Economic Analysis. 2007. Regional economic accounts: Personal and per capita income by county database. Accessed May 9, 2007. URL: http://www.bea.gov/bea/regional/reis/.

United States Bureau of Reclamation. 2007. Hydromet: Daily average stream flow data for PRVO and OCHO Hydromet stations. Accessed September 20, 2007. URL: http://www.usbr.gov/pn/hydromet/.

United States Census (US Census). 2000. American FactFinder: Prineville Oregon. [Cited February, 18 2005] Available from: http://factfinder.census.gov/home/saff/main.html?_lang=en

United States Department of Agriculture Oregon Agricultural Statistics Service (USDA Oregon Agricultural Statistics Service). 1997. Census of Agriculture. [Cited February 21, 2005] Available from: http://www.nass.usda.gov/census/census97/highlights/or/orc007.txt

United States Department of Agriculture Oregon Agricultural Statistics Service (USDA Oregon Agricultural Statistics Service). 2002. Census of Agriculture. [Cited February 21, 2005] Available from: http://www.nass.usda.gov/census/census02/volume1/or/index2.htm

United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS). 1966. *Crook County Soil Survey*. Portland Oregon.

United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS). 2000. *Interpreting Indicators of Rangeland Health*. NRCS Technical Reference 1734-6.

United States Department of Agriculture United States Forest Service (USDA USFS). 1989. *Final EIS: Land and Resource Management Plan: Ochoco National Forest and Crooked River National Grassland.* PNW: Prineville, Oregon.

United States Department of Agriculture United States Forest Service (USDA USFS). 1994. *Viable Ecosystems Management Guide Draft.* Ochoco National Forest. Prineville, Oregon.

United States Department of Agriculture United States Forest Service (USDA USFS). 1996. *Economic Indicators for Rural Development in the Pacific West.* INT-GTR-328: Portland, Oregon.

United States Department of Agriculture United States Forest Service (USDA USFS). 1997. *McKay Creek: Level II Stream Survey.* Ochoco National Forest. Prineville, Oregon.

United States Department of Agriculture United States Forest Service (USDA USFS). 1998. *Annual Monitoring Report on Forest Plan Implementation for Fiscal Year 1997.* Ochoco National Forest and Crooked River National Grassland. PNW: Prineville, Oregon.

United States Department of Agriculture United States Forest Service (USDA USFS). 2003. *Crooked River within the Crooked River National Grasslands: Level II Stream Survey Report.* Ochoco National Forest and Crooked River National Grassland Prineville, Oregon.

United States Department of Agriculture United States Forest Service, United States Department of Agriculture Natural Resources Conservation Service & United States Department of the Interior Bureau of Land Management (USDA USFS, USDA NRCS & USDI BLM). 1998. *Riparian Area Management: A Users Guide to Assessing Proper*

*Functioning Condition and the Supporting Science for Lotic Areas*. TR 1737-15. Denver, Colorado.

United States Department of the Interior Bureau of Land Management (USDI BLM). 1992a. *Lower Crooked Wild and Scenic River, (Chimney Rock Segment) Management Plan*. Prineville District Office: Prineville, Oregon.

United States Department of the Interior Bureau of Land Management (USDI BLM). 1992b. *Middle Deschutes/Lower Crooked River Wild and Scenic Rivers' Management Plan*. Prineville District Office: Prineville, Oregon.

United States Department of the Interior Bureau of Land Management (USDI BLM). 2001. *Analysis of the Management Situation (AMS) for the Upper Deschutes Resource Management Plan and Environmental Impact Statement (RMP/EIS)*. Prineville District Office: Prineville, Oregon.

United States Department of the Interior Bureau of Reclamation (USDI BOR). 2003. *Prineville Reservoir Resource Management Plan and Master Plan: Finding of No Significant Impact and Final Environmental Assessment*. Pacific Northwest Region. Lower Columbia Area Office. Boise, Idaho.

Vale, T.R. 2002. The pre-European landscape of the United States: pristine or humanized? In Vale, T.R. (Ed.), Fire, Native Peoples, and the Natural Landscape, pp. 1-40. Island Press. Washington, D.C.

Walter, P. 2000. *Channel Habitat Type, Riparian and Channel Condition Assessment for Ochoco, Mill, McKay and Marks Creeks, Crooked River Basin Oregon*. Master's Thesis. Department of Planning, Public Policy and Management. University of Oregon: Eugene Oregon.

Watershed Professionals Network. 1999. *Oregon Watershed Assessment Manual.* Oregon Watershed Enhancement Board: Salem, Oregon.

Warm Springs Power Enterprises (WSPE). 1997. *Pelton Round Butte Project, First Stage.* Consultation Document. Warm Springs, Oregon.

Warm Springs Power Enterprises (WSPE). 1999. *Pelton Round Butte Project Draft Relicensing Application.* Warm Springs, Oregon.

Yuskavitch, Jim. 2002. "Leave it to Beavers". *Forest Magazine.* Spring, 2002. Eugene, Oregon.