UPPER DESCHUTES WATERSHED COUNCIL

Upper Deschutes Subbasin Assessment

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EXECUTIVE SUMMARY

The Upper Deschutes Subbasin Assessment began work in 2002 as a project of the Upper Deschutes Watershed Council. From its inception, the assessment has been a cooperative venture with multiple partners, participants, and advisors. Funding for the project came from grants received from the Oregon Watershed Enhancement Board and the National Fish and Wildlife Foundation. In-kind donations of time, technical assistance, contract services, and equipment were generously contributed to the project by the Oregon Department of Environmental Quality, Deschutes National Forest, the Deschutes Resources Conservancy, the Oregon Department of Fish and Wildlife, the Bureau of Land Management, OSU-Cascades, the Nature Conservancy, the Oregon Water Resources Department, Deschutes County Soil and Water Conservation District, and GeoSpatial Solutions among many others.

The purpose of the Upper Deschutes Subbasin Assessment was to gather together existing data and information on all the historic and current conditions that play a role in impacting the watershed health of the subbasin. The details, recommendations, and data gaps discussed within the assessment will assist the Upper Deschutes Watershed Council and other natural resource managers in the area identify key restoration projects and opportunities to enhance fish and wildlife habitat and water quality in the subbasin.

By combining all of the existing available information on watershed resources, the Upper Deschutes Watershed Council hopes to raise community awareness about the interconnections and impacts within the whole Upper Deschutes Subbasin system. The key findings and recommendations within the assessment identify and prioritize opportunities for voluntary actions that are directed toward improving fish and wildlife habitat and water quality.

Key Findings

Water Quantity

The current stream flow regime in the upper Deschutes River is substantially different than it was prior to the management of Deschutes water for widespread irrigation purposes. Winter flows below Wickiup Reservoir are much lower than they were prior to the construction and operation of the reservoir and summer flows below the City of Bend are much lower then they were before irrigation diversions were put in place. As irrigation season begins in the spring, high water releases out of Wickiup can scour sediment from stream banks that have been dewatered in the winter.

Water Quality

There are many sections of the upper Deschutes River that do not meet the Oregon Department of Environmental Quality's water quality standards for either temperature, pH, dissolved oxygen, sedimentation, turbidity, or chlorophyll a. Water quality conditions in the Upper Deschutes Subbasin are inextricably linked to water quantity and flow levels. Temperature, dissolved oxygen, and pH are affected by low flow conditions in the subbasin.

Fish

Low winter flows below Wickiup Reservoir and low summer flows below the City of Bend contribute to poor water quality conditions that are inhospitable for fish. Dewatered in the winter, part of the streambed and the stream banks below Wickiup are exposed to the effects of freezing and thawing. Trout redds are dewatered and the stream banks become more vulnerable to erosion when the flows increase in the spring. Similarly, low flows in the summer months impact fish habitat and water quality below Bend. At the same time as summer low flows, water temperatures below Bend exceed the state's temperature standard during the summer salmonid rearing period.

Bull trout are currently listed as a Threatened species. Indigenous to the Upper Deschutes Subbasin, numbers of bull trout declined following the construction and operation of Wickiup and Crane Prairie Reservoirs. The United States Fish and Wildlife Service has proposed to designate sections of the Deschutes River and Odell Lake as critical habitat for bull trout.

Riparian Areas

The stream banks between Wickiup Reservoir and the City of Bend are eroding at a rapid rate. The artificially low winter river flows and high summer flows of the upper Deschutes River have accelerated lateral erosion of the stream banks. Stream bank erosion can cause channel instability, land loss, diminished water quality, and riparian habitat loss.

Wildlife

There are two key elk habitats adjacent to the upper Deschutes River. In this area, the Deschutes River provides a reliable water supply, valuable food sources, and secure calving areas for elk. This elk habitat is vulnerable to fragmentation from land development and land management activities.

ACKNOWLEDGMENTS

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Thanks to Bonnie Lamb of the Oregon Department of Environmental Quality for her technical advice and participation on the assessment steering committee as well as the technical advisory committee. Thanks to Marc Wilcox, Forest Hydrologist for the Deschutes National Forest, for his hydrologic tales and anecdotes as well as for his technical support and participation in the steering committee and technical advisory committee. Additional thanks goes to UDWC Water Quality Specialist, Nancy Breuner for her daily water quality wisdom and participation on the steering committee and technical advisory committee. A special thanks to Ryan Houston, UDWC Executive Director and helpful advisor, steering committee participant, and technical advisory committee member.

An extra special thanks goes to OSU-Cascades Natural Resources Professor Bob Ehrhart who donated over 100 hours of professional guidance, field-work support, natural resource anecdotes, and priceless pearls of wisdom to the Upper Deschutes River Bank Stability Characterization.

A number of other key players who contributed a great deal of time and technical assistance to the assessment process include Jonathan LaMarche, Regional Hydrologist for the Oregon Water Resource Department; Mollie Chaudet, Project Manager of the Upper Deschutes Resource Management Plan for the Bureau of Land Management; Louis Wasniewski, Forest Hydrologist for the Deschutes National Forest; Tom Walker, Fisheries Biologist for the Deschutes National Forest; Elwin Ross of the Deschutes Soil and Water Conservation District and UDWC board member; Katie Grenier, Forest Botanist for the Deschutes National Forest; Patrick Griffiths, Water Program Specialist for the City of Bend; Darcy McNamara, UDWC board member, editor for *The Bend Riverway,* and brilliant citizen at large; Nate Dachtler, Fisheries Biologist for the Deschutes National Forest; Roger Prowell, Assistant Supervisor for the Water Department for the City of Bend; Steve Marx, Fisheries Biologist for the Oregon Department of Fish and Wildlife; Dan Rife, Fisheries Program Manager for the Deschutes National Forest; and Elmer McDaniels of Tumalo Irrigation District.

The maps for the assessment were created by GeoSpatial Solutions. A distinctive thank you to GIS Analyst Mark Garner for donating extra hours and headaches to the careful delineation of subbasin features and GIS layers for the Upper Deschutes Subbasin maps.

The Upper Deschutes Subbasin Assessment benefited greatly due to the substantial contributions, comments, and reviews from its technical advisory committee. This committee reviewed technical data within the assessment and included members and partners from the Oregon Department of Environmental Quality, Deschutes National Forest, Oregon Water Resources Department, Bureau of Land Management, Oregon Department of Fish and Wildlife, Deschutes County Soil and Water Conservation District, GeoSpatial Solutions, PBS Environmental, Oregon Department of Forestry, Natural Resource Conservation Service, the City of Bend, Deschutes County, and the Upper Deschutes Watershed Council.

Additional thanks to the Deschutes Resources Conservancy for helpful donations of equipment and river time assessing the stream bank conditions on the Upper Deschutes. Thank you, Scott McCaulou and Ray Hartwell.

A kind thanks to the three interns who donated a great deal of time and attention to the Upper Deschutes River Bank Stability Characterization; Alasia Heinritz and Matt Maloney for their many hours collecting data in the field on the Upper Deschutes River, and Deb Quinlan for her many hours entering data in a computer lab for the GIS component of the study.

Last but not least, a thank you goes out to all of the other gracious donations of time, advice, and answers from the many interested landowners, community members, organizations, and agency folks who care a great deal about the beautiful place that is the Upper Deschutes Subbasin.

Abbreviations and Acronyms

BLM	Bureau of Land Management
BOR	Bureau of Reclamation
C	Celsius
F	Fahrenheit
cfs	cubic feet per second
EPA	Environmental Protection Agency
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Water Resources Department
PGE	Portland General Electric
RM	river mile
TID	Tumalo Irrigation District
COID	Central Oregon Irrigation District
GIS	Geographic Information Systems
FEIS	Final Environmental Impact Statement
TMDL	total maximum daily load
UDWC	Upper Deschutes Watershed Council
DRC	Deschutes Resources Conservancy
USFWS	United States Fish and Wildlife Service
USFS	Deschutes National Forest and Ranger Districts
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USGS	United States Geological Survey

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF MAPS

1.0 INTRODUCTION

1.1 Approach

A watershed assessment is one method for evaluating how well the biological, physical, and ecological components of a watershed are working. In other words, a watershed assessment attempts to characterize the past and current conditions of all of the components in the area that play a role in affecting the health of the watershed system. This assessment of the Upper Deschutes Subbasin has synthesized the available existing data and research on the natural and cultural history, ecological features, biology, and ongoing issues within the area.

One of the objectives of the assessment process is to summarize both what is known and what is not known about the subbasin and its watersheds. By identifying data gaps and recommendations, opportunities and priorities for further research and future watershed restoration projects are clarified for watershed councils, land managers, and other stakeholder groups. The information presented within the Upper Deschutes Subbasin Assessment comes almost entirely from existing data including watershed analyses, scientific papers, and technical documents. Some of the sections of the document present a greater level of detail than do others. This discrepancy represents a lack of available information on certain subjects or in certain geographic areas of the subbasin.

The Upper Deschutes Subbasin Assessment was initiated by the Upper Deschutes Watershed Council (UDWC) with funds provided by the Oregon Watershed Enhancement Board (OWEB) and the National Fish and Wildlife Foundation (NFWF). With numerous project partners and valuable technical assistance from the Oregon Department of Environmental Quality (ODEQ), the Deschutes/Ochoco National Forest Service, the Oregon Department of Fish and Wildlife (ODFW), the Bureau of Land Management (BLM), the Deschutes Resources Conservancy (DRC), Deschutes Soil and Water Conservation District (DWCD), and OSU-Cascades, the Upper Deschutes Subbasin Assessment is truly the product of a successful collaborative effort.

This assessment supports the Oregon Plan for Salmon and Watersheds in both principle and practice. The Oregon Plan is designed to improve the health of the state's aquatic resources, and the Upper Deschutes Subbasin Assessment is directed toward assessing resource conditions in order to understand and promote watershed health. With its strong emphasis on voluntary action, collaboration between government agencies and watershed councils, monitoring and accountability, and public outreach and participation, the Upper Deschutes Subbasin Assessment process puts into practice the goals and objectives of the Oregon Plan.

This assessment follows the general format and guidelines defined within the *Oregon Watershed Assessment Manual* developed by OWEB (WPN1999). OWEB's assessment manual was designed provide guidance for broad-scale watershed screening by either watershed councils or soil and water conservation groups. As the OWEB manual is designed for application to 5^{th} field watersheds of approximately 60,000 acres in size and the Upper Deschutes Subbasin is over 800,000 acres in size, the scale for some sections of the Upper Deschutes Assessment will necessarily be broader than for other OWEB assessments. In general, OWEB watershed assessments are designed to accomplish the following goals:

- Identify features and processes important to fish habitat and water quality.
- Determine how natural processes are influencing those resources.
- Understand how human activities are affecting fish habitat and water quality.
- Evaluate the cumulative effects of land management practices over time.

The premise that guides most OWEB assessments is that the character and health of streams and their channels are the result not only of surrounding landforms, geology, and climate, but of all upslope and human influences as well. In order to accurately understand the connections and interactions between human activity and watershed conditions, the assessment process examines broad-scale patterns within watersheds. It uses certain aspects of water quality and fish habitat as indicators of overall watershed health. To assess conditions and thereby identify potential problems, the watershed assessment process consolidates existing data with the local knowledge of land managers and community members and information from field surveys. The combination of anecdotal and on-the-ground information reveals which natural and human-altered processes are contributing to or detracting from a watershed's ability to produce high quality cold, clear water with which to support healthy native fish.

This assessment of the Upper Deschutes Subbasin watershed conditions and characteristics is a synthesis of existing data and research. Approximately 70% of the subbasin consists of land managed by the United States Forest Service, so a high percentage of the information written about the area resides in Forest Service documents. The Deschutes National Forest Service has completed a series of watershed analyses and late successional reserve assessments for 5^{th} and 6^{th} field watersheds within Deschutes Forest boundaries. Including the Odell, Bend, Browns/Wickiup, Cascade Lakes, and Forks/Bridge Watershed Analyses, and the Browns/Round Mountain, Cultus/Sheridan Mountain, and Davis Late Successional Reserve Assessments, these analyses present current and detailed information on each area of study. A substantial amount of data for the Subbasin Assessment comes from these forest service documents.

The remaining 30% of the Upper Deschutes Subbasin consists of a conglomeration of private, city, state, Bureau of Land Management, and a very small section of Bureau of Indian Affairs lands. Watershed data for these areas is a bit more diffuse and fragmented. The Subbasin Assessment attempts to integrate information from a wide and diverse array of sources for the characterization and assessment of the current and historic conditions in these remaining areas; however, there are substantial data gaps for private lands within the subbasin. In order to address these data gaps, the UDWC and other watershed interest groups can collaboratively participate in ongoing efforts to collect and combine information for the current conditions on private subbasin lands.

1.2 Project Limitations

At over 800,000 acres, the large size of the subbasin requires that a very broad scale of analysis be applied to the majority of its assessment. Therefore, additional assessments or research that more closely examines the conditions of specific 6^{th} field watersheds may be necessary prior to the development and implementation of certain restoration and enhancement projects. The assessment provides an overview of conditions for the entire subbasin; however, due to the sheer size of the area, a closer level of detail was only attributed to areas that directly affected or were affected by water quality, fish habitat, and riparian zone conditions.

Due to the fact that this assessment relies primarily on existing data and previously published reports, there are some substantial data gaps in the information presented. Areas of private land within the project area have little to no information published on current watershed conditions. Since one of the primary purposes of this assessment is to identify data gaps, future analyses can focus on assessing conditions on privately owned land.

The only fieldwork completed within the assessment process collected stream bank erosion data for the *Upper Deschutes River Bank Stability Characterization* (see Appendix I).

1.3 Watershed Overview

1.3.1 Description

The Upper Deschutes Subbasin Assessment area covers 878,437 acres. The topographic area included within the subbasin assessment encompasses all of the upland and riparian zone features that drain into the Upper Deschutes River (see Map 1.1). The perimeter for the assessment is generally based on the combined borders of included 6^{th} field sub-watersheds. The subbasin's western border is the crest of the Cascade Range, the southern border extends from the southern ridges that traverse along Odell Lake and follows a northwestern path along the summits of Royce Mountain, Davis Mountain, and Gilchrist Butte until reaching the confluence of the Deschutes and the Little Deschutes River. The assessment border includes none of the Little Deschutes subbasin. At the confluence of the Deschutes and the Little Deschutes, assessment area border cuts through the Little Deschutes to head east toward Lockit Butte. The eastern boundary of the assessment area travels along the high points of elevation from Lockit Butte up to Kelsey Butte and Horse Butte, along the east side of Redmond, over the peak of Haystack Butte and along the west side of the Crooked River. Finally, the northern border of the subbasin extends from the west side of the Deschutes River at Lake Billy Chinook, heads in a southwesterly direction down along the ridge that separates Squaw Creek from the

Deschutes, to Tam McArthur Rim and along the peaks of Broken Top and South Sister. The assessment area does not include the Squaw Creek Subbasin.

South Sister Mountain is the highest point of elevation in the subbasin at 10,358 feet and elevation gradually decreases in a general northerly direction down to 1,900 feet where the Deschutes River meets Lake Billy Chinook.

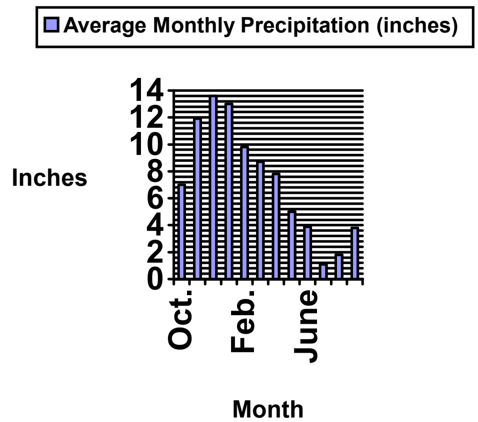
The Deschutes River begins at Little Lava Lake. Little Lava Lake is filled with groundwater inflow from the snowfields of Mt. Bachelor and the Three Sisters mountains. The Deschutes River runs from north to south from its headwaters at Little Lava Lake 8.4 miles down to Crane Prairie Reservoir. After Crane Prairie, the river runs east through Wickiup reservoir at river mile 226, and then north to Lake Billy Chinook at river mile 120. Above Crane Prairie, the main tributaries to the Deschutes are Snow Creek, Cultus River, Cultus Creek, Quinn River, and Deer Creek. Between Crane Prairie Reservoir and Wickiup, Brown's Creek contributes water into the Deschutes and Davis Creek drains into Wickiup Reservoir. Additionally, Sheep Springs contributes water into Wickiup Reservoir. The main tributaries between Wickiup Reservoir and the City of Bend are the Little Deschutes River, Fall River, and Spring River. The major tributaries to the Deschutes between Bend and Lake Billy Chinook are Squaw and Tumalo Creeks. The Squaw Creek watershed is not included within the scope of this assessment, however.

The primary lakes in the subbasin are Odell, Davis, Cultus, Little Cultus, Lava, Little Lava, South Twin, North Twin, Hosmer, Elk, and Sparks. There are also over 400 high elevation lakes in the Cascades (ODFW 1996).

1.3.2 Climate and Ecoregions

The climate in the subbasin is continental. The Upper Deschutes Subbasin sits on the eastern side of the Oregon Cascade Mountains. The rain shadow effect plays a substantial role in defining the climate of both sides of the Cascade Range. Storm clouds approaching from the Pacific Ocean rise as they reach the mountains and release a majority of their precipitation on the westward slopes of the Cascades, thereby creating a much drier climate on the eastern slopes. The majority of the precipitation that reaches the area falls as snow between November and March. The mean annual precipitation varies widely in the subbasin; ranging from 140 inches in higher elevations down to 10 inches in the Deschutes River Valley ecoregion and the eastern parts of the subbasin (ODFW 1996). Figure 1 displays the average precipitation for the mountainous areas that receive the majority of the annual precipitation in the subbasin. As depicted on the Groundwater Recharge (Precipitation) Map 9.1, precipitation is linked to groundwater recharge rates. The higher elevation areas in the Cascade Subalpine/ Alpine and Cascade Crest Montane Forest ecoregion of the Upper Deschutes Subbasin receive the highest levels of precipitation and, simultaneously, the highest rate of groundwater recharge.

Figure 1: High Elevation Precipitation in the Cascade Subalpine/ Alpine and Cascade Crest Montane Forest Ecoregions of the Upper Deschutes Subbasin



Source: Watershed Professionals Network 2001

Temperatures in the subbasin are generally moderate with warm days and cool nights. Bend averages about 10 days per year with temperatures over 90 degrees Fahrenheit. Winter lows average between 20 and 30 degrees Fahrenheit.

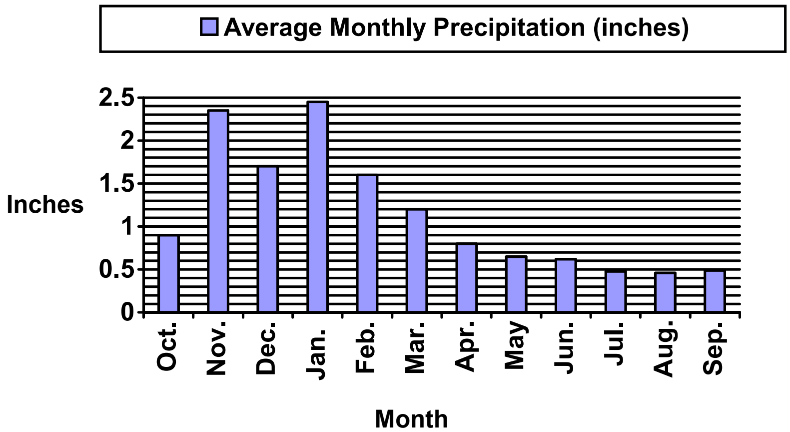
The Upper Deschutes Subbasin includes the Cascade Crest Montane Forest, Cascade Subalpine/Alpine, Ponderosa Pine/ Bitterbrush Woodland, Pumice Plateau Forest, Cold Wet Pumice Plateau Basin, and the Deschutes River Valley ecoregions (see Ecoregion Map 4.4).

The Cascade Crest Montane Forest ecoregion is found along the crest of the Cascade Mountains. The geology consists of lava flows and pyroclastic deposits with high elevation plateaus, buttes, and cones. This high elevation portion of the Upper Deschutes Subbasin sees a large percentage of the precipitation in the area. Often, greater than 75% of the annual total precipitation falls here as snow between November and March. Snow will accumulate into a deep snowpack and store water until spring (WPN 2001).

The Cascade Subalpine/Alpine ecoregion is a highly glaciated region located along the highest of the volcanic mountains in the Upper Deschutes Subbasin. In this area, the geology consists of lava flows and pyroclastic deposits of basalt and andesite and soils are bare rock and rubble. Streams here are generally very high gradient and do not support many fish. The mean annual precipitation in the Cascade Subalpine and Alpine ecoregion is the highest for the Upper Deschutes Subbasin, averaging between 70 and 90 inches (WPN 2001).

The Eastern slopes of the north-central Cascade Mountains hold the Ponderosa Pine/Bitterbrush Woodland ecoregion. This ecoregion is dominated by Mt. Mazama ash and basalt flows with widely ranging soils. The mean annual precipitation for this ecoregion is between 16 and 35 inches. This ecoregion is lower in elevation than either the Cascade Crest Montane Forest or the Cascade Subalpine/ Alpine ecoregions, and therefore sees a much lower level of annual precipitation. Figure 2 represents the average annual precipitation pattern for the Ponderosa Pine/ Bitterbrush Woodland ecoregion (see Ecoregion Map 4.4 and Groundwater Recharge (Precipitation) Map 9.1).

Figure 2: Average Annual Precipitation Pattern for the Ponderosa Pine/ Bitterbrush Woodland Ecoregion of the Upper Deschutes Subbasin



Source: Watershed Professionals Network 2001

The Cold Wet Pumice Plateaus are high elevation basins located south of the City of Bend. The geology of these areas contains Mount Mazama ash underlain by river and lake deposits. Topographically, the area consists of depressions with forested wetlands, marshes, and shallow lakes. Streams are very low gradient and originate in adjacent ecoregions with higher precipitation. The precipitation in this ecoregion ranges between 20 and 25 inches per year.

The Deschutes River Valley ecoregion is part of the Snake River Basin/High Desert ecoregion. Soils in this ecoregion are rocky and thin, low in organic matter and high in minerals. Minerals are derived either from underlying volcanic rock or from sedimentary layers that have been exposed. Erosion rates can vary across an ecoregion as wide as this, but rates remain fairly low due to low precipitation, competent geology, and moderate slopes. The climate in the Deschutes River Valley is arid with extreme ranges in daily and seasonal temperatures. In general, springtime is moist and winters bring precipitation in the form of snow. Summers are hot and dry with occasional thunderstorms.

The Pumice Plateau Forest ecoregion is located in high elevation plateaus east and north of Crater Lake. The geology of these areas is dominated by Mount Mazama ash and pumice. Ash is underlain by basalt and andesite lava flows and the soils range from well-drained coarse sandy loam to loamy course sand derived from ash and pumice. The topography here consists of a high volcanic plateau and isolated buttes. There is a very low stream density within the watersheds of this and many of the ecoregions of the Upper Deschutes Subbasin. Most perennial streams are low gradient and are dominated by flow from springs. The mean annual precipitation in this area ranges from 16 to 30 inches, with most precipitation occurring between November and January.

1.3.3 Geology

Most of the surface landforms and topography as well as the subsurface geology of the Upper Deschutes Subbasin are a diverse mix resulting from 35 million years of glacial and volcanic activity combined with structural faulting and erosion (see Geology Map 1.2). In general, the geologic units found in the subbasin include a majority of quaternary to late tertiary basaltic to andesitic lava (USGS 2001). Pleistocene volcanic rocks traverse the crest of the Cascades and the High Cascade peaks are primarily composed of andesite on top of a foundation of basalt (Loy 2001). In the Bend area, a series of Quaternary ash flow tuff units believed to have originated from the Broken Top area are combined with basalt flows originating in the Cascades. These features cover most of the area west of the Deschutes River. East of the Deschutes River, basalt from Newberry Caldera is the predominant rock type (McNamara 1999).

A large portion of the subbasin had been glaciated in the past. Approximately 14,000 years ago, the Bridge Creek and Tumalo Creek drainage areas were overlain with almost 1,000 feet of ice. Consequently, all pre-glacial soils in these areas were first covered by glacial till and then later layered with coarse pumice and ash from the eruption of Mt Mazama. Mt. Mazama, located south of the subbasin, erupted 6,850 years ago and buried much of the area beneath one to ten feet of volcanic tephra, thus contributing to the predominant soil composition throughout the subbasin (Chitwood 2000). The Mazama tephra is composed of rhyolitic ash and fine light-colored pumice fragments (USGS1986).

The oldest rock unit in the area is a basalt that is believed to be Pliocene to Miocene in age, or around 12 million years old. Awbrey Butte, a small shield volcano in the northwestern part of Bend, is composed of this type of older basalt. Additionally, the Pleistocene basalt occurs down along the west bank of the Deschutes River where the river flows around Awbrey Butte and along the west bank of the Deschutes farther to the south of Bend. The older basalt is overlain in places by varying combinations of Desert Springs Tuff, Bend Pumice, Tumalo Tuff, Shevlin Park Tuff, or younger basalt units. The Desert Springs Tuff, Bend Pumice, Tumalo Tuff, and Shevlin Park Tuff are volcanic ash and ash flow, or pyroclastic deposits, which originated in the Broken Top area of the Cascade Mountains (McNamara 1999).

Various types of Pleistocene volcanic rocks are found throughout the High Cascades. In and around the City of Bend, the Bend Pumice is Pleistocene in age, and ranges up to 33 feet in thickness. It is generally white in appearance, and consists of different sized pieces of loose pumice. The Bend Pumice unit was the source of pumice for the historic pumice mines in the area, and Bend Pumice is still being mined near Bend today. The Bend Pumice is overlain by the Tumalo Tuff, which is also Pleistocene in age and can be up to 72 feet thick. The Tumalo Tuff is a rhyolitic ashflow tuff that is believed to have been deposited from the same eruptive sequence as the Bend Pumice. Tumalo Tuff is characteristically pink to pinkish-orange in color, and has a wide range of texture and strength, from soft and crumbly to very hard. Bend Pumice and Tumalo Tuff have been found along both banks of the Deschutes in areas just upstream and downstream of Bend. The cliffs along the west bank of the river near the Old Mill section of Bend, where the

Tumalo Tuff is exposed, are considered to be an excellent example of a pyroclastic ash flow tuff deposit (McNamara 1999).

The next-youngest geologic unit in the area is a series of basaltic andesite flows that originated in the Cascade Mountains. These flows are fairly extensive west of the river, but do not actually outcrop along the river itself. The Shevlin Park Tuff is a dark gray to black pyroclastic deposit of Pleistocene age, younger than the basaltic andesite flows from the Cascade Mountains. This tuff is up to 135 feet in thickness and has a high range of texture variability-- from soft and crumbly to very hard. Exposures of this tuff are fairly common in parts of west Bend, but not along the Deschutes River itself (McNamara 1999).

Newberry basalt, the basaltic andesite of Newberry Caldera, consists of many recent lava flows. The Newberry flows are believed to be contemporaneous with the basaltic andesite flows from the Cascade Mountains. Newberry basalt is light to medium gray in color, and contains many holes, or vesicles that were left by escaping gas as the lava cooled. Newberry basalt is the predominant rock type east of the Deschutes River and is exposed along much of the east bank of the river in the project area. The Sisters Fault Zone, approximately 10 miles wide and 62 miles in length, stretches across the Upper Deschutes Subbasin from Newberry Crater to north of Black Butte. The zone is comprised of several discontinuous, northwest-trending faults. The Tumalo Fault, a major fault of this zone, crosses the Deschutes River just upstream from Bend (McNamara 1999).

The geologic features present in the Upper Deschutes Subbasin are listed in Table 1. The acreage for each geologic type are listed along with the percentage that each type is present in the subbasin. Map 1.2 displays the geologic distribution of landforms throughout the Upper Deschutes Subbasin. The acreage numbers and percents listed in Table 1 correspond to the geologic distribution in Map 1.2. As shown, basalt and basaltic andesite comprise the greatest percentage of area throughout the subbasin.

Table 1: Geology of the Upper Deschutes Subbasin

TYPE	ACRES	PERCENT OF SUBBASIN
GRANITIC ROCKS	118	0.01%
OPEN WATER	24,687	2.81%
ALLUVIAL DEPOSITS	115	0.01%
BASALT AND BASALTIC ANDESITE	145,695	16.59%
BASALTIC ANDESITE AND BASALT	126,708	14.42%
DUNE SAND	918	0.10%
GLACIAL DEPOSITS	50,579	5.76%
GLACIOFLUVIAL DEPOSITS	22,581	2.57%
PLAYA DEPOSITS	230	0.03%
RHYOLITE AND DACITE	10,127	1.15%
LACUSTRIAN AND FLUVIAL SEDIMENTARY ROCKS	75,746	8.62%
BASALT	253	0.03%
BASALT AND BASALTIC ANDESITE	104,322	11.88%
MAFIC VENT COMPLEXES	73,490	8.37%
PYROCLASTIC ROCKS OF BASALTIC AND ANDESITIC	21,075	2.40%
PYROCLASTIC ROCKS OF BASALTIC AND ANDESITIC	2,130	0.24%
SEDIMENTARY ROCKS	2,092	0.24%
SILTSTONE	22,799	2.60%
MAFIC VENT DEPOSITS	2,533	0.29%
YOUNGEST BASALT AND BASALTIC ANDESITE	83,685	9.53%
BASALT AND ANDESITE	1,548	0.18%
BASALT AND ANDESITE	147	0.02%
CLASTIC ROCKS AND ANDESITE FLOWS	1,510	0.17%
OLIVINE BASALT	71,096	8.09%
TUFFACEOUS SEDIMENTARY ROCKS AND TUFF	28,902	3.29%
SILICIC VENT COMPLEXES	4,972	0.57%
SILICIC VENT ROCKS	380	0.04%
Total Acres	**878,437**	100.00%

1.3.4 Hydrogeology

The general hydrogeologic setting of the assessment area includes lava beds that sit on top of several hundred feet of volcanic and sedimentary rocks. The subsurface geology of the upper Deschutes Subbasin defines and directs the storage and flow of groundwater. The type of subsurface rock and the levels of porosity and permeability within underground rocks direct how and where groundwater will flow. Porosity is based on the percentage of a rock that consists of air pockets or open space. Permeability is a measure of water's ability to move through the soil or rock. Geologic features that have large interconnected open spaces have little resistance to groundwater flow and are considered highly permeable. Rocks with very few, small or poorly connected open spaces have low permeability as they create blockages that stop or redirect groundwater flow (UDWC 2002).

Groundwater travels from high-elevation recharge areas in the Cascades towards the high lakes area, down to the Deschutes River, and then to lower elevation discharge areas near the confluence of the Deschutes, Crooked, and Metolius Rivers. With the exception of a slight gradient to the north, the water table around Bend, Redmond, and Sisters is primarily flat with elevations between 2,600 and 2,800 feet. The water table in Bend is hundreds of feet below the surface of the land; whereas in Redmond, the water table is closer to the land surface. This is due to the fact that the northward gradient of the water table is less than the northward downward slope of the land (USGS 2001). Groundwater flows toward, and discharges into, streams that "act as drains to the ground-water flow system" (USGS 2001). North of Redmond, the deep canyons of the Deschutes are incised down to the elevation of the regional water table, so the river is actually recharged by groundwater here. Water-level contours are generally parallel to the canyons in the confluence area, indicating flow directly toward the rivers (USGS 2001).

1.3.5 Soil

The parent materials for the soils in the subbasin are primarily composed of ash, cinders, and pumice deposited from past volcanic eruptions. Pumice and ash tephras were expelled during eruptions like that of Mt Mazama. This material is present in 0.5 to 1.0 meter depths on a gradient from north to south and is the primary material in which roots of vegetation are active (Beyer 1997). Deposits of ash, cinders and pumice fell on previously developed soils. Almost all of the bedrock materials beneath soils are extrusive volcanic rocks (USDA 1990). Litter and duff on the soil surface also is found in variable depths throughout the watershed, primarily as a function of the aspect and plant association on which a given soil profile is located. Surface litter and duff is a primary component of the productivity of the soils present within the area.

Underlying glacial or volcanic materials within the Upper Deschutes subbasin primarily affect the subsurface flow of water, but can also influence the availability and content of nutrients within the soil profile. Glacial outwash underlies parts of the subbasin where seasonally high water tables are present and glacial till underlies the western portions of the subbasin, providing lateral subsurface flows. Both of these elements can contribute to the presence of riparian soils that are associated with high seasonal water tables (Beyer 1997).

Volcanic ash soils, which make up a large percentage of the Upper Deschutes Subbasin, are light in color and have low fertility levels. They contain minor amounts of hard rock material and have little structural development. They are very loose and are sensitive to lateral soil movement, erosion, and displacement which can be caused by large logging equipment. Soil displacement of topsoil layers can adversely affect soil fertility and productivity (Crown Pacific1998).

Residual and non-forested soils make up a much smaller percentage of the study area. Residual soils are composed of older or weathered ash and residual materials. These residual soils have thicker, darker surfaces and a bit better cohesion than the other volcanic ash soils of the subbasin. Reddish brown in color, the textures range from gravelly to stony fine sandy loam or clay loam. These residual soils are highly susceptible to detrimental soil compaction from mechanical activities (Crown Pacific 1998). These non-forested soils of the subbasin are found in areas of barren lava flows, rocky mountain peaks, wet meadows, canyon walls, barren flats and scabs, cinder cones, and lava flows: all areas with low-density timber stands. These soils are generally shallow and have higher rock contents than the other soils in the area. Non-forested soils also have low water holding capacity. (Crown Pacific1998).

The USDA Natural Resources Conservation Service (NRCS) completed a soil survey for the Deschutes area in 1958 but that survey is currently out of print and unavailable.

1.4 Land Allocations

Approximately 70% of the Upper Deschutes Subbasin is land that is managed by the United States Forest Service. Originally, 78% of the land that is currently within the boundaries of the Deschutes National Forest had been withdrawn from the public domain either by President Grover Cleveland on September 28, 1893 or President Theodore Roosevelt on July 31, 1903. The land within the two presidential withdrawals was known as the Cascade Range Forest Reserve. The present name for the area, "Deschutes National Forest," was officially applied on July 1, 1908. Since 1908, the Deschutes National Forest has grown through purchases and land exchanges (Deschutes and Ochoco Forest Service 2002).

A graphic depiction of the extent of lands managed by the U.S. Forest Service is presented in Map 3.1. The Deschutes National Forest lands within the subbasin contain the Bend/Fort Rock Ranger District and the Crescent Ranger District. The distribution of all remaining land ownership or land management throughout the subbasin is also depicted in Map 3.1. The total acres and the percentage of the subbasin for each land allocation are listed in the Land Use section of the assessment in Table 3.

2.0 HISTORIC CONDITIONS

2.1 Critical Questions

1. How did Native Americans interact with the watershed resources of the Upper Deschutes Subbasin?
2. What were the characteristics of the watershed's resources at the time of European settlement?
3. What historic settlement practices had a direct impact on the Deschutes River?
4. What were the historical trends and locations of land and river use?
5. What are the historical accounts of fish populations and distribution?
6. What was the historical fire regime?
7. How do population growth projections influence watershed stewardship options?
8. What was the historical flow regime of the Upper Deschutes River?

2.2 Approach

The historic conditions section of the Subbasin Assessment will present a general sketch of the natural resource conditions of the subbasin as they existed prior to and during the settlement of the area. Social and cultural information will be included only when it helps to paint a picture of the impact historical communities and activities had on watershed conditions or overall watershed health.

The historic conditions data presented is a synthesis of information collected from the Deschutes National Forest Service, The Warm Springs Tribes, *The River Study* by Craig Nielson, Bob Bristol, Jim Powell, Dave Mohla, and Bill Marlett, *East of the Cascades* by Phil Brogan, *The Riverway: A Community Vision* by Darcy McNamara, and a variety of other excellent local resources. The historic conditions section presents an overview of the history of settlement and land uses throughout the subbasin and additional historic data will be interspersed throughout the appropriate subsections of the assessment.

2.3 Historic Conditions

2.3.1 Native American History

The original native name for the Deschutes River was Towornehiooks. Lewis and Clark used this name when they traveled down the river in 1805, but when they returned home they called it Clarks River. Eventually though, among fur trappers, the Deschutes became known as "Riviere des Chutes," or River of the Falls because its mouth was just above Celilo Falls, the well-known falls of the Columbia River (Bastasch 1998).

The Deschutes River provided immeasurable sustenance and resources to Native Americans in the area. Containing abundant wildlife, what seemed to be a limitless amount of trout, and the lush vegetation that landscapes ranging farther east of the Cascades lacked, the Deschutes was so often used by Native Americans it was also referred to as the "Indian Road" to The Dalles by trappers and explorers (Nielson et al. 1986).

Within Deschutes County, there have been three large archeological surveys conducted on the Deschutes River. The 1948 Smithsonian River Basin Survey recorded 32 Native American cultural sites upstream from Benham Falls, the 1983 USFS and Inn of the Seventh Mountain land exchange documented 12 sites on the west bank of the river near Lava Island Falls, and in 1983 the USFS also recorded 87 archeological sites from Meadow Camp to Wickiup dam.

Rock shelters, pictographs, and lithic scatters derived from obsidian materials found throughout the Upper Deschutes Subbasin indicate substantial and widespread Native American occupation. Projectile point cross-dating has been used to estimate the relative age of sites along the Upper Deschutes River (Nielson et al. 1986). Archeological evidence dates prehistoric occupation in the area from 8,000 to 7,000 years before present. The oldest site excavated thus far produced two knives beneath a layer of Mt. Mazama ash. Analysis of the knives indicates an age of over 7,000 years old. The Deschutes River and the areas surrounding it provided a home with abundant resources to Great Basin Native American tribes including the Klamath, Molalla, and Tenino for thousands of years prior to the 1813 arrival of the first white explorers (Beyer 1997).

Archeological evidence indicates that Native Americans participated in extensive hunting and fishing throughout the area, as well as collecting plants and herbs (Beyer 1997). The Native Americans of Central Oregon depended on deer, roots, fruits, other plants, and fish for food. Due to the abundance of native wild food sources in the area, agriculture was basically unnecessary as a means of food propagation (Warm Springs 2001). Instead, tribes of the Upper Deschutes subbasin made use of what could be found growing and naturally thriving in the area. Fish were pulled out of the rivers with long-handled dip nets and roots were dug out with specialized digging sticks called kapns (Warm Springs 2001).

2.3.1.1 Treaty Rights

During the mid-1850's, conflicts between native peoples and European immigrants to the Upper Deschutes area increased. Between 1855 and 1865, several central Oregon bands were engaged in conflict with the incoming settlers. In order to attempt to minimize tension, several treaties were initiated between 1851 and 1855, but very few of these gained Senate ratification. In 1855, the tribes that lived in Central Oregon and comprised the Chinookan and Shahaptian- speaking peoples of the western part of the Columbia Plateau agreed to sign a treaty with the white settlers (Claeyssens 2001). Including the Upper Deschutes band of the Walla Wallas, the Tenino band of Walla Wallas, the John Day band of Walla Wallas, the Dalles band of Wascoes, the Ki-gal-twal-la band of Wascoes, and the Hood River band of Wascoes, the Native Americans who had been living in and around the Upper Deschutes Subbasin signed the Treaty of 1855.

In 1855 Joel Palmer, the superintendent of Indian affairs in the Oregon Territory, instigated a series of treaties including one that established the Warm Springs Reservation. Only a small portion of the Warm Springs Reservation is within the Upper Deschutes Subbasin Assessment area but, historically, the tribes involved in the treaty of 1855 roamed throughout the subbasin and relied upon many of the rich resources of the Deschutes River and its uplands. The primary intention of the Treaty of 1855, also referred to as the Treaty with the Tribes of Middle Oregon, was to clear Indians from the lands of the Oregon Territory. The treaty required that the Warm Springs and Wasco tribes relinquish ten million acres of land to the Oregon Territory. In addition, the Treaty of 1855 reserved the land of the Warm Springs Reservation on the Deschutes River for use by the Wasco and Warm Springs Tribes. Fishing rights in portions of the Deschutes and other streams flowing through reservation lands were given exclusively to the tribes of Warm Springs. The treaty also preserved the tribal right to harvest fish, game, and other foods in land areas that were not located on the reservation (Warm Springs 2001).

2.3.1.2 Cultural Resources

Natural resources were plentiful for native tribes in the subbasin. Salmon from the Deschutes and the nearby Columbia River was a staple part of the Wasco and Warm Springs Tribes' diets. The Paiutes of the high plains primarily relied on deer and large game, and all three tribes made the most of abundant native roots, fruits, and other plants. Table 2 lists the plant resources that have been documented to have been used by Native American inhabitants within the Upper Deschutes Subbasin.

Table 2: Native American Plant Resources in the Upper Deschutes Subbasin

Common Name	Scientific Name
kause/biscuit root	*Lomatium* spp.
wild onion	*Allium* spp.
ponderosa pine	*Pinus ponderosa*
chokecherry	*Prunus virginiana*
Service berry	*Amelanchier alnifolia*
Bulrush/tule	*Scirpus validus*
wild carrot	*Perideridia* spp.
yellow cress	*Arabis*
rabbit brush	*Chrysothamnus nauseosus*
cattail/ bulrush	*Typha latifolia*
sage brush	*Artemisia tridentate*
Clover	*Trifolium* spp.
squaw current	*Ribes*
quaking aspen	*Populus tremuloides*
Blazing star	*Mentzelia* spp.
wild mint	*Mentha arvensis*
wild rose hips	*Rosa* sp.
willow/ dogwood	*Salix* sp. / *Cornus* sp.
yellow bell	*Fritillaria pudica*
Yarrow	*Archillea millefolium*

Source: USDA 1996

2.3.2 European Settlement

The Deschutes River is and has always been known for its beauty and for the healthy habitat it provides wildlife. In 1916 Warden W.O. Hadley referred to the river by asserting: "The Deschutes River, I think, is the best trout stream in Oregon. I will go further in my claims for this wonderful stream and its tributaries and say that if it is not already, it soon will be the best trout stream in the United States. This stream has a steady flow of good cold water and only varies a few feet from extreme high to low water" (Oregon Sportsman 1916).

The Deschutes River drew many to its cool clean waters. From pre-history to present-day, it has been both an area of settlement and a travel corridor. Table 3 presents an outline of river use information in and around the City of Bend. The detailed river use information presented in the table is from the 1999 Riverway project that assessed and characterized the river use conditions within the boundaries of the City of Bend. A detailed historic account of river uses throughout other parts of the subbasin was unavailable.

Table 3: Highlights in Upper Deschutes River History

Date	Event	Comments
Pre-1900	Lithic scatter and rock shelters in Sawyer Park and other areas.	Evidence of early occupation.
1813	Rock carved by the Astoria Party, earliest evidence of explorers from the east in Deschutes County.	Now in the Deschutes County Historical Museum. Was moved from site on river near Elk Heights (across river from north end of Sunrise Village).
1851	Pioneer Park is reputed to be the spot where immigrant parties crossed the river.	
1877	Farewell Bend Ranch in Old Mill area established.	Owner, John Y. Todd. Ranch is Bend's namesake.
1900	Apple orchard in Sawyer Park is part of the Collins & Stearns Ranch.	Seeds were from a trip to the Willamette Valley.
1901	Pilot Butte Canal built.	Still in use today. Now called the COI main canal.
1910	Reservoir that creates Mirror Pond and hydroelectric powerhouse built.	First hydroelectric power in Central Oregon. Still in use today.
1911	Citizens protest against cutting down trees in Bend.	Bulletin reports that citizens want trees in town for beauty.
1911	Deschutes River stocked with 35,000 fish.	

1911	Citizens urge city to stop dumping sewage into river.	
1911	USGS survey of river.	
1913	New powerhouse built and hydraulic works rehabilitated.	At Mirror Pond.
c. 1914	Steidl & Tweet Reservoir built.	Near Riverview Park, now called North Canal dam.
1915	Shevlin-Hixon begins building mill.	First log sawed in March 1916. Closed in 1950.
1915	Brooks-Scanlon begins building mill.	First log sawed in April 1916. Mill closed in 1993 under a different owner.
1916	Shevlin-Hixon railroad trestle built.	Demolished 1991.
1916	Colorado Street dam built.	
1917	Pilot Butte Inn built.	Located on corner of Wall & Greenwood.
1921	Footbridge in Drake Park was first built.	Rebuilt in 1935, 1953, and 1997
1920	Drake Park established.	
1922	Bandstand at Drake Park built.	Demolished in 1973.
1922	Diversion dam built.	Near 1st Street, now called Steidl dam & owned by Tumalo Irrigation District.
1923	Pioneer Park established.	
1924	Harmon Park established.	
1927	Pioneer Park becomes a city owned "auto park."	Consisted of little cabins.
1927	Rock retaining walls built at Drake and Harmon Park.	Purpose was to reclaim swampy areas for park land.
1929	Lawn seeded at Drake Park.	
1929	Riverside Boulevard paved.	
1931	Sawyer Park becomes a state park.	
1933	Water pageant held annually on July 4th (suspended during WWII).	Pageant discontinued in 1965.
1936	Pine Tavern established on the Deschutes River.	
1938	Brooks Park acquired.	
1949	Pageant Park donated to city for the water pageant.	Floats secured at park until they entered parade through archway.
1950	Shevlin-Hixon mill closed.	
1951	Harmon Park baseball fields built.	
1954	Columbia Park acquired.	

1965	Columbia Park developed.	
1965	Water Pageant ends.	Numerous reasons cited (crowds, silt, streakers, cost, volunteer burn-out)
1967	1st Street Rapids & Deschutes River Trail established.	Built on top of underground canal owned by Tumalo Irrigation District
1967	Pacific Park deeded to Park District by PP&L.	
1973	Pilot Butte Inn demolished.	
1973	Bandstand at Drake Park demolished.	Built in 1922.
1975	Mirror Pond Committee appointed.	Study of silt issue began.
1977	Riverview Park established.	
1980	Sawyer Park deeded to the Park District.	
1980	Pole, Pedal, Paddle race held annually in May.	
1981	Report on Mirror Pond Rehabilitation published.	Report provides detailed analysis of dredging. The cost to dredge Mirror Pond was bid at $275,000.
1982	Mirror Pond dredged.	Dredged material piped upstream to a site on the west side of the river in the Old Mill District.
1983-84	Deschutes flooded riverside district in Bend.	Caused by an ice dam at the Galveston bridge.
1986	River Task Force Committee publishes the River Study.	An incredible reference tool for anyone interested in the river.
1988	Several miles of river within the Riverway added to State Scenic Waterway.	By statewide vote.
1990	Awbrey Hall fire.	
1990	Woodriver Park established.	
1991	Shevlin-Hixon railroad trestle demolished.	
1993	Public plaza near Rademacher House built.	
1994	River setback regulations amended by city.	
1994	Mixed Use Riverfront Development zoning passed.	Set standards for development along river.
1994	Daw/Crown Pacific mill closed.	Originally the Brooks-Scanlon mill.
1995	Fish and wildlife habitat enhancement in Old Mill District begins (created island, added fish ladder to Colorado Street dam).	ODFW biologists worked with Old Mill District developer.
1998	Historic Home tour.	Focus on arts & crafts style architecture.
1998	McKay Park construction began.	

1998	Riverway Project began.	Effort to build and implement a community vision for the river in Bend.
1999	River Bend Partners builds a footbridge in Old Mill District.	
1999	River Bend Partners begins construction on new vehicular bridge in Old Mill District.	Located between Colorado Street and old bridge that is being used for construction (not proposed So. Canyon Bridge).
1999	Log deck land exchange between Park Dist. and River Bend Limited Partners completed.	Resulting in a 22-acre riverfront park.
1999	Park Dist. begins work on Harmon Park upgrade.	Includes new playground equipment, plantings, boat launch.
2003	The Upper Deschutes Watershed Council builds partnership with Bend Metro Parks and Recreation District and the Deschutes Resources Conservancy to restore riparian areas along the river at Farewell Bend Park.	Riparian enhancement projects are scheduled to begin in 2004.
2003	The Upper Deschutes Subbasin Assessment is completed.	An assessment of the past and current conditions of the entire subbasin, the Upper Deschutes Subbasin Assessment is a comprehensive document that can be used to understand the connections between water quality, fish habitat, watershed health, and human impact in the area.
2004	Estimated date that silt will reaccumulate in Mirror Pond.	According to Winzler et. al. 1981.
2005	City of Bend's centennial.	

Source: (McNamara 1999; UDWC 2003)

2.3.2.1 First Pioneers

The earliest artifact found as evidence of white explorers venturing into Deschutes County is a rock carved by the Astoria Party in 1813. The carving was found at a site near the river approximately 1 mile upstream from Bend (McNamara 1999). In approximately the same area, just above Benham Falls, Hudson Bay trappers Tom McKay and Finan McDonald traveled across the Deschutes in 1825. A year later, Peter Skene Ogden also traveled across the Deschutes and ventured down toward Mt. Shasta with Tom McKay (Nielson et. al. 1986). Famous Oregon Trail pioneer, Nathaniel Wyeth lived and trapped along the Deschutes in 1843-1853. His party built dugout canoes along the river and Wyeth purportedly stood in the icy water to pull them over Benham Falls (Nielson et al.1986).

Billy Vandevert was one of the oldest permanent residents in Bend. In 1893, Vandevert built a homestead south of Bend on the Deschutes River and he remained there until his death in 1944 (Deschutes and Ochoco National Forest 2002).

Bend became an official incorporated city in 1905. Residents of the city received Deschutes River water from the Bend Water, Light, and Power Company water system.

Eventually in 1924, the City of Bend purchased the water company and realized the need for an alternate water source due to algae growth in the Deschutes. Tumalo Creek was recommended as a water source due to its high quality water. The City of Bend purchased water rights for Bridge Creek, a tributary of Tumalo Creek, water in 1924 from the Deschutes County Municipal District (now Tumalo Irrigation District) (City of Bend 2001).

During the period of European settlement of the area, the river was one resource among many that was altered for social or economic uses. Between 1911 and 1935 there was community pressure to build a storage reservoir at Benham Falls. The project was only prevented by the large expense and the geologists' warning about the quantity of water losses into the lava flow on the east side of the river. Wickiup Reservoir site was chosen as a compromise (Nielson et al. 1986).

By 1913, the State Engineer withdrew and withheld from appropriation all unappropriated waters in the Deschutes River and its tributaries above Bend for what was referred to as The Deschutes Project. This withdrawal included the flow of the Deschutes River in addition to 900,000 acre-feet of storage in the proposed Benham Falls Reservoir for irrigation, domestic, and power purposes. In 1934 the State Engineer's withdrawal was extended to any storage site or sites found feasible and practical and 187,000 acre-feet were withdrawn for storage of irrigation water in what was then the proposed Crane Prairie Reservoir. The Deschutes Project consists of lands irrigated with water from the Upper Deschutes. All the water appropriated under these withdrawals is used for the irrigation of lands that are outside the Upper Deschutes Subbasin.

2.3.2.2 Historic Land Use

Some of the earliest settlers in the Upper Deschutes subbasin began raising sheep in the 1870's and 1880's. Stock were pastured in river bottoms and meadows during the summer and moved to gold camps in the fall (Claeyssens 2001).

While many areas were initially devoted almost exclusively to grazing, agriculture gradually gained favor with dryland wheat farming. Many dryland wheat farms were established in Jefferson County during wet years, but then discontinued during dry years (Nielson et. al 1986).

The Forest Homestead Act of June 11, 1906 also opened up certain parts of the Upper Deschutes Subbasin that were within the Cascade Range Forest Reserve for homesteading. A parcel of land from the reserve could be listed, occupied, and patented as a homestead if it was proved that the land was agriculturally valuable (Deschutes and Ochoco National Forest 2002).

Homesteading in the Upper Deschutes Subbasin began in 1898 and irrigation coincided with agriculture in approximately 1900. The development and irrigation of most of the arid lands within the subbasin occurred following the passage of the Carey Act in 1894. Passed by the United States Congress, the Carey Act empowered the states to enter into a contract with the federal government for the reclamation of lands. In effect, the Carey Act gave free land to anyone who could build the irrigation systems needed to cultivate the property lands (Nielson et. al 1986). The primary intention of the Carey Act was to have private developers build the irrigation systems that settlers could then tap into and use after paying a tithe to the developer. Once the system was in place, the settler could file a claim to own the land. However, many of the water systems were improperly built by developers and the settlers lacked reliable water (Claeyssens 2001).

In addition to agriculture and homesteading, another initial attraction for settlers to immigrate to the area was the agricultural Tumalo Project. Begun in 1900, the Tumalo Project included an ambitious attempt to store Tumalo Creek water behind a dam west of Bend in Bull Flat (Nielson et al. 1986). Unfortunately, the Tumalo Reservoir would not hold water due to the characteristics of the porous volcanic rock and numerous subterranean lava tubes (Claeyssens 2001). The Tumalo Project failed due to the lack of a water source for irrigation, and a portion of the failed Tumalo Reservoir was later diked off to create upper Tumalo Reservoir that was then used as a regulating reservoir to absorb the daily fluctuation of water flow from Tumalo Creek (Nielson et al. 1986).

In order to continue to draw new residents to fledgling communities, Central Oregon focused on bringing railways to the area. Railroads were necessary as a means to connect Central Oregon to the rest of the world, but they were also critical to the long-term success of the lumber mills. An industrial sawmill could only succeed if it could sell and distribute lumber by rail throughout the country (Claeyssens 2001). Timber management activities began in the area in the early 1900's. The first commercial timber sale occurred on the Deschutes National Forest in 1922.

One notable use of land located adjacent to the Upper Deschutes River was the construction and habitation of Camp Abbott. Camp Abbott was named for Henry Larcom Abbott who worked on the Upper Deschutes Pacific Railroads Surveys in the 1850's. Located along the Upper Deschutes River near present day Sunriver, Camp Abbott was constructed between 1942 and 1943 at a cost of $4 million. The camp was designed for training engineers for service in WWII. The facility operated only until 1944 and was eventually purchased by the Hudspeth Land and Livestock Company. Later, in the 1960's, John Gray of Portland developed this riverfront site into the Sunriver Resort (Nielson et al. 1986). The Great Hall of Sunriver Resort was originally the WWII era Camp Abbott Officer's Club. Currently, the Great Hall is a valuable and much appreciated part of Sunriver resort. It is an historic two-story building constructed of peeled pine logs. The building has a gable roof and vertical board and batten exterior on the second story. It has a massive, open lodge living room with a balcony that encircles the second story. The Officer's Club is the last remaining major structure from Camp Abbott (Nielson et al.1986).

2.3.2.3 Land Managers

The first forest ranger in the area that is now the Deschutes National Forest is purported to be Cy J. Bingham. Bingham administered public lands in the Deschutes and the upper

Willamette from 1900 to 1908. A poet as well as forest ranger, Bingham referred to the hunting, fishing, and aesthetic resources within the forest:

> *In this grand old State in which we dwell,*
> *There's a spot called Lake Odell,*
> *No prettier lake, was ever seen,*
> *Where the hunters killed the spotted fawn,*
> *And speared the dollys as they spawned.*

The Bend District of the Deschutes National Forest was formed in 1933. C.H. Overbay was the first forest ranger in this district of the Deschutes National Forest from its formation in 1933 until 1935. From 1935 on, Overbay worked in timber management in the Deschutes and Wallowa Forests (Deschutes and Ochoco National Forest 2002).

2.3.2.4 Commercial Uses

Agriculture

Irrigation development started in Deschutes County along Squaw Creek near Sisters around 1869. Irrigation was most likely the first major cultural development impacting fish populations in the Upper Deschutes River subbasin. With homesteading underway in 1898, irrigation was undertaken on a relatively large scale in about 1900. Many irrigation companies were formed about this time, but most merged into larger companies that eventually evolved into irrigation districts run by local landowners (Nielson et. al.1986).

The waters of the Deschutes River were used to irrigate as well as to begin to generate power for the area. The dam that created Mirror Pond and introduced the first hydroelectric power to Central Oregon was built in 1910. The powerhouse and hydraulic works for the Bend Hydroelectric Project were renovated in 1913. The dam is located just north of where Newport Bridge is in Bend and is still currently in use today. The dam is operated by Pacific Power and Light and contributes 1,100 kilowatts of energy, enough for 400 homes, to the area's electricity supply. Originally there was a wooden fish ladder, but there is no current means for fish passage (McNamara 1999).

Timber

During the early 1900's, the Upper Deschutes River was home to a vibrant timber industry. Timbermen used axes, crosscut saws, horses, and "high wheel" rigs to cut down and transport huge Ponderosa pine trees to the Deschutes River and the two major mills that operated on its riverbanks. Brooks-Scanlon and Shevlin-Hixon were both Minnesota based lumber firms who built mills near the Deschutes River to cut the timber they had been purchasing throughout Central Oregon. The Shevlin-Hixon Company sawed their first log at their mill on the Upper Deschutes River in March of 1916. The Brooks Scanlon mill operated on the Upper Deschutes River from April 1916 to 1993 (McNamara 1999). Both companies built extensive railroad systems for the transportation of timber throughout the area. Around 1935, logging railroads were replaced by trucks that would haul timber directly out from the woods (Claeyssens 2001). At the height of the industry, the Brooks-Scanlon and Shevlin-Hixon operations were two of the largest pine sawmills in the world, operating twenty-four hours a day and employing more than 2,000 workers each.

As timber supplies in the Upper Deschutes Subbasin diminished, Shevlin-Hixon sold its interests to Brooks-Scanlon. Sitting right on the Deschutes River in the southern part of Bend, the Shevlin-Hixon Mill was abandoned and eventually demolished in 1987. Brooks-Scanlon's Mill A closed in 1938 and Mill B was shut down in 1994 due to a shortage of available timber.

The Deschutes River was historically used to transport logs to downstream lumber mills. In order to facilitate the transportation of logs and prevent log-jams during the early 1900s, much of the naturally occurring large woody material was removed from the river channel between where Wickiup Reservoir is currently located to ½ mile above Benham Falls. The lack of large woody material along the river during the early part of the 20th century contributed to a lack of resistance to erosion along the stream banks (USDA 1996). In 1939, approximately 10-23 million board feet of logs were transported down the upper Deschutes River. It is estimated that 6.5 billion board feet of timber was cut from the Deschutes National Forest between 1992 and 2002 (Deschutes and Ochoco National Forest 2002).

Mineral Resources

Near Lower Bridge, at Deschutes River mile 134, there is a historical open pit diatomaceous earth mine along ½ mile of the west bank of the river. During the 1930's and 40's this was a very active mine, but is currently not in operation (ODFW 1996). There are currently no active mining operations and no water rights for mining. The mineral deposits known to exist in the area are obsidian and scoria or cinders (OWRD 1961).

2.3.3 River Resources

Historically, bull trout were found throughout the Upper Deschutes Subbasin. There are many historic photos of large bull trout taken near Bend. The populations that existed upstream from Big Falls were isolated from the bull trout that lived and spawned in the lower sections of the river (Buchanan 1997).

By all accounts, trout were abundant and plentiful throughout the Deschutes River. Fish fries were very popular in the early 1900's in Bend, Redmond, and Laidlaw (Tumalo). A fish fry took place in Bend during a July 4th celebration in 1906. During the celebration, participants ate approximately 3,400 trout caught on hook and line. One resident remarked on the fish fry asserting that he and three other anglers took "3,125 trout from the Deschutes River in four days fishing" (ODFW 1996).

2.3.4 Historic Flows

The Deschutes River is a spring-fed system that historically had very stable flows. As opposed to river systems that are dominated by surface runoff, a spring-fed river like the Deschutes has an incredibly stable hydrologic regime in which natural daily, monthly, and even annual fluctuations in water flows are minimal. A 1914 U.S. Reclamation Service report referred to the Deschutes River as "one of the most uniform of all streams in the United States, not only from month to month, but also from year to year. The extreme minimum is usually in midwinter when it occasionally drops, for a few days only to (approximately) 1,100 cfs" (USDA 1996).

A spring-fed system with such a stable flow regime, the Deschutes River and its tributaries have not been greatly affected by floods throughout history. There exists a high level of permeability within the volcanic rocks in the subbasin and this permeability allows rain and melting snow to quickly sink into the ground and recharge the water table. Therefore, flooding was historically much less common in the Upper Deschutes than in other less stable, less permeable systems.

2.4 Data Gaps

- There is little data on the historical conditions of some private lands in the subbasin.

2.5 Key Findings

- Historically, the Upper Deschutes Subbasin provided suitable and plentiful habitat for widespread bull trout populations.
- The Deschutes River contained abundant fish and wildlife that provided sustenance and resources to Native Americans in the area.
- Timber was the leading resource for settlers in the early 1900s. At that time, the Deschutes River was home to two of the biggest pine sawmills in the world.
- The forested portions of the Upper Deschutes Subbasin that have not been designated as wilderness have a high forest road density.
- The Deschutes River was historically used to transport logs to downstream lumber mills. The stream banks were scoured of large woody material in order to prevent log-jams. The lack of large woody material along the river during the early part of the 20th century contributed to erosion along the stream banks
- The development and irrigation of most of the arid lands within the subbasin occurred following the passage of the Carey Act in 1894. Irrigation development created the possibility for more settlers to move to and thrive in the drier parts of the subbasin.

2.6 Recommendations

- Collaborate with natural resource agencies and organizations in the area to collect and consolidate historical watershed information that can be used to guide restoration efforts.
- Help secure funding for projects that synthesize and publish accurate historical watershed information.

3.0 LAND USE

3.1 Critical Questions

1. What are the existing land management plans in the area?
2. How do existing management plans impact watershed resources?
3. What are the population growth predictions for the subbasin?
4. What land uses are predominant throughout the subbasin?
5. How have land uses impacted watershed resources?
6. What effects do recreational activities or services have on watershed resources?

3.2 Approach

The land use section examines past and present land use activities within the Upper Deschutes Subbasin. The primary lens through which this section looks at land use information is one that reveals how land use decisions affect long-term watershed health.

Information was gathered from land use management agencies including but not limited to: The Deschutes National Forest, the Oregon Department of Forestry, the Oregon Department of Land Conservation and Development, the Bureau of Land Management, the City of Bend, the City of Redmond, and Deschutes and Jefferson Counties.

3.3 Land Management

Land ownership for the Upper Deschutes Subbasin assessment area is presented in Map 3.1. The acreage for each landowner or management agency is presented in Table 4. The primary land manager for the area is the United States Forest Service with 582,417 acres in the subbasin.

Table 4: Upper Deschutes Subbasin Land Ownership Acreages

OWNER	ACRES	PERCENT OF SUBBASIN
Bureau of Indian Affairs	71	0.01%
Bureau of Land Management	75,581	8.60%
Forest Service	582,417	66.27%
Private Individuals or Companies	215,530	24.57%
State Agencies	4,838	0.55%
Total Acres	**878,437**	100.00%

3.4 Land and River Management Plans

3.4.1 Federal Wild and Scenic Rivers

The federal Wild and Scenic Rivers Act provides for a National Wild and Scenic Rivers System that preserves the free-flowing condition of selected rivers of the United States. National Wild and Scenic rivers are selected based upon their outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, or cultural values, and it is due to these inherent values that Wild and Scenic rivers are to be protected for the benefit and enjoyment of present and future generations. The congressional declaration of policy for the Wild and Scenic Rivers Act asserts that: “the established national policy of dam and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes” (Wild and Scenic Rivers Act P.L. 90-542).

Within the federal Wild and Scenic designation, rivers are classified as either Wild, Scenic, or Recreational river areas. Wild River Areas are described as those that have unpolluted waters free from impoundments, primitive watersheds and shorelines, and are accessible only by trails; Scenic River Areas are free from impoundments and have shorelines or watersheds that are mostly primitive and undeveloped but are accessible by roads; and Recreational River Areas are easily accessible by roads or railroads, have some development along stream banks, and may have a diversion or impoundment (Wild and Scenic Rivers Act P.L. 90-542).

The sections of the Deschutes River that are designated as Wild and Scenic are almost entirely within the Deschutes National Forest. The riverine sections are: a 40.4-mile recreational river segment from Wickiup Dam to the northern border of Sunriver, an 11-mile scenic river section between the northern border of Sunriver and Lava Island, and an additional recreational river segment from Lava Island to the Bend Urban Growth Boundary (USDA 1996). A total of 147.3 miles of stream within the Upper Deschutes Subbasin were added to the Wild and Scenic Rivers program in 1988 (ODFW 1996). Map 1.3 represents the sections of the Upper Deschutes River that are designated as federally Wild and Scenic.

The Federal Wild and Scenic River Act articulates that the Upper Deschutes River Wild and Scenic River Corridor “is to be managed to protect river values and the management plan shall be coordinated with resource management planning for affected adjacent Federal lands (USDA 1996). Rivers can be added to the Wild and Scenic River System in one of two ways: after research by a federal agency rivers can be designated by Congress, or they can be recommended by a state and subsequently designated by the Secretary of the Interior (Bastasch 1998).

3.4.2 State Scenic Waterway

A state ballot initiative in 1970 first established the Oregon Scenic Waterway Act with 496 free-flowing miles of six rivers included. The scenic waterway area includes the river and its shoreline and all tributaries within a quarter mile. The program is intended to protect the free-flowing character of designated rivers for fish, wildlife, and recreation. The segments of the Deschutes River that have been designated as state scenic waterways are located from Little Lava Lake downstream to Crane Prairie Reservoir, from the gaging station below Wickiup Dam to General Patch Bridge, from Harper Bridge to the Central Oregon Irrigation District's diversion, from Sawyer Park to Tumalo State Park, and from Deschutes Market Road Bridge to Lake Billy Chinook (excluding the Cline Falls hydroelectric facility). Rivers can be added to the system either by the Governor, the Legislature, or by a voters' ballot initiative. Most of the State Scenic Waterway segments of the Deschutes were added to the system by the Oregon governor or Legislature. Only two segments of the Deschutes, from Little Lava Lake to Crane Prairie and from Bend's southern urban growth boundary to Central Oregon Irrigation District's diversion, were added to the State Scenic Waterway program through the ballot initiative process in 1988 (USDA 1996).

Oregon's State Scenic Waterways law (ORS 390.805-390.925) declares that the citizens of Oregon believe that many free-flowing rivers, Waldo Lake, and the lands adjacent to these areas possess outstanding scenic, fish, wildlife, geological, botanical, historic, archeological, and outdoor recreation values of present and future benefit to the public. The policy also asserts that any construction of dams or other impoundment facilities must correspond with policies that would simultaneously preserve the natural setting and water quality of Waldo Lake and selected rivers. Specifically, the Scenic Waterways Act declares recreation, fish, and wildlife as the highest and best water uses in scenic waterways (ORS 390. 835 (1)). In the Oregon Supreme Court case *Diack vs. City of Portland,* the court reinforced the strength of the act by ruling that before authorizing a diversion of water within a scenic waterway the Oregon Water Resources Commission must find that the requirements of the Scenic Waterways Act will still be met (ODFW 1996). The Oregon Parks and Recreation Department (PRD) is responsible for the state's scenic waterway program.

The State Scenic Waterway designation refers to areas of the Deschutes including the river and the ¼ mile riparian zone on either side of the river. The sections of the Upper Deschutes that have been classified as State Scenic Waterways are designated as either Community River Areas in recognition of close private development, or Recreational River Areas which have easy access for usage of the area (USDA 1996). These areas have been distinguished as State Scenic Waterway reaches in order to identify and apply appropriate management plans for sections of the river that have differing needs and attributes. The management and administration of each segment is directed toward protecting and enhancing the aesthetic, fish and wildlife, scientific, and recreation features contributing to the special attributes of each area. Map 1.3 represents the sections of the Upper Deschutes River that are designated as State Scenic Waterways.

3.4.3 Upper Deschutes Resource Management Plan

The Bureau of Land Management is currently in the process of creating, developing, and eventually implementing the Upper Deschutes Resource Management Plan and Environmental Impact Statement for approximately 885,883 acres of public and private land. The planning area includes two separate blocks of land: the northern block extends roughly from the town of Sisters east to Prineville Reservoir, and Lake Billy Chinook south to Pine Mountain and the City of Bend on the southern end. The southern planning block encompasses the entire La Pine area.

The Upper Deschutes Resource Management Plan will be the result of a collaborative planning framework including BLM and other agency decision makers, an interagency interdisciplinary team, a public advisory committee, public advisory subcommittees, and issue teams composed of members representative of stakeholders and interest groups. The timeline for the Management Plan follows the process prescribed by the National Environmental Policy Act (NEPA). The schedule for the products of the planning process is as follows:

- Analysis of the Management Situation . . . . *Summer 2001*
- Draft Environmental Impact Statement . . . . *Fall 2002*
- Final Environmental Impact Statement
  and Proposed Management Plan . . . . *Summer 2003*
- Record of Decision and Final Management Plan . . .*Winter 2003*

The published Analysis of the Management Situation (AMS) summarizes the existing conditions, explains the need for revising the previous Brothers/La Pine Resource Management Plan (1989), and proposes a range of management opportunities. The AMS is the preliminary document that presents the biological, physical, social, and economic factors that could be affected by the proposed Upper Deschutes Resource Management Plan (UDRMP). The issues that will be addressed in the UDRMP are land ownership, transportation and access, land uses, ecosystem health and diversity, recreation, special management areas, archeological resources, public health and safety, and socio-economic issues.

3.4.4 The Upper Deschutes River Subbasin Fish Management Plan

The Oregon Department of Fish and Wildlife (ODFW) and the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWS) worked with a Public Advisory Committee and a Technical Advisory Committee to develop the Upper Deschutes River Subbasin Fish Management Plan. The Management Plan was written in an effort directed toward effectively managing the upper 132 miles of the Deschutes River and its tributaries and lakes within the Upper Deschutes River subbasin. The specific objectives of the plan are to set fish management direction within areas including acquiring habitat, developing angling regulations, and stocking fish.

3.4.5 Northwest Forest Plan

The Northwest Forest Plan is a federal management plan for late-successional and old-growth forest related species within the range of the northern spotted owl. The goals of the Northwest Forest Plan are to protect and enhance habitat for late-successional or old-growth forest related species by setting standards and guidelines for the effective management of allocated land (Attachment A- NWFP Record of Decision, A-1). The Standards and Guidelines for the Northwest Forest Plan outline methods for establishing and applying an ecosystem approach to forest management as a means to "maintain a healthy forest ecosystem with habitat that will support populations of native species, including protection for riparian areas and waters; and maintain a sustainable supply of timber and other forest products that will help maintain the stability of local and regional economies on a predictable and long-term basis" (Standards and Guidelines A-1).

3.4.6 Interior Columbia Basin Ecosystem Management Project

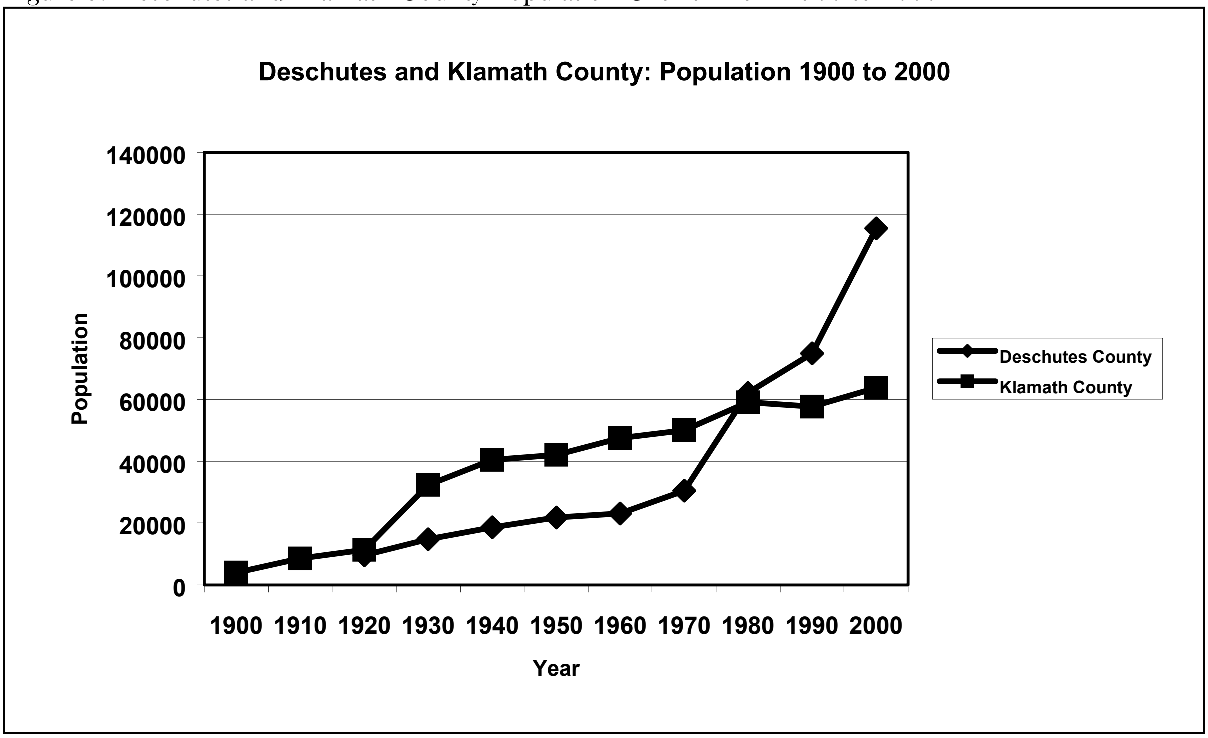
The Forest Service and the Bureau of Land Management initiated the Interior Columbia Basin Ecosystem Management Project (ICBEMP) as a response to President Clinton's direction in 1993. Its ultimate goal is to use an interagency ecosystem-based management strategy to address and respond to resource issues without subdividing ecosystems or watersheds. Alternative S2 of the ICBEMP "focuses on restoring and maintaining ecosystems across the project area and providing for social economic needs of people, while reducing short-and long-term risks to natural resources from human and natural disturbances." ICBEMP provides strategies for restoring forest health, rangelands, and aquatic-riparian ecosystems in the project area. The project also takes steps to attempt to recover plant and animal species, avoid listing future species, and provide a defined level of goods and services from BLM and Forest Service land (USDA 1996).

3.5 Population Growth and Trends

The Upper Deschutes Subbasin is primarily composed of land within Deschutes County. However, on the north and south ends of the subbasin there are also portions of Jefferson and Klamath Counties included within the area. Population trends have included growth throughout all counties of the subbasin, with the primary increases occurring in Deschutes County. Deschutes has been the fastest growing county in Oregon since 1989. Between 1990 and 2000, Deschutes County increased by over 40,000 residents (Deschutes County 2003). According to data prepared by the Population Research Center at Portland State University, this is an increase of almost 54%, which is the highest percent change in population of all Oregon counties between 1990 and 2000 (Deschutes County 2003).

The Deschutes County Community Development Department (DCCDD) asserts that almost 90% of the county population growth between 1990 and 2000 was due to individuals and families moving into the area and not directly linked to a change in the level of "natural increase" or births over deaths. This means that the rapid growth of the past decade has been primarily driven by national and broader regional factors rather than local land use conditions and costs. Central Oregon has been and continues to be a very pleasant place for people to migrate to in order to live, work, and retire (Deschutes County 2003). The Population Distribution map (Map 3.2) depicts the 2000 census population densities per square mile for the Upper Deschutes Subbasin. Data from the U.S. Census and the Portland State University Population Research Center shows that Deschutes County grew 53.9% from a population of 74,958 in 1990 to 115,367 people in 2000. This growth was the result of 4,713 births and a migration of 35,696 new residents to Deschutes County (Deschutes County 2003). Figure 3 displays a comparison of the population growth of Deschutes and Klamath Counties between the years 1900 and 2000.

Figure 3: Deschutes and Klamath County Population Growth from 1900 to 2000



Source: Watershed Professionals Network 2002

3.5.1 Future Projections

A division of the Department of Administrative Services, the Oregon Office of Economic Analysis (OEA) is a state agency that released a draft population forecast for the entire state as well as for each of the 36 counties in Oregon. The OEA is the main population and employment forecasting unit for the state. Table 5 lists the population growth estimates they calculated for Deschutes County for the next 22 years.

Table 5: Oregon Office of Economic Analysis Draft Population Forecast

Oregon Office of Economic Analysis Population Forecast	
Year	Deschutes County Population
2000	116,600
2005	134,397
2010	151,635
2015	171,167
2020	192,329
2025	209,919
Source: OEA February 2003 Report	

The Deschutes County planning staff joined with the planning staff from the cities of Bend, Redmond, and Sisters to develop their own coordinated population forecast for Deschutes County and for each jurisdiction within the county. Table 6 lists the population predictions for Bend, Redmond, and Sisters as well as for non-urban county areas and Deschutes County as a whole.

Table 6: Population Forecast for Deschutes County

Deschutes County 2002 Coordinated Population Forecast*					
Year	Bend UGB	Redmond UGB	Sisters UGB**	Non-Urban County	Total County
2000	52,800	15,505	1,100	48,283	117,688
2005	67,180	21,582	1,556	53,564	143,882
2010	76,211	27,873	2,200	60,619	166,903
2015	84,123	34,795	2,757	67,427	189,101
2020	93,712	41,051	3,394	73,447	211,604
2025	102,750	47,169	4,167	77,134	231,220

Source: Deschutes County Coordinated Population Forecast Final Report February 2003

**At the time of print, the 2002 forecast was in an appeal process. However, verbal confirmation on the estimated figures was obtained from the long range planner's office.*

***Sisters' UGB is outside of the boundaries of the Upper Deschutes Subbasin study area. The population estimates for Sisters contribute to the total county estimates and provide a point of comparison for growth forecasts.*

The main difference between the OEA and the DCCDD population forecasts is in the level of growth between 2000 and 2010. DCCDD explains this difference by asserting that, due to the recent nationwide recession and sluggish economy, the OEA expects the rate of growth in Deschutes County in the next few years to be significantly less than the growth rates experienced in the 1990's, while the local forecast looks more closely at strong regional housing and employment trends and therefore expects continued strong growth rates for the area to continue (Deschutes County 2003).

3.6 Land Use Industries

Portions of the subbasin that are managed by U.S. Bureau of Land Management and the U.S. Forest Service support the resource uses of grazing, logging, and recreation. Within the Deschutes National Forest, there is an estimated total carrying capacity of 35,000 Animal Unit Months (AUM's). Due to a relatively consistent demand for livestock grazing, most of the cattle allotments are used each year (USFS 1990).

While agriculture currently plays a relatively small role in employment and earnings contributions within the Upper Deschutes Subbasin, it plays a rather large role on the stage of water resources and use. The Upper Deschutes area has a water storage capacity of approximately 250,00 acre-feet that is used almost entirely for irrigation purposes outside the subbasin. Of the irrigated crops that use waters of the Upper Deschutes, forage crops such as alfalfa and other hay make up the highest percentage of the total acreage. Cereal crop types including barley, oats, and wheat make up the next largest irrigated crop followed by peppermint and spearmint (Environmental Defense Fund et al. 1995).

Since the 1980's, extraction industries in the subbasin have been slowing down a bit. The two major lumber mills in the area, Brooks-Scanlon and Shevlin-Hixon were both closed by 1994. Recently, recreation and tourism has been evolving as one of the area's leading industries. According to the Oregon Employment Department, the principal industries within Deschutes County are lumber, agriculture, and tourism (Oregon Economic and Community Development Department 2003). Map 3.2 represents the current distribution of land use zoning within the subbasin as defined by the Oregon Department of Land Conservation and Development (DLCD). As the administrative arm of the Land Conservation and Development Commission, the DLCD is a small state agency that administers all land use planning statutes and policies within the statewide planning goals.

The diversity of the natural features within the Upper Deschutes Subbasin invites a wide range of tourism and recreation opportunities including: river rafting, fly fishing, golfing, hiking, backpacking, skiing, mountain biking, and rock climbing. Communities and businesses have been responding to the shift in natural resource availability. Recreation-based tourism has been steadily increasing for the past decade and the City of Bend has responded to this trend by supporting and growing recreation-oriented services. 55% of the jobs in Bend are within the retail and services sector (Bend Chamber of Commerce 2002). Mt Bachelor, a ski resort located in the western part of the subbasin saw 475,303 visitors during the 1999-2000 season. In January of 2002, Mt. Bachelor was the third largest employer for the city of Bend with 825 employees and Sunriver Resort was the fourth with 770 employees for the same year (Oregon Economic & Community Development Department 2003). There are over 25 golf courses within the Upper Deschutes Subbasin that draw thousands of visitors per year to the area (Loy 2001).

State and federal agencies have also been responding to the shift in the use and application of Central Oregon's natural resources. The Forest Service and the Bureau of Land Management are beginning to manage forest resources less for resource extraction and more for recreation purposes (Loy 2001). In 1999, two state parks within the subbasin, Tumalo and The Cove Palisades, had approximately 175,000 and 750,000 visitors respectively (Loy 2001). An increase in the recreational use of watershed resources has corresponded with an increased need for roads, recreational access, transportation infrastructure, and public facilities. As almost 70% of the subbasin acreage is managed by the Forest Service, the greatest impacts from increased recreation have fallen on this agency. The Deschutes National Forest sees and attends to 8 million visitors per year (Deschutes and Ochoco Forest 2002). Playing a substantial role in contributing to both the economy and the impacts within the subbasin, the high number of annual visitors to Deschutes National Forest lands indicates the rising popularity of outdoor recreation activities within the area.

In the higher elevation areas within the subbasin, there are a number of different recreation locations and opportunities. Located adjacent to the Cascade Lakes Highway, Browns and Wickiup sub-watersheds see high levels of concentrated recreation use in the summer. There are nine developed campgrounds in the areas of Wickiup Reservoir and North and South Twin Lakes, with a total of 235 overnight campsites and three day use sites. Data on these sites indicates an increase of usage of 35% between 1987 and 1997 (Beyer 1997). There are 140 dispersed camping sites in areas near Wickiup Reservoir and the Deschutes River. Many fishing guide services operate in the area angling for rainbow trout, eastern brook trout, brown trout, kokanee, coho salmon, largemouth bass, brown bullhead, and mountain whitefish (Beyer 1997).

Table 7 corresponds to the data from the Oregon Department of Land Conservation and Development presented in Map 3.2, reflecting the acres and percentage of the Upper Deschutes Subbasin used or allocated for land uses including: urban, rural residential, rural service center, rural industrial, agriculture, forestry, Indian reservation, natural resource, parks and recreation, or open water. The names for each land use designation are determined by the Oregon Department of Land Conservation and Development.

Table 7: Land Use Industries in the Upper Deschutes Subbasin

Land Use Acres and Percentage of Subbasin

Land Use	Acres	Percent of Subbasin
Agriculture	171,262	19.50%
Forestry	586,262	66.74%
Indian Reservation	123	0.01%
Natural Resource	43,709	4.98%
Park and Recreation	12,824	1.46%
Rural Industrial	290	0.03%
Rural Residential	33,243	3.78%
Rural Service Center	511	0.06%
Urban	28,626	3.26%
Water	1,587	0.18%
Total Acres	878,437	100.00%

3.7 Impacts on Watershed Resources

Central Oregon has historically been economically dependent on the timber industry. In order to facilitate the transportation of logs down the Upper Deschutes River, the timber industry removed much of the naturally occurring large woody material was removed from the river channel between where Wickiup Reservoir is currently located to ½ mile above Benham Falls. The lack of large woody material along the river during the early part of the 20th century contributed to a lack of resistance to erosion along the stream banks (USDA 1996). Although the emphasis on timber in the subbasin has been dwindling as the resource itself dwindles, the timber industry still holds a substantial position in the subbasin.

There has been no specific analysis of forest service roads in the Upper Deschutes Subbasin as a contributor of sediment into the Deschutes River system (Rife 2003); however, roads have been associated with an assortment of negative effects on aquatic resources. Including disruption of basin hydrology and increased chronic and acute sedimentation, erosion and sediment analyses in other areas have revealed the impacts of roads on watershed resources, especially in riparian areas (Beschta et. al 1995). In order to reduce the potential for erosion and thereby improve riparian ecosystem health and limit the amount of soil entering the river, the Upper Deschutes Wild and Scenic River Record of Decision and Final Environmental Impact Statement recommends road closures in riparian areas.

Agriculture plays a large role in the use of water resources. The Upper Deschutes area has a water storage capacity of approximately 250,00 acre-feet that is used almost entirely for irrigation purposes outside the subbasin. As the subbasin population rapidly grows, so too grows the impact from increasing water demands and water use. The diversion of stream flow from the Deschutes for irrigation purposes has reduced instream water for other beneficial uses including fish and aquatic life, recreation, and aesthetic quality.

The many golf courses in the subbasin vary in their use of watershed resources, but the average water use for each golf course is approximately 700,000 to one million gallons per day. The exact daily water usage is dependent upon the amount of acreage for each golf course. Most courses in the area rely on well water from privately owned wells (Prowell 2003). As groundwater and surface water are hydrologically linked throughout the Upper Deschutes Subbasin (please see groundwater and surface water sections), the use of wells as a source of water is synonymous with the use of surface water.

As recreation increases in popularity throughout the subbasin, so too does the impact on watershed resources and overall watershed health. The high number of visitors to the Deschutes National Forest as well as to other recreation destinations in the subbasin indicates that recreation will play a substantial role in the growth of the subbasin. Increased usage of forested or riparian areas leads to increased impact on the vegetation, soils, habitats, and water quality within those areas. One example of this is occurring in many of the dispersed camping sites are near the river. They currently experience degradation of vegetation, an increase in soil compaction, and sanitation problems (Beyer 1997).

3.8 Data Gaps

- The watershed impacts from private land management and private land use and are not well documented.
- The potential impacts that a rapid shift from a resource-based economy to a tourism/recreation-based economy will have on the watershed resources of the Upper Deschutes Subbasin are not well understood.

3.9 Key Findings

- Deschutes has been the fastest growing county in Oregon since 1989. Almost 90% of the county population growth between 1990 and 2000 was due to new individuals and families moving into the area. The new residents moving to the area are frequently unfamiliar with the specific watershed issues, history, and concerns of the Upper Deschutes Subbasin.
- One of the most distinctive characteristics drawing growth to the subbasin is the Deschutes River system and its aquatic life. The health of the river will continue to be threatened by the growth that is drawn to it unless proactive steps to protect watershed resources are taken by community members, resource agencies, landowners, and regulators.
- Rapid population growth is the most challenging issue facing the Upper Deschutes Subbasin. All resource and land managers must take the brisk rate of growth into consideration when choosing and prioritizing projects in the area.
- The rapid growth in urban centers will impact watershed resources in cities as well as in downstream rural areas.
- Outdoor recreation and natural resource-based tourism are rapidly growing to be some of the primary industries providing jobs and attracting both visitors and new residents to the area.
- As the combined social and economic base in the area shifts from a focus on resource-based industries such as timber and agriculture to an emphasis on outdoor recreation and urban services, there are increasing conflicts in water and resource allocation.
- The Upper Deschutes Wild and Scenic River Management Plan and the Upper Deschutes Subbasin Fish Management Plan are data rich and comprehensive management plans that provide accurate water quality, fish, and fish habitat information for resource managers to use when choosing, prioritizing, and coordinating watershed enhancement projects.

3.10 Recommendations

- Promote awareness about the impact of past, present, and future land use decisions on watershed resources.

- Respond to the rapid influx of new residents to the area by implementing outreach programs that raise awareness among community members about watershed health and current watershed concerns such as water quantity and water quality for fish, wildlife, and human use. Use outreach programs to apply citizen involvement toward monitoring watershed and stream health conditions.
- Present watershed resource information at public gatherings. As a way to raise community awareness about watershed issues, support existing outreach activities and programs such as Riverfest, the Kokannee Karnival, and Salmon Watch.
- Collaborate with recreation-based organizations and companies to foster the informed use of watershed resources; thereby reducing negative impacts on the watershed during recreation activities.
- Work with policy makers to promote a watershed-based understanding of urban issues.
- Initiate and support projects that promote the objectives for preserving fish, wildlife, and watershed resources as articulated within the Upper Deschutes Wild and Scenic River Management Plan and the Upper Deschutes Subbasin Fish Management Plan.

4.0 UPLAND VEGETATION

4.1 Critical Questions

1. What were the historic vegetation types in the subbasin?
2. What are the dominant cover types?
3. What is the condition of current upland vegetation?
4. Are there any upland plant communities of special status or concern?
5. What are the noxious weed species in the watershed?
6. What effects are invasive plant species having on native vegetation?

4.2 Approach

This section identifies the role that upland vegetation plays in the larger picture of watershed health. The land use activities that occur on the upslope portions of a watershed are inherently linked to the water quality and health of all downslope river and stream systems. Understanding the characteristics of the vegetation currently and historically present in the upslope portions of the Upper Deschutes Subbasin can help land managers better understand the conditions of the watershed system as a whole.

The two following types of vegetation analysis exist within the Upper Deschutes Subbasin:

- Oregon GAP Analysis Project (GAP)
- Deschutes National Forest Plant Association Groups (PAG)

Both Oregon GAP vegetation and PAG data will be presented in this assessment. A discussion of the details of each type of analysis will accompany maps of the GAP and PAG vegetation found within the subbasin (Maps 4.1 and 4.2). Additionally, a map of historic vegetation of the Upper Deschutes Subbasin will be included (see Map 4.3)

A detailed examination of noxious weeds will be presented. Just as elsewhere across the west, noxious weed species have been encroaching on the native vegetation and soils of the Upper Deschutes Subbasin throughout the past century. Noxious weeds have a distinctly negative impact on the health of the soils, native vegetation, and overall watershed quality. The identification and eradication of noxious weeds in the Upper Deschutes Subbasin is becoming a priority for local land and resource managers. Accompanying a list of the most prevalent noxious weeds in the area, the human impacts or activities that have affected or modified the vegetation pattern in the subbasin will be discussed.

4.3 Upland Vegetation

The physical connection between tributaries and the river, uplands and riparian zones in the Upper Deschutes Subbasin is referred to as *connectivity.* Due to the connectivity within the Upper Deschutes Subbasin, upslope areas greatly influence the character of associated stream systems and riparian plant communities. Terrestrial areas often occupy 95 percent or more of a watershed area; therefore, even subtle changes in the hydrogeomorphic processes of upslope areas can significantly affect riparian systems, channels, and downstream areas. It is on the hillsides that climate, vegetation, geology, topography, and soils interact to affect precipitation, snowmelt patterns, and groundwater recharge that will ultimately produce stream flow. These factors vary dramatically from watershed to watershed, ultimately leading to a variety of different pathways by which water will take to arrive at a channel (Beschta 1998).

Healthy upland vegetation and hydrologically functional terrestrial ecosystems capture water in the soil system, store water in the soil profile, and slowly release hillslope water to the stream network through subsurface pathways. In order to ensure that the hydrologic health of an upslope ecosystem is not negatively altered or impacted, it is important to maintain high levels of plant biomass, a diversity of plant species, and high amounts of litter cover on the soil surface. Foresters, range managers, farmers, and other resource managers should strive to not increase sediment production during land management activities. Increased sediment production and movement from upland areas can overwhelm the character and integrity of even a relatively intact and functional riparian and aquatic ecosystem (Beschta 1998.)

4.4 Historic Vegetation

Early explorers were documented to remark about the type of species and condition of the vegetation as they traveled through the area either on foot or horseback. One such observation was noted by the Williamson and Abbott railroad survey conducted during the spring, summer, and fall of 1853. In the survey, Abbott wrote:

We found yellow pine still abundant, forming by far the most constant feature in the vegetation of our route from Pit River to the Columbia. Near or distant, trees of this kind were always in sight; and in the arid and really desert regions of the interior basin we made whole days marches in forests of yellow pine, of which the absolute monotony was unbroken either by other forms of vegetation, or the stillness by the flutter of a bird, or the hum of an insect. The volcanic soil, as light and dry as ashes, into which the feet of our horses sank to the fetlock, produces almost nothing but an apparent unending succession of large trees of P. ponderosa (DNF 1998).

Historic vegetation patterns in the areas of the dry mixed conifer plant association group (PAG) (see Map 4.2) were shaped by frequent fire activity. Most stands were previously open in appearance and were dominated by ponderosa pine. Subbasin stands usually only reached a true mixed conifer composition on higher elevation buttes and north facing slopes that received greater amounts of precipitation. Cascade Reserve Forest Survey notes of 1903 describe this PAG as having no commercial value-- containing large amounts of yellow pine and minor amounts of lodgepole pine. Other species including mountain hemlock were also noted (DNF 1998).

In some areas throughout the subbasin, huckleberry, laurel, manzanita, willow, and alder were documented. Survey notes also refer to large areas of fire-scarred trees. Spruce, heavy pine, and chaparral are noted on Cultus Mountain from a cadastral survey in 1882-1884. Vegetation patterns of the dry mixed conifer PAG are significantly outside the historic range of variation in terms of seral stage, canopy closure, and patch size and distribution (O'Neil and Lee 1995).

The vegetation types historically present in the subbasin are listed in Table 8. The ponderosa pine forest and woodland vegetation type historically dominated the subbasin with 277,603 acres and the lodgepole pine forest and woodland vegetation type had the second highest distribution with 210,628 acres. The historic distribution of Upper Deschutes Subbasin vegetation is represented in Map 4.3.

Table 8: Vegetation Historically Present in the Upper Deschutes Subbasin

UPPER DESCHUTES SUBBASIN HISTORIC VEGETATION

Class Name	Acres	Percent of Total
Lava Flow	14,118	1.61%
Alpine Fell-Snowfields	6,677	0.76%
Open Water	16,669	1.90%
True Fir-Hemlock Montane Forest	90,878	10.35%
Lodgepole Pine Forest and Woodland	210,628	23.98%
Subalpine Fir-Lodgepole Pine Montane Conifer	18,836	2.14%
Ponderosa Pine Forest and Woodland	277,603	31.60%
Douglas Fir Dominant-Mixed Conifer Forest	10,413	1.19%
Western Juniper Woodland	149,198	16.98%
Manzanita Dominant Shrubland	3,282	0.37%
Sagebrush Steppe	31,652	3.60%
Big Sagebrush Shrubland	48,482	5.52%
Total Acres	**878,437**	100.00%

4.5 Current Vegetation Cover Types

Vegetation characteristics and types can be identified and mapped in a variety of different ways. In the Upper Deschutes Subbasin, there are two primary means for understanding vegetation characteristics. Both Oregon GAP vegetation and Deschutes National Forest Plant Association Groups (PAG) data will be presented in this assessment. A discussion of the details of each type of analysis will accompany maps of the GAP and PAG vegetation found within the subbasin (Maps 4.1 and 4.2).

4.5.1 Oregon GAP Vegetation

The Oregon Gap Analysis Project (GAP) is a cooperative endeavor that began in 1988 and is currently managed by the Oregon Natural Heritage Program (ONHP). With tremendous support and assistance from the Oregon Department of Fish and Wildlife, Oregon State University, the Environmental Protection Agency, the Defenders of Wildlife, the Nature Conservancy, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey, the project is designed to identify the current level of biodiversity in a given area. Specifically, GAP analysis examines how native animal species and natural vegetation communities are currently represented in the combination of conserved land areas. The species and habitat that are not adequately represented constitute conservation "gaps." The ultimate objectives of GAP analysis are the following:

- Map actual land cover, historical land cover types, land stewardship, and land management status.
- Map the predicted distribution of those terrestrial vertebrates that spend any substantial part of their life history in the project area and for which adequate distributional habitats, associations, and mapped habitats are available.
- Document the representation of natural land cover types and animal species in areas managed for the long-term maintenance of biodiversity.
- Identify land cover types and terrestrial vertebrate species that are either **not** represented or are under-represented in areas managed for long-term maintenance of biodiversity; i.e. "gaps" in biodiversity.
- Make all GAP Project information available to the public and those charged with land use research, policy, planning, and management.
- Build institutional cooperation in the application of this information to state and regional management activities (ONHP 1999).

The GAP vegetation classes for the Upper Deschutes Subbasin are delineated in Map 4.1 and are presented in Table 9. Both the total acres for each class and the percentage of the total subbasin area for each class are listed.   True Fir-Hemlock Montane Forest, Western Juniper Woodland, Ponderosa Pine Forest and Woodland, and Douglas Fir Dominant-Mixed Conifer Forest are the most prevalent vegetation types in the subbasin.

Table 9: GAP Vegetation Types in the Upper Deschutes Subbasin

UPPER DESCHUTES SUBBASIN GAP VEGETATION

Class Name	Acres	Percent of Total
Agriculture	40,086	4.56%
Alpine Fell-Snowfields	5,505	0.63%
Big Sagebrush Shrubland	11,257	1.29%
Douglas Fir Dominant-Mixed Conifer Forest	89,137	10.15%
Grass-shrub-sapling or Regenerating young forest	19,969	2.27%
Lava Flow	15,812	1.81%
Lodgepole Pine Forest and Woodland	32,625	3.71%
Manzanita Dominant Shrubland	3,228	0.37%
Mountain Hemlock Montane Forest	37,684	4.29%
NWI Estuarine Emergent	507	0.06%
NWI Palustrine Emergent	3,812	0.43%
NWI Palustrine Shrubland	7,099	0.81%
Open Water	30,421	3.46%
Ponderosa Pine Dominant Mixed Conifer Forest	2,659	0.30%
Ponderosa Pine Forest and Woodland	101,841	11.59%
Ponderosa Pine-W. Juniper Woodland	1,425	0.16%
Ponderosa-Lodgepole Pine on Pumice	75,478	8.59%
Sagebrush Steppe	12,530	1.43%
Subalpine Fir-Lodgepole Pine Montane Conifer	43,678	4.97%
Subalpine Grassland	992	0.11%
Subalpine Parkland	13,741	1.56%
True Fir-Hemlock Montane Forest	156,227	17.78%
Urban	19,040	2.17%
Western Juniper Woodland	153,685	17.50%
Total Acres	**878,437**	100.00%

4.5.2 Deschutes National Forest Plant Association (PAG)

On the Deschutes National Forest, fire exclusion and the selective harvesting strategies that have occurred over the last century have led to an alteration in forest structure, density, and species composition. Prior to fire suppression, frequent smaller natural fires actively shaped plant species and the structural composition of forests. Forest communities that were once somewhat stable and more fire resistant have been replaced by thick, multi-storied stands of fire susceptible species (Hann 1996).

The Deschutes National Forest developed a vegetation cover type map from the 1988 ISAT image data interpreted by Pacific Meridian Resources. These data are classified by size, stand structure, and crown cover classes. The Forest GIS staff and silviculturist combined these classes to allow for a more manageable data set to support their Landscape Assessment Plan (LAP). This classification is termed Plant Association Group (PAG).

The Plant Association Groups found on the Deschutes National Forest are represented in Map 4.2 and the acres for each group are listed in Table 10. The PAG appearing in the highest percentage of acres on the Deschutes National Forest is Ponderosa Pine Dry at 20.01% of the total forest area.

Table 10: Acreage for Plant Association Groups on the Deschutes National Forest

DESCHUTES NATIONAL FOREST PLANT ASSOCIATION GROUPS

Plant Association Group	Acres	Percent of Total
ALPINE DRY	93	0.01%
ALPINE MEADOW	3,444	0.55%
ALPINE SHRUB	140	0.02%
CINDER	1,929	0.31%
GLACIER	233	0.04%
JUNIPER WOODLANDS	1,319	0.21%
LAVA	14,325	2.27%
LODGEPOLE PINE DRY	98,226	15.55%
LODGEPOLE PINE WET	47,320	7.49%
MEADOW	1,235	0.20%
MIXED CONIFER DRY	112,475	17.80%
MIXED CONIFER WET	44,172	6.99%
MOUNTAIN HEMLOCK DRY	109,003	17.24%
NOT DESCHUTES	235	0.04%
PONDEROSA PINE DRY	126,428	20.01%
PONDEROSA PINE WET	31,892	5.05%
QUARRY	45	0.01%
RIPARIAN	6,484	1.03%
ROCK	4,214	0.67%
WATER	28,046	4.44%
WHITE BARK PINE DRY	14	0.001%
XERIC SHRUBLANDS	524	0.08%
Total DNF* Acreage	**631,798**	100.00%

**DNF= Deschutes National Forest*

Currently, the upper elevation portions of the subbasin are dominated by medium and large tree early seral stages that fall consistently below the amount expected given historic processes. This shift is believed to be the result of a combination of fire suppression and selection harvesting. This type of land management is causing the historic relatively open large tree dominated forest to be replaced by dense, multi-storied forest structures dominated by smaller trees. The few remaining old growth stands of ponderosa pine in the Upper Deschutes Subbasin provide valuable food and shelter for wildlife such as: the northern spotted owl, marten, woodducks, white-headed woodpecker, and ash-throated flycatchers.

Combined with density and structural changes, species composition has shifted from being dominated by fire climax species of large ponderosa pines to predominantly shade tolerant true fir species. This shift has caused an increase in overall canopy cover above that which occurred historically. This shift is primarily the result of fire suppression and selection harvesting (O'Neil and Lee 1995).

4.5.3 Insects and Disease Agents

The shift in vegetation structure, density, and species composition throughout the Upper Deschutes Subbasin has lead to a general increase in overall susceptibility to insect and disease agents.

4.5.3.1 Armillaria Root Disease

The proliferation of selection cutting throughout the Deschutes National Forest has provided a large food base for the root decay fungus *Armillaria ostoye.* As a result, this root disease also known as "shoestring root rot" is spreading rapidly throughout parts of the Cascade Lakes area and is able to successfully attack and kill live trees more readily than it could have under historic conditions (O'Neil and Lee 1995).

Armillaria root disease is caused by fungi which live as parasites on living host tissue or as saprophytes on dead woody material (Williams 1989). Living as parasites, the fungi cause root and butt rot, wood decay, uprooting, growth reduction, and tree killing. The fungi infect and kill weakened trees that have been impacted by competition, other pests, or climatic factors. Normal tree harvesting does not reduce or prevent infection and may in fact aggravate the problem (USDA 2003). The U.S. Department of Agriculture has made the following suggestions for managing the detrimental impact of the fungus in commercial forests:

- Reforest stands with a mixture of species ecologically suited to the site.
- Maintain vigorous tree growth without causing undue damage to soils.
- Minimize stress to crop trees.
- Reduce the food source by uprooting infected or susceptible root systems and stumps (Williams 1989).

On most infected conifers in the subbasin, the lower stems are slightly enlarged and they release heavy amounts of resin. Infected portions of the roots often become encrusted with resin, soil, and occasionally fungal tissue (Williams 1989).

4.5.3.2 Pine Beetles

Increased forest densities in the Upper Deschutes Subbasin are also causing increased susceptibility to bark beetle attack. Large pines are highly vulnerable to attack by the western pine beetle, *Dendroctonus brevicomis,* in overstocked conditions such as those found in the Cascade Lakes watershed. Group killing of trees is common in dense, overstocked stands of pure, even-aged young timber (DeMars 1997). Most often, the beetles breed in and kill trees that have been weakened by lightening, fire, or mechanical injury.

Lodgepole pine is also highly susceptible to attack by the mountain pine beetle, *Dendroctonus ponderosae.* The four primary hosts for the mountain pine beetle are lodgepole, ponderosa, sugar, and white pines (Amman 1997). Mountain pine beetle attack of the plant associations in the Cultus Lake area has been increasing in intensity over the past five years. In addition, beetle attacks around Lava Lake, Elk Lake, and Hosmer Lake have been increasing over the last several years (O'Neil and Lee 1995).

The mountain pine beetle begins attacking most pine species on the lower 15 feet of the trunk. Female beetles bore into the tree and create pitch tubes through the bark. The beetles carry blue-staining fungi into the tree and eventually the sapwood begins to discolor. The first sign of beetle-caused mortality is often faded or discolored foliage. From several months to a year after the beetles attack, the needles change from green to yellowish green to red, and finally to a rusty brown color (Amman 1997).

4.5.3.3 Western Dwarf Mistletoe

The present structural character of some of the dense stands throughout the Upper Deschutes Subbasin has, in many cases, enhanced the ability of western dwarf mistletoe, *arceuthobium campylopodum* to spread and intensify. Western dwarf mistletoe, also called ponderosa pine dwarf mistletoe, has ponderosa, Jeffrey, and knobcone pines as its principal hosts and lodgepole pine as a secondary host.

Near the southern end of the subbasin, east of Crane Prairie Reservoir, Lookout Mountain has a mistletoe infected ponderosa pine overstory that shelters heavily stocked understories of young ponderosa pine. These infected overstories have been and will likely continue to contribute to the infection of the new pines that are growing in. This is a condition that did not exist historically and has been created by land management activities (O'Neil and Lee 1995).

4.5.4 Special Status Plants

Table 11 lists the Sensitive Plant Species present within the Deschutes National Forest. As lands managed by the Deschutes National Forest Service comprise almost 70% of the Upper Deschutes Subbasin, this sensitive plant species list will serve as representative for the purposes of the subbasin assessment. There may be other sensitive plant species present throughout other parts of the subbasin, but no list of other species was known or available. All of the sensitive plant species documented for the Deschutes National Forest, including upland and riparian plants, are included in Table 11.

Table 11: 1999 Deschutes National Forest Sensitive Plant Species List

Scientific name	Common name	Occurrence
Agoseris elata	tall agoseris	Suspected
Arnica viscosa	Shasta arnica	Documented
Artemisia ludoviciana ssp. *Estesii*	Estes' artemisia	Documented
Aster gormanii	Gorman's aster	Suspected
Astragalus peckii	Peck's milk-vetch	Suspected
Botrychium pumicola	pumice grape-fern	Documented
Calamagrostis breweri	brewer's reedgrass	Suspected
Calochortus longebarbatus var. *longebarbatus*	Long-bearded Mariposa lily	Suspected
Carex hystricina	porcupine sedge	Suspected
Carex livida	Pale sedge	Suspected
Castilleja chlorotica	green-tinged paintbrush	Documented
Cicuta bulbifera	Bulb-bearing water-hemlock	Suspected*
Collomia mazama	Mt. Mazama collomia	Suspected*
Gentiana newberryi var. *newberryi*	Newberry's gentian	Documented
Lobelia dortmanna	water lobelia	Suspected
Lycopodiella inundata	bog club-moss	Suspected
Lycopodium complanatum	ground cedar	Suspected
Ophioglossum pusillum	adder's-tongue	Suspected
Penstemon peckii	Peck's penstemon	Suspected
Pilularia americana	American pillwort	Suspected
Rorippa columbiae	Columbia cress	Suspected*
Scheuchzeria palustris var. *americana*	Scheuchzeria	Documented
Scirpus subterminalis	water clubrush	Suspected
Thelypodium howellii ssp. *Howellii*	Howell's thelypody	Suspected

Definition of codes: Suspected = Suspected to occur on the district; Documented = Documented to occur on the district; Suspected* means that more information is needed to determine if the species is suspected to occur in the district.
Source: Deschutes National Forest Service 1999

A 1993 biological survey along the Upper Deschutes River found the Federal Category 2 Candidate *Artemisia ludoviciana estesii,* or estes wormwood. As a candidate species more study is needed for the final listing of estes wormwood under the Endangered Species Act. Estes wormwood was found in very small numbers at three spots in the upper margins of the marshy zone along the river corridor of the Upper Deschutes. Before the 1993 survey, *Artemisia ludoviciana estesii* was known to exist only downstream on the Deschutes between Cline Falls and Lower Bridge.

4.5.5 Actinorhizal Shrubs

The Central Oregon Interagency Ecology Program has identified actinorhizal plant species *Purshia tridentate,* or bitterbrush, and *Ceanothus velutinus,* snowbrush, as playing critical ecological roles in the health and maintenance of the Upper Deschutes Subbasin. The term "actinorhiza" refers to the bacteria *Frankia,* which is an actinomycete, and to the root location of nitrogen-fixing nodules (Wall 2000). In general, actinorhizal plants are a diverse group of trees and shrubs that have the ability to form a nitrogen-fixing symbiosis with *Frankia* bacteria. Many actinorhizal species play important ecological roles in the habitats where they occur. These roles include:

- Increasing fertility in agricultural areas,
- Preventing soil erosion,
- Contributing to soil development by adding substantial nitrogen back into disturbed soils,
- Providing important wildlife browse species,
- Contributing to plant community succession following fire or other disturbance (Paschke 1997).

Representing eight families, there are more than 200 actinorhizal plant species (Berry 1994). The species that are most predominantly found in the Upper Deschutes Subbasin are bitterbrush and snowbrush. Bitterbrush is a fire sensitive, dominant understory shrub found throughout much of the east-side ponderosa pine and Jeffrey pine forests of Oregon and California. Bitterbrush is a member of the *Rosaceae* family and its distribution extends from southern British Columbia to New Mexico. It is found throughout much of the Upper Deschutes Subbasin, it is an upland species that is known to be present in close proximity to riparian zones. Bitterbrush is intolerant to fire and is of very high value for wildlife browsing (Klemmedson 1979). It, along with snowbrush is in fact one of the most important wildlife browse species in the western United States (Paschke 1997, Riegel 2002). Snowbrush is a member of the *Rhamnaceae* family and is also widespread in the western states and can flourish in a variety of habitats. It is a fast-growing, seral species capable of seed germination, even after several hundred years of dormancy (Conrad 1985) and is fire tolerant with rapid resprouting typical after fire. The nitrogen fixing ability is well characterized for pure stands of snowbrush. Studies from shrub fields on the slopes of the Cascade Range in Oregon estimate high annual rates of fixation (Binkley 1982).

Biological nitrogen fixation (BNF) is vital to the terrestrial nitrogen budget, balancing nitrogen losses providing nitrogen for organism growth and maintenance. Both snowbrush and bitterbrush were found to be efficient nitrogen fixers in the ponderosa pine understory of Central Oregon; about 85% of their total plant nitrogen was derived from fixation. Snowbrush fixed nitrogen at a substantial annual rate at sites with low to moderate shrub cover. Although this rate is lower than that reported for snowbrush shrub fields on the western slope of the Cascades, it would provide enough nitrogen to offset losses from periodic prescribed fire or harvesting (Busse 2000). Rates of nitrogen fixation by snowbrush and bitterbrush were quantified at three study sites on the eastern slope of the central Oregon Cascades, along a north-south transect of the Deschutes National Forest (Busse 2000).

Actinorhizal plants serve numerous functions in forest ecosystems such as the Upper Deschutes Subbasin. They are valued for wildlife browse and habitat, erosion control, improvement of soil quality and nitrogen fixation. Although, in contrast, they also compete for site resources and contribute to fuel loading and potential wildfire danger, their presence plays a critical role in the composition of the ecoregions of the Upper Deschutes. Future work is needed to identify an appropriate balance between all contributing factors in the management of these understory shrubs (Busse 2000, Riegel 2002).

4.5.6 Noxious Weeds

The term "noxious weed" is a combination of "noxious," which is a legal classification rather than an ecological term, and "weed," which is loosely used to refer to non-native plant species. Agencies may designate a plant species as a noxious weed if it directly or indirectly imposes ecological or economic threats to agriculture, fish, wildlife, public health, and native vegetation. Noxious weeds can impart extreme biological degradation or ecological and economic destruction. Noxious weeds come to North America as stowaways, usually from Europe, Asia, or Russia. Their seeds are often inadvertently mixed in shipments of grain. Once they arrive here, plants and their seeds are transported around the country by birds, wind currents, deer, rivers, horses, vehicles, or trains.

Over 4,000 exotic plants are now recognized as botanical "pests" by the U.S. government. Ninety of these exotics are federally listed noxious weeds, and dozens more are listed by various states. Noxious weeds infest about 100 million acres of North America. They debilitate more than 3 million acres each year, invading an estimated 6 million square miles of Forest Service and BLM lands every day. Noxious weeds have claimed approximately 7 million acres of national parks. Due to the absence of predators or natural checks and balances on these foreign plants, noxious weeds multiply unhindered (Rocky Mountain Elk Foundation 2000*)*.

From 1994 to 1997 the number of known noxious weed sites on the Deschutes National Forest grew from 44 sites to 215 known sites (Grenier, DNF briefing paper, unpublished).

Noxious weeds are expanding their range throughout the Upper Deschutes Subbasin, and five species are of particular concern to land and resource managers in the area: knapweed, dalmation toadflax, bull thistle, mullein, and scotch broom. These noxious weed species play a negative role in impacting the overall health of the subbasin by:

- Crowding out native vegetation,
- Reducing water infiltration and soil nutrients,
- Increasing soil erosion,
- Intoxicating other plants, animals, and humans,
- Ruining grazing areas, recreation sites, and state parks.

4.5.6.1 Spotted and Diffuse Knapweed

Two noxious weeds, spotted knapweed (*Centaurea maculosa)* and diffuse knapweed (*Centaurea diffusa)* came to the United States from central Europe. Purportedly, they were mixed in with shipments of alfalfa and clover seeds. Spotted knapweed has a pink or purple flower head with dark spots on the bud. Diffuse knapweed has pink, purple, or white flower heads with light spots on the bud. Knapweed has effectively crowded out native plants throughout Central Oregon. It can most often be found along dry riverbanks, roads, irrigation ditches, and rangelands. With a narrow taproot that does not hold arid desert soil in place, knapweed actually exacerbates and increases the erosive potential of soil. Knapweed is also known to displace desirable forage. One plant can produce up to 25,000 seeds per year and each seed can remain viable in the soil for up to eight years.

4.5.6.2 Dalmation Toadflax

Dalmation toadflax (*Linaria dalmatica)* is a perennial plant that can grow to be up to four feet tall. It has small, alternate heart-shaped clasping leaves and bright yellow flowers which bloom from June through October. One plant can produce up to 500,000 seeds per year and the seeds remain viable for up to 10 years. Toadflax reproduces by both seeds and rhizomes, so manually pulling the plant is not effective unless the entire root is removed. If any part of the root remains, another plant will sprout from the broken root. Toadflax reproduces aggressively and displaces native vegetation and forage for deer.

4.5.6.3 Bull Thistle

Bull thistle *(Cirsium vulgare)* comes from Eurasia and is not edible by livestock due to its prickliness. In its second year of growth Bull thistle produces flowers that create and disseminate high quantities of seeds. Its large number of seeds make bull thistle difficult to control (Deschutes and Ochoco National Forest 2002).

4.5.6.4 Mullein

Mullein *(Verbascum thapsis)* originated in Asia and came to the United States through Europe. Mullein is inedible due to its wooly leaves and it displaces other native plants that are suitable for livestock browse. During its first year, mullein grows as small rosettes close to the ground. In its second year of growth, mullein produces flowers on long stems that, akin to bull thistle, cast large numbers of seeds (Deschutes and Ochoco National Forest 2002).

4.5.6.5 Scotch Broom

Scotch broom *(Cytisus scoparius)* has been found in old timber sale units in the Deschutes National Forest. With its bright yellow flowers, scotch broom was introduced as an ornamental to the Pacific coast. Now scotch broom is a widespread noxious weed. The shrub is very aggressive in seed dispersal and growth and it has become a problem in pastures, forests, and wasteland. Scotch broom is a member of the pea family and, at maturity, the pods can burst open and eject the seeds a substantial distance away from the plant. The seeds remain viable in the soil for many years (Whitson et al. 1999).

Table 12 presents the current list of noxious weeds known or suspected to occur in Deschutes County. The list is subdivided into three sections; List A denotes species that, due to small infestations, are high priority sites for treatment, List B includes species that are abundant and are therefore a high priority for strategic treatment and control to prevent further spreading, and List C presents species that are not a high priority for immediate treatment.

Table 12: Deschutes County Noxious Weed List

List A: A weed **that occurs in small enough infestations** to make eradication containment possible; or is not known to occur, but its presence in neighboring counties make future occurrence in Deschutes County seem imminent. List A also includes weeds that are actively managed by neighboring counties due to agricultural concerns (e.g. Jefferson County produces carrots and wild carrot poses a threat to agricultural carrot crops). List A weeds are **high priority sites for treatment**

Management Goal: eradicate or contain populations; prevent List A weeds from becoming more abundant and moving onto the B List.

Species Name	Common Name
Cardaria spp.	Whitetop, hoary cress
Carduus nutans	Musk thistle
Centaurea pratensis	Meadow knapweed
Centaurea repens	Russian knapweed
Centaurea solstitialis	Yellow starthistle
Centaurea virgata	squarrose knapweed
Chondrilla juncea	Rush skeletonweed
Cynoglossum officinale	Common houndstongue
Daucus carota	Wild carrot
Euphorbia esula	Leafy spurge
Hydrilla verticiliata	Hydrilla
Isatis tinctoria	Dyer's woad
Lepidium latifolium	Perennial pepperweed
Lythrum salicaria	Purple loosestrife
Onopordum acanthium	Scotch thistle
Peganum harma1a	African rue
Potentilla recta	Sulfur cinquefoil
Salvia aethiopis	Mediterranean sage
Senecio jacobaea	Tansy ragwort
Solanum rostratum	Buffaloburr
Taeniatherum caput-medusae	Medusahead rye
Tamarix ramosissima	Tamarisk, Salt cedar
Tribulus terrestris	Puncturevine

List B: A weed that is **abundant** in Deschutes County and **of area of concern** because it causes economic and ecological losses. Eradication of List B weeds in the county may not be realistic; however, they are still **high priority species for strategic treatment and control top prevent further spread.**

Management Goal: Control List B 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.

Species Name	Common Name
Centaurea diffusa	Diffuse knapweed
Centaurea maculosa	Spotted knapweed
Cirsium arvense	Canada thistle
Conium maculatum	Poison hemlock

Cytisus scoparius	Scotch broom
Kochia scoparia	Kochia
Linaria dalmatica	Dalmation toadflax
Linaria vulgaris	Yellow toadflax or "butter and eggs"
Ranunculus testiculatus	Bur buttercup
Salsola iberica (= S. kali)	Russian thistle
List C: A weed that is abundant. These 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.	
Management Goal; Treat List C species as 'incidental' and control on a case-by-case basis.	
Species Name	**Common Name**
Agropyron repens	Quackgrass
Cicuta maculate	Water hemlock
Cirsium vulgare	Bull thistle
Convolvulus arvensis	Field bindweed
Conyza Canadensis	Horseweed
Cuscuta spp.	Dodder
Elodea densa	South American waterweed
Hypericum perforatum	St. Johnswort
Iva axillaries	Poverty stump weed
Melilotus alba	White sweetclover
Melilotus officinalis	Yellow sweetclover
Melilotus indica	Indian sweetclover
Verbascum thapsis	Common mullein
Xanthium spinosum	Spiny cocklebur

Source: Deschutes County

4.5.6.6 Human Impact

Noxious weeds are often spread by human movement and travel. Roads, recreation sites, and old timber sales units account for almost 75% of the known sites in the Deschutes National Forest (Grenier 2002). Most of the noxious weed infestations in the Deschutes Forest are found along highly traveled roads. Spotted knapweed, for example, is a "road runner" that is dispersed primarily by vehicles and people along road corridors. Bend and Redmond are both "hubs" for spotted knapweed; knapweed now dominates nearly every disturbed location in the city of Bend. It is found in vacant lots, along irrigation canals, and along roads.

Just as humans contribute to the perpetuation of noxious weeds, we also can actively make choices that eradicate or at least slow down their spreading. Some effective methods for controlling and containing invasive weeds include:

- Identify invasive plant species and report them to land and wildlife managers.
- Carry only weed-seed-free forage for pack animals in the backcountry.
- Thoroughly clean vehicles and livestock before entering the forest or wilderness areas
- Avoid traveling through weed-infested areas.
- Pull and pack out weeds in sealed containers.
- Do not pick and transport any pretty unidentified flowers as they might be noxious weeds.

- Choose landscaping materials and plants carefully. Make sure there are no invasive plants in your own yard.
- Get involved in local weed-control projects.

4.6 Data Gaps

- There is currently no systematic method for mapping the distribution and abundance of noxious weeds on all lands in the assessment area.
- There have been no comprehensive maps created that present current or historic noxious weed populations across management boundaries. The noxious weed maps that have been assembled are not comprehensive; generally these maps include only sites that are easily accessible by roads or trails.

4.7 Key Findings

- Combined with density and structural changes, species composition of vegetation throughout the higher elevation portions of the subbasin has shifted from being dominated by fire climax species of large ponderosa pines to predominantly shade tolerant true fir species. Primarily the result of fire suppression and selection harvesting, this shift has caused an increase in overall canopy cover above that which occurred historically.
- The shift in vegetation structure, density, and species composition throughout the Upper Deschutes Subbasin has lead to a general increase in overall susceptibility to disease agents such as armillaria root disease.
- Specifically, increased forest densities are leading to a higher vulnerability to insect attack. Pines are highly vulnerable to attack by the western pine beetle in the high density conditions present throughout some parts of the subbasin.
- The remaining old growth ponderosa pine stands in the Upper Deschutes Subbasin provide valuable food and shelter for wildlife such as: the northern spotted owl, marten, woodducks, white-headed woodpecker, and ash-throated flycatchers.
- As throughout most of the Western states, noxious weeds are invading the Upper Deschutes Subbasin due to past introductions, soil disturbances, land use practices, and increased access to introduce exotic weed species to new areas. Weeds continue to crowd out native plants and exacerbate erosion problems.
- Many effective groups have formed in response to the increasing noxious weed problem in the Upper Deschutes Subbasin. Including the Deschutes County Weed Board, BLM and Deschutes National Forest weed programs, the Deschutes County Soil and Water Conservation District, From the Ground Up, and the Upper Deschutes Watershed Council, many organizations have coordinated weed pulls and have provided some limited weed mapping,

4.8 Recommendations

- Support programs that raise awareness about the impacts of the shift in vegetative species composition throughout the subbasin.
- Support efforts to combine weed data from natural resource agencies and organizations to create a comprehensive noxious weed map of the Upper Deschutes Subbasin.
- Raise awareness among local community members and landowners about the causes of weed invasions and the impacts of noxious weeds on watershed resources.
- Support and collaborate with the existing weed programs of the Deschutes National Forest, BLM, and Deschutes and Jefferson Counties to manage volunteer groups in large-scale weed pulls.
- Continue to support organized events such as Riverfest as a way to increase widespread awareness of noxious weed problems in the Upper Deschutes Subbasin.

5.0 WILDLIFE

5.1 Critical Questions

1. What are the primary mammals, birds, reptiles, and amphibians of interest in the watershed?
2. What wildlife species in the watershed have received special status or protective designations?
3. What are the wildlife habitat conditions in the subbasin?
4. Is wildlife or wildlife habitat impacted by land use patterns in the watershed?
5. What are the impacts of fire management on wildlife and wildlife habitat?

5.2 Approach

The focus of the wildlife section is to consolidate and summarize what is known about wildlife species and wildlife habitat conditions throughout the Upper Deschutes Subbasin. Wildlife and their habitat are both inherently linked to the overall health of the watershed. In addition to being valuable components and participants in an interconnected watershed system, wildlife can provide informative indicators of either watershed degradation or health. Under the Wild and Scenic Rivers Act, portions of the Upper Deschutes River have been designated as outstandingly remarkable for wildlife.

Due to space and time limitations, not every wildlife species present or suspected to be present within the assessment area will be discussed. Instead, the wildlife section will examine and emphasize wildlife species and wildlife habitat areas of special concern or interest within the context of watershed health

Information on wildlife species and wildlife habitat conditions in the Upper Deschutes Subbasin was obtained from the *Cascade Lakes Watershed Analysis* (O'Neil and Lee 1995), *Odell Watershed Analysis* (Hurlocker 1999), *Forks/Bridge Watershed Analysis* (Moscosco 1995), *Browns/Wickiup Watershed Analysis* (Beyer 1997), *The Upper Deschutes Wild and Scenic River Record of Decision and Final Environmental Impact Statement* (USDA 1996), and *The Analysis of the Management Situation for the Upper Deschutes Resource Management Plan and Environmental Impact Statement* (USDI 2001).

5.3 Special Status Wildlife

Wildlife Species of Special Concern include Threatened and Endangered species listed under the federal Endangered Species Act (ESA) in addition to those considered or under review for proposed listing. These species are regulated through the U.S. Fish and Wildlife Service. Species that are listed by the Oregon Department of Fish and Wildlife are regulated through the Oregon Fish and Wildlife Commission. The Bureau of Land Management (BLM) also has a policy for designating special status species. The BLM in

Oregon currently uses three categories for special status species and they are: Bureau Sensitive, Bureau Assessment, and Bureau Tracking. Specific habitat and location data for each species are available to land management agencies from Oregon State University's Oregon Natural Heritage Program (ONHP) (Watershed Professionals Network 2002).

The BLM has completed an Analysis of the Management Situation (AMS) for some portions of public and private land that fall within the boundaries of the Upper Deschutes Subbasin Assessment area. The BLM will use the AMS to understand the biological, physical, social, and economic components that could potentially be impacted by land management decisions. Wildlife and wildlife habitat conditions in the Upper Deschutes Subbasin can be greatly affected by land use and land management activities.

Table 13 is a list that has combined the special status wildlife species that inhabit or potentially inhabit areas within BLM lands with the proposed, endangered, threatened, sensitive, and selected wildlife species known or suspected to occur within the Deschutes National Forest. The assumption has been made that by combining the special status species lists of the BLM and the DNF, most or all of the special status species residing in the entire Upper Deschutes Subbasin will be documented.

Table 13: Special Status Wildlife Species Inhabiting or Potentially Inhabiting the Upper Deschutes Subbasin

Common Name	Scientific Name	Status
Mammals		
Canada lynx	*Lynx Canadensis*	T/R6S
Pacific fisher	*Martes pennanti pacifica*	SoC/SC
California wolverine	*Gulo gulo luteus*	SoC/T/R6S
Pygmy rabbit	*Brachylagus idahoensis*	SoC/SV
Preble's shrew	*Sorex preblei*	SoC/R6S
Fringed myotis	*Myotis thysanodes*	SoC/SV
Long-eared myotis	*Myotis evotis*	SoC/SU
Long-legged myotis	*Myotis volans*	SoC/SU
Silver-haired bat	*Lasionycteris noctivagans*	SoC/SU
Western small-footed myotis	*Myotis ciliolabrum*	SoC/SU
Townsend's big-eared bat	*Corynorhinus townsendii*	SoC/SC/R6S
Yuma myotis	*Myotis yumanensis*	SoC
California bighorn sheep	*Ovis canadensis californiana*	SoC
Amphibians		
Oregon spotted frog	*Rana pretiosa*	C/SC
Columbia spotted frog	*Rana luteiventris*	C/SU
Cascade frog	*Rana cascadae*	SoC/SV
Tailed frog	*Ascaphus truei*	SoC/SV
Northern leopard frog	*Rana pipiens*	SC

Reptiles		
Northern sagebrush lizard	*Sceloporous graciosus graciosus*	SoC/SV
Birds		
Northern bald eagle	*Haliaeetus leucocephalus*	T/T/R6S
American peregrine falcon	*Falco peregrinus anatum*	E/R6S
Northern goshawk	*Accipiter gentiles*	SoC/Sc
Ferruginous hawk	*Buteo regalis*	SoC/SC/R6S
Northern spotted owl	*Strix occidentalis caurina*	T/T/R6S
Western burrowing owl	*Athene cunicularia hypugea*	SoC/Sc
Flammulated owl	*Otus flammolus*	SC
Western sage grouse	*Centrocercus urophasianus phaios*	SoC/SV
Mountain quail	*Oreortyx pictus*	SoC/SU
White-headed woodpecker	*Picoides albolarvatus*	SoC/SC/ROD
Black-backed woodpecker	*Picoides arcticus*	SC/ROD
Three-toed woodpecker	*Picoides tridactylus*	SC
Lewis woodpecker	*Melanerpes americanus*	SoC/Sc
Sage sparrow	*Amphispiza belli*	SC
Yellow-billed cuckoo	*Coccyzus americanus*	SoC/SC
Olive-sided flycatcher	*Contopus borealis*	SoC/SV
Willow flycatcher	*Empidonax trailii*	SoC/SU
Yellow rail	*Coturnicops noveboracensis*	SoC/SC
Upland sandpiper	*Bartramia longicauda*	SoC/SC
Western Snowy Plover	*Charadrius alexandrinus nivosus*	T/R6S
American White Pelican	*Pelecanus erythrorhynchus*	SoC/R6S
Long-Billed Curlew	*Numenius americanus*	R6S
Greater Sandhill Crane	*Grus Canadensis*	SoC/R6S
Great Gray Owl	*Strix nebulosa*	ROD
Harlequin duck	*Histrionicus histrionicus*	SoC/SU

Federal Status: T= Threatened; C= Candidate; SoC= Species of Concern; R6S= USFS Region 6 Sensitive: ROD= ROD Protection Buffer

State/ODFW Status: SoC= Species of Concern; SC=Critical; SV= Vulnerable; SU= Undetermined

Source: ONHP 2001

Due to the lengthy list of special status species that are found throughout the subbasin, only the wildlife species that have been designated as federally Threatened will be discussed in detail in this assessment. Although amphibians are presented on the wildlife list of special species, they will be discussed in greater detail in the Fish and Aquatic Species section of this assessment.

5.3.1 Canada Lynx

The Canada lynx *(Lynx Canadensis)* is listed as Threatened under the Endangered Species Act (ESA). There are historical records from 1916 that indicate lynx presence approximately 35 miles west of Bend near Lava Lake. Although recent surveys have been conducted for Canada lynx on the Deschutes National Forest, there have been no confirmed sightings or hair samples found anywhere in Oregon (Watershed Professionals Network 2002). Currently, there are no specific standards or guidelines, designated Management Areas, or other requirements protecting historic or potential lynx habitat. Lynx Analysis Units (LAUs) have been developed by the Forest Service for the examination of proposed projects on the Forest lands and one LAU was identified on the Deschutes National Forest within the Three Sisters area (Watershed Professionals Network 2002).

5.3.2 Northern Spotted Owl

Northern spotted owls *(Strix occidentalis caurina)* are listed as Threatened under the ESA. These owls require mature or old-growth coniferous forests with complex structures and multiple stand layers. The population size of the species is relative to the amount and distribution of suitable habitat. Nesting, roosting, and foraging habitat for northern spotted owls is available on the Deschutes National Forest. The eastern margin of the Upper Deschutes Subbasin is reported to be the eastern extent of the owl's range. Spotted owl pairs are generally located within the mature/old growth conifer PAGs associated with the buttes or high elevation mountains of the subbasin (UDWC 2002).

The Cultus Mountain Late Successional Reserve (LSR) contains five pairs of northern spotted owls. The Cultus LSR represents one of the three important centers of owl activity on the Deschutes National Forest. Late-successional forest structure is also present in the adjacent Three Sisters Wilderness and Administratively Withdrawn lands of the Cascade Lakes Watershed. The Three Sisters Wilderness area currently maintains effective connective and dispersal habitat to the Willamette National Forest to the west and to the Sisters Ranger District to the north. Connectivity to the Sheridan LSR to the northeast is threatened by the mountain pine beetle epidemic and the existing fragmentation of the dry mixed conifer plant association group. Connectivity to the Odell LSR and the Umpqua NF in the south is in part provided by wilderness lands but is restricted by timber harvest fragmentation in the southern portion of the Cascade Lakes Watershed. Twenty-four percent or 39,840 acres of the Cascade Lakes area currently provide suitable nesting, foraging, and roosting habitat for the northern spotted owl (O' Neil and Lee 1995). Within the Upper Odell Creek, Middle Odell Creek, and Lower Odell Creek 6^{th} field watersheds that were analyzed in the Deschutes National Forest 1999 Odell Watershed Analysis, there are currently 16,556 acres of suitable nesting, roosting, and foraging owl habitat (Hurlocker 1999).

5.3.3 Northern Bald Eagle

In 1967, the northern bald eagle *(Haliaeetus leucocephalus)* was listed as a Threatened species under the ESA. On July 6, 1999 it was proposed for delisting in the conterminous states, but the bald eagle has not yet been officially delisted as a Threatened species.

Although there exists no specific documentation on historical nesting sites in the Upper Deschutes subbasin, bald eagles were most likely in the Lava Lakes area, near Davis and

Odell Lakes, and along the Deschutes River. Bald eagles were first sighted at Crane Prairie reservoir in 1968 (Anderson 1983). Common threats to bald eagles in the Upper Deschutes Subbasin include recreation, logging, shooting, pesticides, and land development. Recent bald eagle mid-winter survey data is available in the Cascade Lakes Watershed Analysis (O'Neil and Lee 1995). It is believed that some of the eagles in the area may reside year round during milder winters, while during colder winters they most likely migrate south to the Klamath marsh area (O'Neil and Lee 1995).

Since the mid-1970's, nesting season data has been collected from the Oregon Eagle Foundation Inc. The Deschutes National Forest has identified Bald Eagle Management Areas (BEMAs) that have specific requirements for maintenance and protection of eagle habitats. The majority of BEMAs are in ponderosa pine associated plant communities. Some are also in mixed conifer PAGs. In general, all of the BEMAs in the Deschutes National Forest have existing forest health concerns associated with a high basal area of understory trees stressing the overstory trees that serve as suitable habitat for eagles. Many stands also lack sufficient mid-age class ponderosa pine trees for replacement nest trees. All of the listed BEMAs include existing or historic nest sites that are adjacent to lakes and streams in the Upper Deschutes Subbasin (Watershed Professionals Network 2002). Currently, there is suitable nesting habitat for seven known pairs of eagles located at Crane Prairie Reservoir, Hosmer Lake, Lava Lake, and Benchmark Butte (O'Neil and Lee 1995).

5.3.4 Western Snowy Plover

Both historically and currently, Davis Lake and its associated wet meadows sustains high quality western snowy plover habitat. The lake's extreme water fluctuations provide excellent shorebird foraging and nesting habitat, which is ideal for western snowy plovers (Hurlocker 1999).

5.4 Wildlife Habitat Conditions

Geologic, hydrologic, and vegetative resources combine together to create and form the wildlife habitat conditions throughout the Upper Deschutes Subbasin. In the high lakes areas there is a broad range of wildlife habitat types including wet and dry lodgepole pine, wet and dry mixed conifer, and mountain hemlock. From its headwaters in the mountains at Little Lava Lake and downstream, the Deschutes River is a mixture of wet marshes, dry meadows, willow clumps, aspen clumps, alder, lodgepole pines, and ponderosa pines that create a mosaic of different habitats. Many species of wildlife require more than one habitat type. For many wildlife species, the river corridor contains a portion of their habitat needs and upland forested habitats fulfill the remaining habitat requirements (USDA 1996). The Upper Deschutes Subbasin is a conglomeration of riparian and forest habitat wildlife types that change and evolve as the Deschutes River meanders southward and then north to Lake Billy Chinook.

The higher elevation sections of the Upper Deschutes subbasin contain the 5th field watershed known as the Cascade Lakes. The Cascade Lakes watershed is composed of

Soda Creek, Quinn Creek, Elk Lake, Snow Creek, Cultus River, Cultus Creek, Deer Creek, Charlton Creek, and Crane Prairie Reservoir 6th field subwatersheds. Within the Cascade Lakes area, there is a broad and diverse range of wildlife habitats. Forested habitats include lodgepole pine, mixed conifer, and mountain hemlock. A good portion of the Cascade Lakes watershed is wilderness and unroaded. Therefore, the habitats in these areas have not been as heavily impacted by harvest activities as some other portions of the subbasin. Instead, the Cascade Lakes area has primarily been influenced by natural disturbances such as fire, wind, and insects. Areas that have been impacted by harvest activities are now heavily fragmented and have gone from a small – large tree landscape to a pole – medium tree landscape. Late-successional interior habitats are poorly connected to one another in this watershed (O'Neil and Lee 1995).

In general, the high elevation Cascade Lakes area supports a variety of wildlife and wildlife habitats. According to the Deschutes National Forest, there are over 262 species of wildlife known or suspected to utilize this watershed at some time during the year. 220 of these species will use riparian areas as their primary habitat for breeding, foraging, and resting. The quantity and quality of remaining habitat and the types of disturbances that take place will affect both current and future wildlife species and how they will use the habitat (O'Neil and Lee 1995).

On the Upper Deschutes River, the riparian areas represent less than one percent of forest habitats yet contain 128 different species identified within the Deschutes National Forest. Riparian habitat on the Upper Deschutes consists of wet and dry land near and affected by the river. Vegetation in riparian areas consists of sedges, rushes, cattails, and willows that provide food and cover for many small mammals, songbirds, waterfowl, amphibians, and reptiles (USDA 1996).

Currently, there are concentrated osprey populations around Wickiup and Crane Prairie Reservoirs. However, some birds have been displaced from the reservoirs and they may be occupying habitat along the Deschutes River and thereby increasing the number of nesting pairs between Wickiup and Fall River. Between Wickiup Reservoir and La Pine State Park there is available habitat for osprey and bald eagles. Snags and wildlife trees in the river corridor can be used by a variety of different primary and secondary cavity nesters (USDA 1996). Large ponderosa pine trees adjacent to the Deschutes River provide ideal roosting and nesting habitat; however, in this same section of river, foraging opportunities for heron, bittern, rails, and other bird species that rely on the wet habitats for prey such as frogs, salamanders, aquatic invertebrates, and aquatic insects are basically limited to the irrigation season. Additionally, the increased water turbidity that is the result of heightened flows at the beginning of the irrigation season may limit the success of fish-eating birds during their reproduction period. (See Appendix I for supplemental information on connections between turbidity and flows in the Upper Deschutes.) Affected birds might include osprey, bald eagles, kingfishers, cormorants, and mergansers (USDA 1996).

One area that has unique habitat qualities is the river corridor from Benham Falls Bridge to Lava Island Falls. In this area, the riparian area on the east side of the Deschutes is part of the Newberry National Volcanic monument. This area is dominated by the Lava Butte lava flow and wildlife habitat is characterized by occasional trees and openings that provide unique habitats for such mammalian species as pika and marmot (USDA 1996).

When combined together, riparian areas and adjacent forested uplands create succulent forage and valuable cover for wildlife. The Deschutes Land and Forest Management Plan recognizes two Key Elk Habitats near the Deschutes River. The Fall River elk area lies between Fall River and Pringle Falls. Downstream, Ryan Ranch Meadow stretches from Sunriver to the Inn of the Seventh Mountain. This area has been designated as the Ryan Ranch Key Elk Habitat Area. Ryan Ranch supports a resident herd of 75 animals in the summer and even more during the winter months. Its ongoing usefulness as suitable elk habitat has been reduced by recreation use and livestock grazing, which occurs during calving season. The cattle allotment fencing around Ryan Ranch Meadow is an obstacle to wildlife and has the potential to cause injuries to young elk (USDA 1996).

Though the river corridor consists of only a small part of the space utilized by elk, it is an important habitat ingredient due to the reliable water supply, important food sources available in wet and dry meadows, and secure calving areas in thickets and on vegetated islands surrounded by lava flows on the east side of the river. The Fall River corridor is an important area for habitat resources as well as being an important migration pathway for deer and elk moving from winter to summer range and back again (USDA 1996). Elk found along the Deschutes River winter over either in the Fall River or Ryan Ranch key habitat areas or they will travel miles and miles to winter on the west side of the Cascade Range (USDA 1996).

Forest habitat types are distributed throughout the Upper Deschutes Subbasin. There are some forest habitat types that include both wet and dry riparian vegetation. With this combination there is additional cover for species such as ruffed grouse and raccoons. Important nesting habitat is also created for species such as woodducks, heron, and bald eagles which use riparian areas for feeding but require forest trees for nesting (USDA 1996). Specifically on the Deschutes National Forest, most forest habitats are characterized by young ponderosa and thinned lodgepole pine stands combined with a few stands of old-growth ponderosa pine interspersed with dense lodgepole thickets. Old growth stands provide valuable food and shelter for marten, woodducks, white-headed woodpecker, and ash-throated flycatchers. The thickets are important sources of shelter and thermal cover for songbirds and big game. Thinned stands provide forage for towhee, kingbird, robins, and chipping sparrows (USDA 1996).

Wildlife habitat between Sunriver and the City of Bend continues to be of moderate to good quality for some aquatic and foraging species. Beaver, muskrat, and otter are found along this section although they are still impacted by fluctuations in the river level. Ponds and backwater wetlands, particularly in the area around Benham Falls, are extremely important to wildlife. More than 150 swans have been observed at one time near Benham Falls and many ducks and geese use these wetlands. Stable water levels are required in sloughs and backwater areas during the nesting season. Fluctuating water levels either flood nests or expose animals to predators. For example, the draining of Ryan Ranch

Meadow and the construction of a dike between the meadow and the river dried out the area and substantially altered the habitat. The meadow can no longer support sandhill cranes, great blue herons, rails, or waterfowl (USDA 1996).

5.5 Human Impact

Wet and dry meadows and wet marshes all provide important habitat for wildlife. Tetherow Meadows is a series of wet and dry meadows along the Deschutes River. Large portions of the vegetation in Tetherow Meadow are currently damaged by off road vehicles, which compact soils and substantially increase erosion problems. In the Tetherow Meadow area, wet marshes have become established on oxbows where the river channel has meandered. Sedges and cattails have grown and established themselves on deposited sediments. Vegetation in some of these marshes is trampled in the summer by fishermen (USDA 1996).

The yearly fluctuation of river levels as they are currently managed on the Upper Deschutes limits the productivity of wet riparian habitat for wildlife. In the winter months, the flows below Wickiup Reservoir are reduced from natural levels of approximately 1200 cubic feet per second (cfs) down to an average of 30 cfs. The dewatering of the wet riparian vegetation community eliminates an essential element for many riparian inhabiting wildlife species and consequently leads to the death of many animals ranging from micro-organisms to amphibians. One example of the negative effects of dewatering occurs when the dens of bank dwellers are dry and thereby vulnerable to predators, thus increasing the mortality rate of species such as beaver and muskrat. Conversely, the increased flows in the spring create additional problems when river levels flood waterfowl nests and beaver and muskrat dens. Predators may also be negatively affected if the springtime flooding of nests and dens reduce the amount of prey. The habitat problems in riparian areas are most significant between Wickiup Reservoir and La Pine State Park. It is in this section of the Deschutes that the yearly flow fluctuation of the river is the most extreme (USDA 1996).

Marten and ruffed grouse have been historically present between Wickiup Reservoir and La Pine State Park, but critical nesting habitat for ruffed grouse has been diminished due to timber harvest and recreation impacts. As marten utilize mature and old growth stands along the Deschutes River, any removal of these trees reduces suitable habitat (USDA 1996).

There are currently five developed recreation sites in addition to multiple dispersed camping sites between Wickiup Reservoir and La Pine State Park. In these areas, campers and recreationists have destroyed or degraded a high percentage of both riparian and upland habitat vegetation. Regeneration of vegetation in some is not likely or even possible due to heavily compacted soils. Additionally, human presence in habitat areas can flush wildlife away from foraging sites, forcing animals to expend energy needed for other survival activities. Tetherow Meadow is an example of the problems created by human disturbance in wildlife habitats. Due to human disturbance in the summer, elk stay away from the river during the day, moving in to drink and forage at dawn and late in the evenings. Roads compound this problem as open road density can lead to substandard habitat effectiveness for mammals and birds (USDA 1996).

According to the Wild and Scenic River Record of Decision, areas where there has been private property development along the Upper Deschutes River have been fragmented and much of the available forested habitat for wildlife has been eliminated. The area was historically a major migration corridor for deer, but development has forced deer to seek out other sections of the river and riparian areas (USDA 1996). Specifically, between La Pine State Park and Sunriver there is a large percentage of private land where there are increased human and wildlife conflicts. Wildlife habitat in this area has been heavily modified, reduced, and even eliminated due to land development. Travel corridors and habitat cover have been decreased and the probability for wildlife harassment from domestic pets is increased. Livestock grazing in Besson Meadows has reduced riparian vegetation, consequently displacing many small mammals and songbirds previously found there. Fluctuations in river flow during critical nesting times and the harassment of young by motorboats are two specific problems for waterfowl that are identified by the Upper Deschutes Wild and Scenic River Record of Decision (USDA 1996).

5.6 Data Gaps

- The condition of wildlife habitat and the extent and degree of habitat loss due to land management, development, and urban growth is generally understood by resource agencies and organizations, but is poorly documented or conveyed to the public.
- Many species of wildlife are migratory and they therefore winter in areas outside of the subbasin. Since land use and land management practices in critical habitat areas and in migration corridors influence these species viability, it is difficult for land managers in the Upper Deschutes Subbasin to document or quantify the effects of human impact on wildlife populations.
- The habitat relationships for nongame species such as reptiles, amphibians, bats, rodents, and passerine birds are not well understood.

5.7 Key Findings

- There are two key elk habitats adjacent to the Upper Deschutes River. The Fall River elk area is between Fall River and Pringle Falls, and the Ryan Ranch Elk Habitat extends from Sunriver to the Inn at the Seventh Mountain resort.
- The Upper Deschutes river corridor provides a reliable water supply, important food sources, and secure calving areas for elk.
- The low winter water flows in the Upper Deschutes River between Wickiup and the City of Bend and the low summer water flows in the Middle Deschutes area just downstream from Bend reduces the water quality and the quality of fish habitat in those areas. As the flows have an impact on the fishery, they also play a role in limiting the food source for wildlife such as river otters, mink, bald eagles, osprey, and kingfishers that feed on fish.

- Songbirds and big game find important shelter and thermal cover in dense lodgepole thickets along the Upper Deschutes River.
- Towhee, kingbirds, robins, and chipping sparrows seek forage in thinned stands of young ponderosa and lodgepole pines.

5.8 Recommendations

- Raise awareness and provide landowners with information about the impacts on elk habitat conditions between Fall River and the Inn at the Seventh Mountain.
- Research connections between flows in the Upper and Middle Deschutes River and the fish populations as a food source for osprey, eagles, and other wildlife in those sections.
- Raise awareness among community members and recreation user groups about the connections between water quantity and quality, fisheries, and wildlife.

6.0 FIRE

6.1 Critical Questions

1. What role does fire play in western forests such as those found in the Upper Deschutes Subbasin?
2. What are the historic fire frequencies in the watershed?
3. Do the historic fire frequencies differ from current fire frequencies?
4. Are there forest fuel load issues in the subbasin?
5. What impacts do fire suppression and fire management activities have on watershed resources?

6.2 Approach

The purpose of this section is to present historic and current fire conditions and fire frequencies in the subbasin. This section will attempt to understand what forest fuel load issues are present in the subbasin and how fire management activities have affected watershed resources.

The data and information for the fire section primarily comes from Deschutes National Forest watershed analyses, *Wildland Fire in Ecosystems: Effects of Fire on Flora* (USDA 2000)*, Integrated Natural Fuels Management Strategy* (DNF 1998), and the *Central Oregon Fire Management Services Fire Management Plan* (BLM 2002).

6.3 Fire Frequency

The frequency of fires in a given area is primarily defined by the climate, ignition sources, and fuels found within that area. Climate remains relatively static over time, fuels are increased or modified by fire suppression and timber harvest, and ignition sources change with alterations in human use (O'Neil and Lee 1995). Recently, there has been a substantial increase in the numbers of severe wildfires in ponderosa pine type forests due to a combination of heavy forest floor fuels and dense sapling thickets acting as ladder fuels, combined with the normally dry climate, frequent lightening and human-caused ignitions (Arno 1996; Williams 1995).

In western forests consisting primarily of ponderosa pines, fires were historically frequent, with mean intervals between 5 and 30 years in most areas (USDA 2000). During historic periods of high fire frequency, fuels were primarily herbaceous material and forest floor litter. After fire suppression became common and highly effective, forest floor duff and living fuels such as shrubs and conifers increased. Historic fires were frequent low-intensity surface fires that occurred in open stands of trees whose lower branches were then killed by fire. Later, with the introduction of fire suppression activities, accumulated fuels supported higher intensity fires. Higher intensity fires bring with them increased burn severity which can lead to greater mortality among plants and soil organisms. The significance of these forest floor fuels is sometimes overlooked. The upper litter layer and part of the middle layer that includes the fermentation process provide the highly combustible surface fuel for flaming combustion and extreme fire behavior during severe fire weather. The lower part of the fermentation layer and the humus layer make up the ground fuel that generally burns as glowing combustion (USDA 2000).

The Upper Deschutes Subbasin is a landscape impacted by a wide range of fire regimes. Classified from I to V, the frequency of fires in fire regimes range from zero up to 200+ years. All five fire regimes are found occurring in the Upper Deschutes Subbasin. Table 14 presents the current regime, frequency, severity, and percent of area for the fires in the subbasin.

Table 14: Fire Regimes Found Throughout the Upper Deschutes Subbasin

Regime	Frequency	Severity	%of Area
I	0-35 years	low	26%
II	0-35 years	high	9%
III	35-100+ years	mixed	27%
IV	35-100+ years	high	24%
V	200+ years	high	15%

Source: The Upper Deschutes Basin Fire Learning Network 2003

There are three condition classes that are used to characterize the degree of departure from historical fire regimes. Class one conditions are referred to as *Maintenance* condition classes and they describe areas that have fire regimes that are within or near the historical range. 32% of the Upper Deschutes Subbasin falls within the condition class one. Class two and three conditions are referred to as *Restoration* condition classes and their fire regimes have been moderately to severely altered from their historical range. 68% of the Upper Deschutes Subbasin is in the restoration condition class (UDBFLN 2003).

6.3.1 Pre-1900

Before 1900, semiarid forest types like the pine communities found in the Upper Deschutes Subbasin experienced frequent fires due to the presence of highly combustible leaf litter, a wealth of dry herbaceous vegetation, and a long season of dry warm weather. Forests had an open, park-like appearance, dominated by large old trees that were more fire-resistant than younger stands. This predominance of widely-spaced larger trees was the result of a pattern of frequent, low-intensity fires (Agee 1990). Dendrochronology evidence from a 600-year-old pine tree at Pringle Butte indicates that approximately 139 fires occurred between 1362 and 1900, with a mean fire interval of 4 years and an average of 11 years for individual plots (Youngblood and Riegel 1999).

According to documents from the Department of Agriculture and early settlers' journals, shrubs, understory trees, forest litter, woody undergrowth and downed logs were historically sparse in the subbasin. It is claimed that travelers often rode horseback or pulled wagons for miles through these forests, unhampered by undergrowth or the need to cut trails. Shrubs were naturally suppressed by the combination of frequent fires and vigorous overstory competition. It has been estimated that in most stands, duff depth probably averaged only about half an inch. The majority of large overstory trees survived each fire, while many of the understory trees were killed. The overstory trees were comprised of the most fire resistant species including: ponderosa pine, Jeffrey pine, and western larch. In large areas of the subbasin where ponderosa pine is seral, it has maintained dominance due to its resistance to the frequent fires (USDA 2000).

Historically, lightening was the major ignition source of large fires in the area, with some additional influence by Native Americans. Intentional fires were used by the Paiute tribes as a way to retain open areas for deer habitat and simultaneously maintain the productivity of huckleberries and root crops (Robbins 1997). These intentional fires combined with natural lightening-caused fires to produce the historic open ponderosa and lodgepole forests of the subbasin. The weather patterns throughout the subbasin frequently brought thunderstorms in July and August. The storms came at a relatively high frequency for the Deschutes Basin. Specifically, the upper elevation Cascade Lakes watershed is in a high lightening frequency zone (O'Neil and Lee 1995).

6.3.2 Post-1900

The structure and composition of forests east of the crest of the Cascade Range has changed substantially in the past hundred years. Most of the changes in eastside forests can be attributed to two specific management activities: effective fire exclusion strategies initiated with the creation of the Forest Reserves in 1905, and widespread selective timber harvesting that began with the first European settlers and continued to accelerate after World War II. According to *Wildland Fire in Ecosystems,* reduced fire began in the late 1800s as a result of the following activities:

- Relocation of Native Americans and disruption of their traditional burning practices.
- Fuel removal by heavy and extensive livestock grazing.
- Disruption of fuel continuity on the landscape due to irrigation, cultivation, and development.
- Adoption of "fire exclusion" as a management policy (USDA 2000).

Fire exclusion has increased understory tree density in low elevation forests, modified stand composition to include more lodgepole pine and grand fir, and increased the risk for stand replacing fires. Old-growth ponderosa pines now represent only 3 to 5 percent of historic levels (Karr and Chu 1994). The interruption of frequent natural burning in these forests has led to notable changes in the subbasin. Nonlethal fire has decreased while lethal fire has increased.

Fire suppression and exclusion has led to the establishment of dense conifer understories, adding as many as 200 to 2,000 small trees per acre beneath old growth stands or increasing thickets to 2,000 to 10,000 small trees per acre where the overstory was removed. Throughout the subbasin, there are areas where the ponderosa pine type has received inadequate thinning treatments and overstocked conditions have resulted in slow growth and poor vigor for most trees. Poor growth makes even dominant trees highly vulnerable to mortality from bark beetles, defoliating insects, diseases such as dwarf mistletoe, and various root rots. Inadequate vigor and growth in tree stands can be accompanied by a limited representation of nonflowering herbs and shrubs, which leads to a loss of natural biodiversity and a decrease in forage for wildlife (USDA 2000).

Currently, the majority of fire occurrences in the higher elevation parts of the subbasin are the result of lightening or recreational use and are usually suppressed when they are less than one-quarter of an acre in size. Additional road building and recreation activities in the Cascade Lakes area have increased the number of ignition sources by approximately 50% since the 1950’s. Forest service locations that are of particular concern include the undeveloped camping areas along the Deschutes River, Cultus Lake, and Crane Prairie Reservoir. These areas have unusually high fire occurrence rates. Fire occurs within the protection areas of the Deschutes National Forest at a mean number of 168.8 fires a year. Studies conducted on data collected from the years 1971 to 1994 show that 95% of the time, the Deschutes Forest experiences between 136 to 201 fires per year (O’Neil and Lee 1995).

The Upper Deschutes Subbasin has had many wildland fires in the 1990’s. A total of 1,395 fires were managed in that 10-year period. About 40% of these were human caused, lightning accounted for approximately 57%, and the remaining fires were of undetermined cause. Thirty fires exceeded 100 acres in size, and 10 were larger than 1000 acres. The total area burned in this decade was 43,695 acres, for an annual expected acres burned value of about 4,400 acres (BLM 2002).

Between the years 1990 and 2002, the lowest amount of acres burned in wildland fires on the Deschutes National Forest was 102 in 1997. In 1996, the largest number of acres, 27,511, burned on forest service land. 3,552 acres burned in wildland fires in 1990 and 22,687 acres burned on the Deschutes National Forest in 2002 (Stewart 2003).

6.3.3 Fire Frequency by Ecoregion

Table 15 presents the ecoregions present in the Upper Deschutes Subbasin. The total acres for each ecoregion and the percentage of presence in the subbasin are listed. The fire characteristics common for each ecoregion are described. There is no current published data on the fire characteristics for the Deschutes River Valley ecoregion. The distributions, locations, and sizes for the ecoregions in the Upper Deschutes Subbasin are depicted in Map 4.4.

Table 15: Fire Frequency Characteristics by Ecoregion

ECOREGIONS	FIRE CHARACTERISTICS	ACRES	% of Total Subbasin
Cascade Crest Montane Forest	Infrequent fires.	191,622	21.81%
Cascade Crest Subalpine/Alpine	Infrequent fires result in low survival of dominant tree species. Fire intensity depends on weather conditions.	26,910	3.06%
Cold Wet Pumice Plateau Basins	Fire suppression reduces fire frequency.	83,883	9.55%
Deschutes River Valley	No current data.	216,165	24.61%
Ponderosa Pine/Bitterbrush Woodland	Fire suppression has altered stand density and composition. Fire frequency in ponderosa pine forests was historically from 8 to 20 years.	173,119	19.71%
Pumice Plateau Forest	Frequent, low-intensity fires common in ponderosa pine forest in the past, current fire suppression efforts have reduced frequency.	186,738	21.26%
TOTAL ACRES		**878,437**	100.00%

Source: Watershed Professionals Network 2001

21.81% of the Upper Deschutes Subbasin is a part of the Cascade Crest Montane Forest ecoregion. Although there are generally infrequent fires in this ecoregion, repeated fire in the Cascade Crest Montane Forest can create semi-permanent big huckleberry communities in mountain hemlock forest areas (Watershed Professionals Network 2001).

Comprising 21.26% of the subbasin, the Pumice Plateau Forest ecoregion contains lodgepole pines whose canopy closure is dependent on the fire cycle. Lodgepole pine forests have a 40-50 year fire cycle. While newly burned areas are open, the young forests that eventually develop as a result of a fire become very dense. As they mature, these lodgepole forests will thin out and burn again. The mountain pine beetle also influences forest crown closure and fire fuel loads in this ecoregion. Historically, ponderosa pine forests in this ecoregion had less or equal to 30% crown closure. Fire frequency in ponderosa pine forests was historically from 8 to 20 years (Watershed Professionals Network 2001).

The Ponderosa Pine/Bitterbrush Woodland ecoregion makes up 19.71% of the subbasin. Historically, frequent, low-intensity fires were common in ponderosa pine forests, but recent fire suppression has reduced fire frequency (Watershed Professionals Network 2001).

6.3.4 Recent Fires

The Bridge Creek fire started on July 24, 1979 and burned a total of 3,400 acres. The fire burned all vegetation within its boundaries (Moscosco 1995). The intensity and heat of the fire caused the pumice soils to become hydrophobic. Immediately following the fire, there were structures placed on slopes to prevent the downhill flow of sediment into Tumalo and Bridge Creeks. The Forest Service designated the fire as a catastrophic event due to the size, impact on soils, and impact on vegetation (Moscosco 1995).

The Awbrey Hall fire burned 22 homes in the Bend area on August 4, 1990. The fire destroyed property valued at approximately 9 million dollars. Although the fire was determined to have been caused by arson, the climate and the sagebrush fuels that contributed to its rapid spreading are similar to the conditions that exacerbate wildfires.

The Four Corners fire began on July 24, 1994 due to lightening. The fire was burning in a mature stand of dense lodgepole pine. The tree mortality from the mountain pine beetle was 50-60 percent. Most of the dead trees were standing with the needles attached. According to the 1997 Browns/Wickiup Watershed Analysis "ground fuels in the area were relatively light, but there were large patches of heavy down fuels and ladder fuels where mortality had occurred several years previous to 1994. The fire made the transition from ground to crown fire within 30 minutes. The fire displayed extreme fire behavior characteristics: horizontal roll vortices, 150-300 foot flame lengths, and long-range spotting. Crane Prairie Campground and Resort were evacuated. Eventually, the fire was contained the next day after burning approximately 1,500 acres (Beyer 1997).

The Davis Fire began near East Davis Lake campground and consumed more than 21,000 acres in the southern corner of the Upper Deschutes Subbasin in July 2003. The fire cost approximately $4.6 million to contain and required about 1,000 firefighters and support personnel. The Central Oregon Arson Task Force determined that the fire was human-caused. A post-fire team, the Burned Area Emergency Rehabilitation Team, including a hydrologist, soil scientist, archeologist, and civil engineer was assembled to coordinate a reconstruction plan for the area.

6.4 Impacts of Fire on the Upper Deschutes Subbasin Landscape

Fire has always played a valuable role in the subbasin. The intensity of fire throughout the area ranges broadly from low in western portions of the subbasin to higher intensity in areas farther east. The Deschutes National Forest has analyzed the processes and impacts of fire within different watersheds and reached the following conclusions for the high elevation sections of the subbasin known as the Cascade Lakes Watershed. The 1995 *Cascade Lakes Watershed Analysis* states:

- Historic fire records indicate that fire occurrence was moderate and that fires affected larger areas in the Cascade Lakes Watershed. Burned acreage appeared to be greater (30,000 acres historic vs. 2,000 acres current).

- Currently, the landscape has a fire return interval that is prescribed by management rather than by fuels and the environment. Fire suppression has resulted in extended fire return intervals and increased fire intensities, particularly in the moderate fire regime.
- The fire return interval in all but the high elevation portion of the watershed has been lengthened significantly. There are significant increases in the fuel accumulations in the wet and dry lodgepole pine PAGs. The combination of large dense patches and heavy fuel accumulations in the central lodgepole and eastern dry mixed conifer PAG contribute to increasing potential for catastrophic fire events across the landscape.
- Hazards associated with fire suppression have increased to the point where much larger areas can be expected to burn, especially in the dry lodgepole stands. Additionally, suppression cost can be expected to increase.
- Changes in fire occurrence patterns indicate that the distribution and frequency of fire on the landscape has been altered. Roading and recreation have increased the number of ignition sources by approximately 50% since the 1950's. Areas of particular concern include the undeveloped camping areas along the Deschutes River, Cultus Lake, and Crane Prairie Reservoir.
- Fire suppression has moved vegetation towards the later seral stages and has resulted in the almost total elimination of high elevation early seral habitat (O'Neil and Lee 1995).

High intensity burns that occur in riparian areas destroy most of the present vegetation. The area becomes immediately subject to bank and surface erosion when the stabilizing and filtering nature of riparian vegetation is burned and removed. However, lower intensity fires can actually increase riparian vegetation. Many of the deciduous species found in riparian areas resprout following low intensity fires; some species put up new sprouts for each burned plant thereby increasing plant density. Relatively little is known about specific interactions between Pacific Northwest riparian habitats and fire, so further research would help to determine the effects of burning in riparian areas (O'Neil and Lee 1995).

6.5 Fuel Load Issues

Fires ignited by people or through natural causes have interacted over evolutionary time with ecosystems, influencing many ecosystem functions. Fire recycles nutrients, reduces biomass, influences insect and disease populations, and is the principal disturbance agent affecting vegetative structure, composition, and biological diversity. As humans change fire frequency and intensity through fire suppression, many plant and animal communities are experiencing a loss of species diversity, site degradation, and increases in the size and severity of wildfires due to the buildup of fuel loads (UDWC 2002).

There are heavy fuel loads in and around the City of Bend (COFMS 2003). The primary causes of fuel load issues in forests across the west include fire suppression, livestock grazing, commercial logging, and insect and disease infestations. Current and ongoing research has revealed both the value of fire disturbance within forest ecosystems as well as the negative effects of fire suppression.

6.6 Fire Suppression

Fire management and fire suppression alters the natural or historic frequency of fires in a forest. Typically, fire suppression leads to increased stand densities, increased crown closure, alterations in vegetative composition, smaller stand diameter, decreased percentage of undergrowth, increased forest litter, higher quantities of woody debris, and higher fuel loads. The results of fire suppression can lead to the degradation of forest ecosystem integrity and the increased likelihood of large, high-severity wildfires (Stephens 2002). High-intensity, stand replacing events are now likely to occur in many areas that historically burned less frequently. Those areas are now large homogenous areas that are comprised of interconnected and fuel-laden stands vulnerable to severe fires (Agee 1993).

Prior to fire suppression activities, fires burned with less intensity in areas influenced today by human use. Estimates from the current successional development, stand age, and evidence of fire in current stands from the Deschutes National Forest Fire Atlas suggest that approximately 12,000 acres were affected by fire by the turn of the century in the Cascade Lakes region. Large fire occurrence after organized fire suppression began around 1910 was rare. Since 1910, the largest fire recorded to occur in the Cascade Lakes region was the 1994 Four Corners Fire (O'Neil and Lee 1995).

Fire suppression and exclusion in the Upper Deschutes Subbasin has resulted in highly unstable conditions throughout many of the ponderosa pine and dry mixed conifer stands, consequently increasing the potential for more frequent and larger disturbances. Conditions which contribute to these disturbances include encroachment of fir into pine stands which were once relatively fire tolerant. Currently, over-crowded and weakened trees are competing for limited water and nutrients. Although dead and dying trees are an important component of ecosystem processes, significant acres of weakened stands are imminently vulnerable to insects and disease (Beyer 1997).

The 1995 report, *Recommendations for Ecologically Sound Post-Fire Salvage Logging and Other Post-Fire Treatments On Federal Lands in the West,* published cooperatively by OSU, USFS, University of Montana, Idaho State University, and the Columbia Inter-Tribal Fish Commission, asserts that the impact of certain fire suppression activities on watershed resources is significant. Specifically, fire suppression activities including bulldozing in stream channels, riparian areas, wetlands, or on sensitive soils or on steep slopes negatively impacts water quality and fish habitat conditions by increasing erosion and sediment transport into the system (Beschta et. al 1995).

6.7 Fire Management

There are ongoing fuels and fire management planning efforts at BLM, ODF, DNF, as well as within county agencies. Federal land managers have several natural fuels management documents completed, and a new Fire Management plan is currently being drafted. Bill Johnson, with the U.S. Forest Service, and Sue Stewart, with the BLM in Prineville, are the lead staff on the current Fire Management Plan. In addition, representatives from many groups have indicated the need for an assessment of fire risk on private lands.

The May 1998 Integrated Natural Fuels Management Strategy for the Deschutes National Forest provides guidance for prescribed fire, mechanical brush mowing, and small diameter tree thinning and release. The BLM and the Deschutes National Forest both have fire potential mapped. In addition, within the Deschutes National Forest, 100 years of fire history has been mapped. Deschutes National Forest risk assessment is on hold until the Fire Management Plan is updated.

ODF does have fire risk maps to use in their fire fighting efforts and is working with private landowners to reduce fuel loading by thinning. However, ODF claims that there is a lack of consistency in fuel load management in areas of private land ownership. New buildings tend to pose less fire hazard because they must use the building code for high fire risk areas, such as a prohibition of shake roofs (UDWC 2002).

Fire suppression and other management practices have allowed less fire-resistant species such as lodgepole pine and true firs to become established within the mixed conifer areas. Now when fires do occur, they will most likely be stand replacing fires such as the Pringle and Labor Fires of 1995. The mixed conifer dry plant association group is now more vulnerable to large catastrophic wildfires than it was historically (O'Neil and Lee 1995).

The pressing need to restore health and resiliency to eastside forest ecosystems is widely acknowledged by land managers and stakeholders in the Upper Deschutes Subbasin. Land managers are attempting to restore the historic frequency and intensity of disturbances by using underburnings that reduce fuels and minimize stand-replacement fires. Although fire is well recognized as a natural disturbance process that affects stand structure, nutrient availability, wildlife habitat, and insect and plant disease population, the comprehensive short and long term effects of its silvicultural application in low elevation, late successional or old-growth ponderosa pine forests are not well understood (Youngblood and Reigel 1999).

6.7.1 Integrated Natural Fuels Management Strategy

Historic fires in the Upper Deschutes Subbasin played a valuable role in the evolution of ponderosa and Jeffrey pine forests. The Deschutes National Forest published its Integrated Natural Fuels Management Strategy (INFMS) in May of 1998. The purpose of the document is to provide an integrated strategy for the treatment of natural and activity fuels within the Deschutes National Forest. The strategy guides district level planning efforts for fuel management within the forest. As listed in the INFMS, the following are the functional key issues developed for the fire and fuels program:

Key Issue #1: Firefighter and public safety is jeopardized as a result of heavy fuels accumulations and high snag density in and adjacent to wildlands.

Key Issue #2: Ecosystems and critical habitats are at risk to loss from catastrophic fire due to fuels accumulations.

Key Issue #3: Due to increasing wildfire losses throughout the West in recent years, wildland agencies are under greater scrutiny as to their ability to manage fire suppression and prescribed fire programs. Declining budgets and support for fire organizations further exacerbate this issue.

Key Issue #4: The Natural Fuels Program and Unit Costs. The INFMS critiques the emphasis of unit costs within the Natural Fuels Program. The INFMS claims that if Forest plans and natural fuels projects are driven solely by unit costs then the natural fuels program is likely to fail at effectively addressing Forest's goals across the forested landscape. A natural fuels program that balances project costs across varying plant associations would be more effective in addressing the Forest's goals across the landscape.

According to the Integrated Natural Fuels Management Strategy (INFMS) for the Deschutes National Forest, prescribed fire and wildland fire are the most feasible substitutes for filling the ecological role of natural fires in restoring the wildland ecosystems of historic forests. Employing prescribed fire and fuels management treatments can improve overall forest health and reduce excessive ladder fuels in ponderosa pine and pine-mixed conifer types. Important resources or forest values can be enhanced or protected by a variety of different fire management strategies including: maintenance of old growth in a natural area; encouraging browse and cover on a big game winter range; maintaining forest structure favored by neotropical migrant bird species, northern goshawk, flammulated owl, and other species of concern; and protecting homes and watersheds from severe wildfires (USDA 2000).

Once the desired stand and fuel conditions have been established, stands can thereafter be maintained more routinely with periodic burning or a combination of cutting and fire treatments. Prescribed fire can be used in wilderness and natural areas to maintain natural processes (USDA 2000).

The INFMS for the Deschutes National Forest asserts that the advantages of using fire and improvement cuttings to restore and maintain seral, fire-resistant species include:

- Resistance to insect and disease epidemics and severe wildfire.
- Providing continual forest cover for aesthetics and wildlife habitat.
- Frequent harvests for timber products.
- Stimulation of forage species.
- Moderate site disturbances that allow for tree regeneration (Mutch and others 1993) (USDA 2000).

Frequent prescribed fires will not produce heavy screening or hiding cover, which is not sustainable over large areas in these forests. However, such fires do help maintain moderate cover and screening in the long run (Martin and others 1988). Management of forests in open conditions can help ensure protection of strategically located patches of heavier cover (Camp et al. 1996). Frequent disturbance cycles can also produce and maintain large old trees characteristic of pre-1900 forests with good opportunities for wildlife habitat, desirable aesthetics, and selective harvesting for lumber. Therefore, a management approach that uses a modified selection system and periodic burning can be used to maintain remnant old growth stands and to create conditions suitable for future old growth (Fiedler et al. 1996, Fiedler and Cully 1995).

Prescribed fires must be introduced carefully in stands where leave trees have poor vigor or where tree roots are located in a deep duff layer (Harrington and Sackett 1992). Burning thick forest floor fuel layers can mortally injure roots and boles of old pines that in past centuries survived many fires (Sackett and Haase 1996). Poor tree vigor is reflected by growth stagnation in the dominant trees of both second growth and old growth stands. This widespread stand stagnation is the consequence of basal area stocking levels that are two or more times those of historic conditions. Fire can be highly stressful to trees that are suffering from growth stagnation, and may, in fact, allow bark beetles to inflict excessive damage to the weakened trees (Fiedler et al. 1996).

The acres that received prescribed burns, or fuels treatments in the Deschutes National Forest are listed in Table 16. The data shows that although fuels treatments were variable throughout the years, they more than tripled between 1996 and 2002.

Table 16: Fuels Treatment Acres in the Deschutes National Forest

Year	Deschutes National Forest Acres
1996	5,264
1997	4,766
1998	7,376
1999	5,253
2000	2,695
2001	18,395
2002	19,648

Source: Stewart 2003

6.7.2 Post-burn Management Activities

Salvage logging has been used following past fires in the Upper Deschutes Subbasin. Due to the fact that burn sites are especially sensitive, logging after a fire can lead to accelerated erosion, sedimentation, and soil compaction. Post-burn soil conditions can certainly vary depending on fire severity, steepness of slopes, and inherent erodability, but regardless, soils are exceptionally vulnerable in a burned landscape (Beschta et. al 1995). Many riparian areas along the Upper Deschutes River are already highly susceptible to erosion due to loose volcanic soils, and logging post-burn areas at or near riparian zones has been shown to increase erosion and subsequent sedimentation in the river. Sedimentation is already a concern on the Upper Deschutes River between Wickiup and the City of Bend; this section of the river is on DEQ's 303 (d) list for sedimentation and turbidity and management activities that increase erosion into the river negatively impact fish and other aquatic species.

Sediment transfer and reduced soil productivity are two major concerns in a burned landscape (McIver 1998). Understanding the effects of post-fire management activities in the Upper Deschutes Subbasin is especially critical due to the sensitive condition of wildfire sites. Soil disturbance and erosion vary based on the type of logging activity and whether or not roads were built. According to ecologist and research coordinator for the Blue Mountains Natural Resources Institute Forestry and Range Sciences Laboratory, James McIver, road building causes the greatest impact and plays the biggest role in contributing to post-fire erosion. An estimated 90% of sedimentation from logging activities comes from road building. Sedimentation, erosion, and run-off all increase in areas that are logged when compared to unlogged areas. Post fire ground- based logging and the associated road-building can compact soil and lead to more run-off (McIver 1998). According to the collaborative 1995 report:

> *Roads are associated with a variety of negative effects on aquatic resources, including disruption of basin hydrology and increased chronic and acute sedimentation. Under no circumstances should new roads be introduced into sensitive areas, including roadless or riparian areas (*Beschta et al. 1995).

Logging and the associated road-building within burn areas contributes not only to accelerated erosion and soil compaction, but also involves the removal of large wood which is valuable for the recovery of the forest. Any activity that disturbs litter layers, the soil surface, or removes stabilizing features such as downed trees can accelerate soil erosion and sediment delivery to aquatic systems (Beschta et al.1995).

There is extensive research regarding the erosion and sedimentation that can occur with post-burn land management. However, according to fisheries biologists, hydrologists, and soil scientists from the Deschutes National Forest, there has been no specific assessment or analysis of the erosive impacts of fire management activities in the Upper Deschutes Subbasin. A predictive model for forest activities, erosion, and sedimentation has been developed by the research arm of the U.S. Forest Service. This model, the Water Erosion Prediction Project (WEPP), has not been used on the Deschutes National Forest, but it is applicable as a model to predict the impacts from forest and fire management activities.

6.7.3 Constraints

Due to heavy fuels and a rapidly growing population, fuels treatments specifically around the City of Bend are a high priority but present significant concerns regarding air quality and difficult and expensive prescribed fore treatments. The challenges in the urban area are compounded by the fact that there is a lack of skilled personnel. Planning and fuels treatments in a wildland urban interface (WUI) are more time consuming and expensive, and finding funding for these projects is difficult. Mechanical treatment is a low risk option that does not affect air quality, but it is expensive and not completely accepted by the public. Mapping of WUI is currently being completed by the Oregon Department of Forestry. In general, the public throughout the subbasin lacks an understanding of fire as an ecological disturbance agent.

6.7.4 Opportunities

The Nature Conservancy is currently using the Upper Deschutes Basin as a demonstration site for the National Fire Learning Network. This project will integrate existing and planned local, state, and federal fuels projects. The Upper Deschutes Basin Fire Learning Network will combine efforts to design conditions that support "fire safe" communities, communicate concepts describing ecosystems that are functioning within expected parameters, and facilitate the exchange of information to achieve the above goals.

6.8 Data Gaps

- There are no current fire risk assessments on private lands in the subbasin.
- Developing and coordinating effective fire treatments for the Upper Deschutes Subbasin depends in part on collecting more information on down woody material loading.
- Although a large body of information exists on the erosion and sedimentation impacts of forest roads and new road construction in post-burn areas, little data has been compiled or published regarding the impacts of roads specifically in the Upper Deschutes Subbasin.
- More data is needed on the effects of fire on post-burn noxious weed colonization.
- More information on juniper crown fire potential is needed.
- More information is needed on Threatened and Endangered species locations and the effects of fire and forest harvesting on neotropical bird habitat in the Upper Deschutes Subbasin.

6.9 Key Findings

- Fire plays an important role in the natural disturbance and recovery patterns of native species and ecosystems. Specifically, western ecosystems have evolved with and in response to wildfire.
- Fire suppression has altered the historic frequency and intensity of fires in the Upper Deschutes Subbasin.
- Fire suppression activities can lead to modified forest structures including: increased stand densities, increased crown closure, altered vegetative composition, smaller stand diameter, decreased percentage of undergrowth, increased forest litter, higher quantities of woody debris, and higher fuel loads.
- The results of fire suppression can lead to the degradation of forest ecosystem integrity and the increased likelihood of large, high-severity wildfires.

- Roading and recreation have increased the number of ignition sources by approximately 50% since the 1950's. Areas of particular concern in the subbasin include the undeveloped camping areas along the Deschutes River, Cultus Lake, and Crane Prairie Reservoir.
- Heavy fuels and a growing population have led fuels treatments to be a priority around the City of Bend.

6.10 Recommendations

- Support fire management activities that seek to protect soil integrity, avoid new road construction in sensitive areas, and reduce the sedimentation effects from existing roads.
- Research the effects of salvage logging in sensitive areas of the Upper Deschutes Subbasin. Make existing information widely available to the public.
- Promote natural regeneration of post-fire plant species.
- Support and initiate monitoring projects that track unintended consequences from fire management and incorporate implementation and effectiveness monitoring.
- Raise community awareness in both rural and urban areas about the roles that fire, fire suppression, and forest harvesting play in the Upper Deschutes Subbasin.
- The large body of existing information documenting the erosion impacts of forest roads, particularly new road construction, on the sedimentation of spawning habitat must be applied to future fire suppression, fire prevention treatments, and thinning or logging in the Upper Deschutes Subbasin.
- An evaluation of the impact of the existing forest road systems on aquatic resources in the Upper Deschutes Subbasin is needed.
- A predictive model for forest activities, erosion, and sedimentation has been developed by the research arm of the U.S. Forest Service. This model, the Water Erosion Prediction Project (WEPP), has not been used on the Deschutes National Forest, but it is applicable to predict impacts from forest and fire management activities.
- Support programs that continue to research the effects of fire management activities on watershed resources.

7.0 RIPARIAN ZONE

7.1 Critical Questions

1. What are the primary functions of riparian vegetation communities?
2. What are the current conditions of riparian zones in the subbasin?
3. What type of native and non-native vegetation is found within the riparian zones in the subbasin?
4. What are the effects of land use patterns on riparian vegetation?
5. How does water management affect riparian areas in the subbasin?
6. What are the riparian restoration opportunities in the subbasin?
7. What are the limitations to restoration of riparian communities?

7.2 Approach

Due to the large scope of the subbasin and the substantial acreage of the riparian zones in the subbasin study area, the assessment chose to focus on the riparian zones in target areas impacted by primary watershed issues of concern.

This section will first present a brief overview of the role that riparian vegetation plays in preserving and perpetuating watershed health. Next will follow descriptions of the specific riparian plant associations and plant association groups found in the Upper Deschutes Subbasin. The current conditions and the role of human impact on the target riparian zones in the study area will be assessed and presented.

Most of the riparian areas between Wickiup Reservoir and the City of Bend fall within the same boundaries as the Upper Deschutes Wild and Scenic River designated areas. Therefore, the *Upper Deschutes River Wild and Scenic River Record of Decision and Final Environmental Impact Statement* was a primary resource used for data in these areas. There exists a great deal more published research on both the historic and current riparian conditions upstream from the City of Bend than between Bend and Lake Billy Chinook. A large portion of the land downstream from Bend is privately owned and consequently lacks the focused analysis, research, and data collection efforts that lands managed by either the Forest Service or BLM have received.

7.3 Riparian Zone Functions

Riparian zones are ecological areas that are adjacent to rivers or streams. Riparian areas are comprised of hydrophitic, or water-loving plant species that are dependent on the stream system for their biologic integrity. Riparian vegetation includes plant associations that are determined by the elevation of landforms relative to the surface or subsurface water. These plant communities can tolerate soil conditions that are wetter than normal during the growing season (Kolvalchik 1987).

Riparian vegetation, either individual plants or the plant communities within riparian zones on the Upper Deschutes, has a fundamental influence on local environmental conditions such as microclimate, water temperature, and ecosystem processes. The above-ground values of riparian vegetation have been widely recognized as providing habitat for both wildlife and aquatics, contributing to shading aquatic areas, providing sources of vegetative litter for carbon and nutrients, and instream woody debris recruitment.

The health and productivity of riparian and aquatic ecosystems are closely linked to the ongoing interaction of riparian vegetation with varying flow regimes and sediment transport loads. The intersection between the riparian vegetation on the stream systems within the Upper Deschutes Subbasin and the hydrologic components is an element of channel development essential to sustaining the productivity of the aquatic ecosystems. The riparian and aquatic ecosystems interact in an important combination of physical processes such as: streamflow, sediment transport, energy exchanges and structural features including floodplains, channel banks, pools, and riffles interacting with dynamic populations of riparian plant communities and aquatic organisms (Beschta 1999). In general, riparian areas with high vegetation densities are more conducive to sustaining relatively narrow, deep, and sinuous channels, the development of overhanging banks, long-term floodplain deposition, high water quality, and general food-web support. Streamside vegetation in the Upper Deschutes Subbasin and elsewhere plays an essential role in a number of ecological functions:

- During periods of overbank flow, the above-ground portion of a riparian plant community provides important roughness known as hydraulic resistance. This resistance promotes deposition of fine sediments on floodplains, thereby maintaining channel morphology.
- Plant establishment and sediment accumulation can occur along stream margins, narrowing channels by reducing width-to-depth ratios and thus influencing the spatial distribution and dimensions of aquatic habitat units (pools and riffles), flow patterns, effectiveness of streamside vegetation for shading a stream, and temperature fluctuations from solar heating.
- Vegetation anchors stream bank soils with fibrous and woody root systems that resist the erosive forces of high flows.
- Stream bank vegetation acts as sediment traps for lateral erosion from upland areas.
- The interaction of flow and vegetation forms overhanging banks, thus creating important aquatic habitat niches and protection from predation for some species.
- Vegetation helps stabilize point bars, which in turn affects the long-term morphology of a stream reach (Beschta 1999).

Many other important ecological attributes of riparian plants are associated with their root systems. Although the below-ground component of riparian plants is a primary component of restoring or maintaining healthy riparian/aquatic ecosystems, it has had very limited scientific study (Beschta 1999). Riparian root systems can increase bank stability, and streamside vegetation reduces the impact of the peak velocities of high flows, thereby decreasing energies that could otherwise erode banks, elevate sediment loads, and widen channels. By stabilizing soils, the root systems of healthy streamside vegetation also helps reduce or mitigate potential erosive damage that could result from upland management activities such as logging or livestock grazing (Kennedy 2000).

A healthy riparian zone provides valuable functions for the health of the stream system as well as for the surrounding wildlife and wildlife habitat. There are a variety of means and methodologies for assessing and characterizing the current condition of a riparian zone. The federal agency Riparian Management Service Team comprised of the Bureau of Land Management, the Fish and Wildlife Service, and the Natural Resources Conservation Service developed one method for assessing the health of riparian areas. Referred to as the Proper Functioning Condition methodology, this method takes into account soils, geomorphology, bank stability and water quality as they contribute to or influence riparian health. Another method for assessing riparian conditions has been developed by the Riparian and Wetland Research Program (RWRP) at the School of Forestry at the University of Montana, Missoula. The RWRP has a condition assessment methodology that private landowners can use to assess the riparian conditions on their land (UDWC 2002).

Although there are many field survey, inventory, and research-based ways to assess riparian conditions, the Proper Functioning Condition methodology seems to be the most widely used and the most comprehensive. Its definitions regarding functioning and nonfunctioning characteristics of a riparian zone are useful when attempting to understand what the parameters of desired riparian conditions might include. The BLM and the Riparian Management Service Team defines the proper functioning condition of riparian areas in this way: A riparian area is considered to be in properly functioning condition when adequate vegetation, or large woody debris is present to:

- Dissipate stream energy associated with high flows, thereby decreasing erosion and improving water quality
- Filter sediment, capture bedload, and aid floodplain development
- Improve water retention and ground-water recharge
- Develop root masses that stabilize stream banks against hydrologic cutting action
- Develop diverse ponding and channel characteristics to provide habitat and the water depth, duration, and temperature necessary for fish production and waterfowl breeding
- Support greater biodiversity (Prichard 1998)

Healthy riparian plant communities are essential components for proper stream ecosystem processes and function. Riparian zones in rangelands provide critical sources of diversity and biomass productivity for both plant and animal species. Stream bank vegetation also produces essential organic matter for headwater communities as well as processed material for downstream catchments. Moreover, riparian habitat conditions exert a strong influence on stream channel morphology (Kennedy 2000).

If a riparian zone or a wetland area is not functioning properly, it can be characterized as one of the following:

- Functional- At Risk: Riparian/ wetland areas that are in functional condition, but an existing soil, water, or vegetation attribute makes them susceptible to degradation.
- Nonfunctional: Riparian/ wetland areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows, and thus not reducing erosion or improving water quality.
- Unknown: Riparian/ wetland areas that managers lack sufficient information on to make any form of determination (Prichard 1998).

7.4 Riparian Zone Plant Associations

For the Deschutes, Ochoco, Fremont, and Winema National Forests, Bernard Kolvachik defines and characterizes two distinct ecosystems in the riparian zone: true riparian and transitional. The riparian ecosystem is defined as the area of land adjacent to water that supports plants and plant communities that are dependent on a continual source of water. According to Kolvachik, riparian zones include fluvial surfaces such as stream banks, active stream channel shelves, active flood plains, and overflow channels. Comparatively, the transitional ecosystem occurs on sub-irrigated sites that lie somewhere between the riparian zone and upland areas. This ecosystem does not have true riparian vegetation such as sedges and willows, but is still considerably different from the uplands. Transitions sites can include inactive floodplains, terraces, toe-slopes, and meadows. Transitional sites such as these are known to have seasonally high water that recedes below the rooting zone in mid to late summer (Kolvachik 1987). Mesic (moist) meadows in particular, transitional sites in the Upper Deschutes Subbasin provide valuable forage areas for livestock and wildlife.

Both riparian and transitional ecosystems are found along the interface between aquatic and terrestrial ecosystems. These zones are well defined and are surrounded by much drier upslope ecosystems. Kolvachik has also classified Riparian Zone Plant Associations for the Deschutes National Forest (Kolvachik 1987). Table 17 presents a list of the riparian zone plant associations occurring on the Deschutes National Forest.

Table 17: Riparian Zone Plant Associations in the Upper Deschutes

Lodgepole pine/Kentucky bluegrass (*Pinus contorta/Poa pratensis)*
Lodgepole pine/bearberry (*Pinus contorta/Arctostaphylos uva-ursi)*
Lodgepole pine/Douglas spiraea/forb association *(Pinus contorta/Spiraea douglasii/forb)*
Lodge pole pine/Douglas spiraea/widefruit sedge (*Pinus contorta/ Spiraea douglasii/Carex eurycarpa)*
Lodge pole pine/Bog Blueberry/Forb (*Pinus contorta/Vaccinium occidentalis/forb)*
Lodgepole pine/bog blueberry/widefruit sedge *(Pinus contorta/Vaccinium occidentalis/Carex eurycarpa)*
Lodgepole pine/widefruit sedge (*Pinus contorta/Carex eurycarpa)*
Quaking aspen/blue wildrye (*Populus tremuloides/Elymus glaucus*)
Quaking aspen-Lodgepole pine/Douglas Spiraea/widefruit sedge (*Populus tremuloides-Pinus contorta/Spiraea douglasii/Carex eurycarpa)*
Mountain alder (Alnus *incana)*
Mountain alder-Common Snowberry *(Alnus incana-Symphoricarpos alba)*
Mountain alder-Douglas spiraea *(Alnus incana-Spiraea douglasii)*
Willow/Kentucky bluegrass (*Salix/Poa pratensis)*
Willow/widefruit sedge (*Salix/Carex eurycarpa)*
Willow/Sitka sedge (*Salix/Carex sitchensis)*
Cusick Bluegrass (*Poa cusickii)*
Kentucky Bluegrass (*Poa pratensis)*
Tufted hairgrass (*Deschampsia cespitosa)*
Nebraska sedge (*Carex nebraskensis)*
Widefruit sedge (*Carex eurycarpa)*
Short-beaked sedge (*Carex simulate)*
Slender sedge (*Carex lasiocarpa)*
Small-fruit bulrush/Bigleaf sedge (*Scirpus microcarpus /Carex amplifolia)*
Sitka sedge (*Carex sitchensis)*
Inflated Sedge (*Carex vesicaria)*
Beaked sedge (*Carex rostrata)*
Creeping spikerush (*Eleocharis palustris)*

Source: Kovalchik 1987

7.4.1 Plant Association Groups

The United States Forest Service created a system for organizing and classifying the vegetation of the Deschutes National Forest. Using 1988 ISAT image data interpreted by Pacific Meridian Resources, the Deschutes National Forest developed a vegetation cover type map. These data are classified by size, stand structure, and crown cover classes. The Deschutes National Forest GIS staff and silviculturalist combined these classes to allow for a more manageable data set to support their Landscape Assessment Plan (LAP). This type of classification is termed Plant Association Groups (PAG) (UDWC 2002).

Assessed for the Upper Deschutes Wild and Scenic River Management Plan, the riparian and upland areas located in the Deschutes River areas between Wickiup Reservoir and the City of Bend's urban growth boundary have been mapped by plant association group. Table 18 presents the approximate acres for each plant association group within the boundaries of the Upper Deschutes River Wild and Scenic designation. The table presents the acres for upland vegetation as a point of comparison with the acreage of riparian zones. The specific acreage for plant association groups on other distinct private, federal, or state lands within the subbasin have not been compiled.

Table 18: Plant Association Group Distribution

Upper Deschutes River: Approximate Acres by Plant Association Group		
Plant Association Group	Forest Service Lands	Other Lands
RIPARIAN		
Meadow	600	1250
Lodgepole Pine (wet)	2,360	2,710
UPLAND		
Ponderosa Pine	5,740	490
Lodgepole Pine (dry)	1,780	626
Mixed Conifer (dry)	920	1

***Acreage for plant association groups within the Upper Deschutes River Wild and Scenic boundaries. Data for other portions of the subbasin has not been compiled.**
Source: USDA 1996

7.5 Riparian Zone Conditions

7.5.1 Upper Deschutes River

Along the Upper Deschutes River populations of water-loving species occur due to frequent springs and seeps along the stream banks between Wickiup Dam and the City of Bend. The riparian communities found along the length of the Deschutes include combinations of the following vegetation: an overstory of stands of lodgepole pine and ponderosa pine; a shrub understory of spirea, snowberry, alder, or willow; and a herbaceous layer of forbs and sedges. Many large willow/sedge meadows are also prevalent along the river. In addition to the meadow, the lodgepole (wet) plant association group is also included in the riparian classification. This lodgepole (wet) association is found in areas with high water tables or partially or frequently inundated soils. Approximately 1,850 acres of meadow and 5,070 acres of lodgepole (wet) habitat occur along the Deschutes River above Bend. Although they may occupy a relatively small amount of land, "riparian zones and wetlands are extremely important. They provide important habitat for approximately four-fifths of the area's wildlife, fish, and other aquatic organisms." (USDA 1996).

Riparian vegetation is inherently valuable for the habitat it provides as well as for the stream bank stabilization that accompanies healthy riparian zones. The primary issue of concern facing residents, land managers, natural resource agencies, scientists, and decision makers in the Upper Deschutes Subbasin is the rapid rate at which the Upper Deschutes River banks are eroding. Stream bank erosion is a concern due to the channel instability, land loss, diminished water quality, and riparian/aquatic habitat loss and modification that often follow such erosion. Identified as a critical issue in the *Upper Deschutes Wild and Scenic River Record of Decision and Final Environmental Impact Statement*, Upper Deschutes River banks are particularly sensitive to erosion due to the minimal natural resistance of the volcanic soils (see Appendix I). Currently, the artificial flood stages resulting from high irrigation releases during the spring and summer months follow the dewatering of the winter months and thereby accelerate lateral erosion on the banks of outside bends in the river and subsequently increase deposition on the inside of river bends. Simultaneously, riparian vegetation is very difficult to restore on outside bends and very difficult to maintain with the current managed flow levels that are much greater or less than those that occurred prior to water management out of Wickiup Reservoir (USDA 1996).

The Deschutes National Forest and the Crescent Ranger District have completed *The Odell Watershed Analysis* (1999) for the combined subwatersheds surrounding Odell and Davis Lakes. The analysis characterizes the overall quality of the riparian conditions in the area as excellent in over 99% of the watershed. With the exception of specific areas that have experienced high use over the years, the floodplain function and the quality of riparian vegetation is good.

The primary effects that are the results of a high concentration of people in riparian zones are: trampled vegetation, a slight increase in runoff, erosion, increased sediment, and stream bank damage. In recreation areas near Odell and Davis Lakes, vegetation has been trampled and moist soils have been compacted. Riparian vegetation has been altered or destroyed in high use resorts and campgrounds and the stream banks and lakeshores in many areas, particularly along Trapper Creek, have been trampled (Hurlocker 1999). There are some hiking, snowmobile, and off road vehicle trails in the area that traverse or run alongside riparian zones. These trails have had a negative impact on some wet meadows in the area. Near Davis Lake, there are many sites where four-wheel drive usage has caused vegetation damage and has disrupted hydrologic function by concentrating water flow through the meadow (Hurlocker 1999).

Along the Deschutes River in the area between Wickiup Reservoir and Pringle Falls, there has been harvesting or thinning of some of the lodgepole pine. In the area around Tetherow Meadow, Abbott Meadow, and Ryan Ranch Meadow, livestock grazing has trampled grasses and destroyed willows (USDA 1996). There is also vegetative disturbance in the riparian zone between Wickiup Reservoir and the south boundary of La Pine State Park that is the result of motor vehicles, campgrounds, and other recreational use (USDA 1996).

Tetherow Meadow is located along the Deschutes River approximately ten miles upstream from the confluence with Fall River. The cattle grazing allotment within the Tetherow Meadow area includes a total of 244 acres. 82 acres of this are primary and secondary range and 162 acres are unsuitable. The meadow is moist and wet. It is well documented that grazing by livestock has been a significant factor in the decline of riparian forests. Livestock can compact soils, exacerbate bank erosion, and consume seedlings and saplings of woody riparian species (Kennedy 2000). Due to stream bank and vegetation resource degradation from grazing, the cattle allotment in Tetherow Meadow has been inactive since 1989. Monitoring in the area showed native plant vigor to be decreasing and undesirable non-native plants to be increasing prior to 1989 (USDA 1996).

Ninety-six percent of the riparian land between General Patch Bridge and Harper Bridge is privately owned. In this area, private development and the alteration of land have affected wetlands and native riparian vegetation to a greater degree than in any other section of the upper Deschutes River. The lodgepole pine dominated vegetation community has been altered by the pervasive construction of golf courses, houses, roads, power lines, boat docks, lawns, and fences. To create access to the river, many slough areas have also been dredged in this area (USDA 1996).

From just downstream of the Sunriver Marina to the Meadow Camp area, the predominant riparian vegetation consists of shrubs and marsh grasses associated with wetlands. Lodgepole pine can be found in the wetter areas of the terraces and sinks. Alder and quaking aspen grow adjacent to the river throughout this area. Ponderosa pine is dominant on the slopes and in the higher elevations. On the east side of the Deschutes, a portion of the river corridor is located within the USFS Newberry Volcanic Monument. From Benham Falls to Lava Island Falls the Lava Butte lava flow stretches to the river and thereby limits the opportunities for vegetative growth. Here, too, ponderosa pine dominates the vegetation with alder and quaking aspen growing adjacent to the river. Due to the apparent maturity, consistency in distribution, and lack of obvious management, vegetation on the east side of the river seems natural and relatively undisturbed. The west side of the river, however, contains a designated dispersed campground that receives intense day and overnight use with both riparian and upland vegetation suffering from trampling and soil compaction. A user trail system has developed on the west bank of the river and frequent use of the trail has damaged and destroyed some of the riparian vegetation (USDA 1996).

Between Cardinal Bridge and the Meadow Picnic area, there is a series of sloughs on both sides of the river. Based on a photographic comparison of pictures taken in 1943 and 1991, the *Upper Deschutes Wild and Scenic River Record of Decision and Final Environmental Impact Statement* has documented that riparian vegetation has decreased within these sloughs. Apparently this is due to the greater fluctuation of flow levels that now occurs in the river. Historically, some sloughs contained at least a few inches of water year-round, but they now range from having virtually no water at all for 6 months to having over 2 feet of water for a period of 6 months. Under these conditions it is difficult for many native riparian species to survive. The effects of flow on sloughs may have been modified by the construction of levees between some sloughs and the river (USDA 1996).

Appendix II lists detailed descriptions of the riparian zone plant associations found throughout the Deschutes National Forest. At the northern or downstream end of the Deschutes National Forest, the riparian zones within the urban growth boundary for the

City of Bend have been characterized by the 1999 Bend Riverway project. Table 19 presents the riparian zone conditions as found at the time of the Riverway study.

Table 19: Descriptions of Riparian Zones Through the City of Bend

Reach	Location & Description
Upstream From Bend, Near River Mile 168	Nearly the entire length of the Reach on both sides of the river has undisturbed quality riparian vegetation. There is a small wetland on the east side of the river between the hydro plant and the end of the Wood River Park trail. The water is fast moving through most of the reach, discouraging the formation of wetlands. Important elk and deer wintering area in the southern portion. The Awbrey Hall fire in 1990 changed the ecological structure and function of the area.
The Old Mill District in the City of Bend	Except for the important Colorado St. wetland located on west side of river and a few other isolated areas, Old Mill Reach is almost completely disturbed for the entire reach. The east bank of the river is nearly devoid of vegetation or overcome with invasive plants like knapweed. The 5-acre Colorado St. wetland is perhaps the largest wetland in the Riverway. Over the past 15 years the vegetation has changed in a natural way resulting in high quality urban habitat. The Old Mill area is being developed and will have a mix of uses including trails. The new McKay Park plantings will attempt to restore some native vegetation. This reach could provide links to "refuge" areas to the south. Rocks and islands have been created to provide fish habitat up and down stream of the Colorado Bridge and more riparian restorations are planned. An osprey platform and perch have been installed and have been used by osprey to successfully fledge chicks.
Near Pioneer Park in the City of Bend	Completely developed with homes, businesses, or parks. However, soft vegetative edges prevail in the southern end of reach providing cover and food for many species. River otter are seen frequently. Parks and some homes have concrete retaining walls and lawns that provide little wildlife habitat – except to Canada geese. Naturescaping education could help neighbors and the Park District develop new areas for wildlife habitat.
Just Upstream of North Canal Reservoir	Mostly developed with a mix of residential and commercial, the area is considered the best wildlife habitat in the urban area by ODFW biologists. There are 3 undeveloped areas that provide high quality urban wildlife habitat. One area was recently rezoned to commercial and will likely be developed. Otter are seen regularly here and the trumpeter swans were released and remain in this area. Marsh-like areas have formed on the river's edge in areas of slow moving water above the North Canal Dam. Vegetation, including rushes, cattails, willow and alder provide cover and food for wildlife. Osprey have successfully raised chicks using a platform located east of the river on Highway 97. They are frequently seen fishing in front of Riverview Park.
Sawyer Park	This Reach begins at Sawyer Park, which has remarkable riparian and upland habitat for birds like dippers, owls and hummingbirds, and many mammals. The river is in a canyon for much of this Reach resulting in some high quality riparian habitat that is not easily accessible by humans. There are no river trails beyond the gate at Awbrey Meadows and residents report many wildlife sightings including cougar, bobcat, deer, fox and others. The undeveloped section of land and rural surroundings to the north function as a refuge for wildlife. Rapid water discourages formation of wetlands.

Source: McNamara 1999

The riparian zones along the Deschutes River between the City of Bend and Lake Billy Chinook are approximately 61% privately owned, 34% federally managed, 3% state lands, and 2% county. Most of the area that is public land is included in the Deschutes River Recreation Area within the Crooked River National Grasslands, which is administered by the Ochoco National Forest. Public access within the riparian zones between Bend and Lake Billy Chinook is very limited due to a high percentage of private ownership as well as due to the rough canyonlike nature of the landscape (ODFW 1996).

The habitat type along the river below Bend reflects a more arid, high desert climate and evolves from forest to desert canyon (ODFW 1996). Near the confluence with Tumalo Creek, the Deschutes River flows through a transition zone between the upper forested watershed and the desert canyon dominated by juniper and pine trees.

7.5.2 Fall River

Fall River is approximately eight miles from its headwater springs to the mouth of the Deschutes River. There is moderate density coniferous vegetation at its source. From the headwaters, Fall River flows in a very gentle gradient with riparian willows and marsh vegetation paralleling most of the river. Upland from marsh grasses and willows, ponderosa pine and bitterbrush are the dominant vegetation. Most of the riparian habitats are in relatively good condition and have been documented to be supporting garter snakes, spotted frogs, pacific tree frogs, Oregon newt, and western skink. (Nielson et al.1986). The wet meadow habitats along the river support coyote, snowshoe hare, raccoon, and badger. The shallow channel of the river averages 32 feet across and meanders at slow to moderate velocities (Nielson et al.1986).

7.5.3 Tumalo and Bridge Creek

The high quality waters of Tumalo and Bridge Creeks originate as springs of the Happy Valley area and as snowmelt from the Broken Top area in the western portion of the Tumalo watershed. Tumalo Creek runs first in an easterly direction and then northerly. The slope of Tumalo is 200 feet fall per mile for the 17.8 miles of stream. The mean elevation for the system is 5,630 feet (Hammon 2002).

Tumalo Creek runs through two 6^{th} field sub-watersheds before converging with the Deschutes River. Originating in Upper Tumalo Creek sub-watershed and then traveling through Lower Tumalo Creek 6^{th} field, Tumalo Creek runs through the subalpine parkland vegetation near Broken Top, down through Douglas fir dominant-mixed conifer forest, into a stretch of manzanita dominant shrubland, through ponderosa pine forest and woodland, and finally into western juniper woodland right at the confluence with the Deschutes River (see Map 4.1).

Located primarily in the Upper Tumalo Creek sub-watershed, the Bridge Creek fire started on July 24, 1979 and caused heavy short-term and long-term impacts to the riparian zones of 3 miles of Tumalo Creek and 1 mile of Bridge Creek. The fire burned a total of 4,300 acres. Some of the subsequent impacts include the recruitment of elevated quantities of fine sediment from upper stream bank and adjacent hillside erosion. With very little remaining gravels or sand, the substrate is primarily cobble (Wasniewski 2002). Following the fire, salvage operations removed a great deal of large woody material from the streams and along stream banks. In contrast, the riparian zones that were outside of the fire damage area currently remain in good condition with stands of fairly large spruce, mountain hemlock, and fir (Lee 1999).

Riparian zone and instream restoration of Tumalo Creek began in the early 1990's. Whole trees were placed and anchored into the channels within the Bridge Creek fire area. Some willow, cottonwood, and Englemann spruce were planted along the banks. The inserted wood structures shifted during high flows in 1995 and 1996 due to rain on snow events. This caused stream bank erosion and created a few very large log jams. Along Bridge and Tumalo Creek, loss of canopy after the fire has resulted in slightly increased water temperatures. The stream has likely become more biologically productive due to additional exposure to sunlight with the loss of the streamside canopy. Eventually, if the canopy becomes re-established, biological productivity will return to pre-fire levels (Lee 1999).

As a result of major differences in height and slope of opposing stream banks, each side has very different vegetative components (Hammon 2002). The downstream right bank terrace supports sparse populations of pine, spruce, sage, and grasses that are outside and much higher than the flood prone area. The small right bank flood prone area consists of horsetail and sedges. On the other side of the creek, the functional floodplain consists of a more diverse population of sedges, rushes, Kentucky bluegrass, horsetail, red osier dogwood, alder, and willow. The left bank outside of the flood prone area is composed of mature ponderosa pine, western larch, lodgepole pine, and aspen with a dense understory of brush species that include current bush (Hammon 2002).

7.5.4 Noxious Weeds

The range of noxious weeds is expanding throughout the western states. Almost all of the listed noxious weed species in Central Oregon have increased in both area and numbers of populations in the last 15 years (USDI 2001). Although the noxious weeds along riparian areas within the Upper Deschutes Subbasin have not been comprehensively mapped, there is some documentation regarding known infestations.

The riparian zones in the upper 6th field subwatersheds of the Upper Deschutes Subbasin are relatively free from noxious weeds (Grenier 2002). While there are noxious weed infestations in the area, they are primarily found along highly traveled roads such as the Cascade Lakes highway.

There is currently a small percentage of reed canary grass (*Phalaris arundinacea)* within riparian zones in the upper Deschutes subbasin (Grenier 2002). Reed canary grass is an extremely aggressive species that creates problems along rivers, streams, canals, and irrigation ditches.

Although the riparian zones on the Upper Deschutes River are relatively free from noxious weed invasions, there are some small patches of bull thistle *(Cirsium vulgare)* in riparian zones near Fall River, a large patch of mullein *(Verbascum thapsis)* downstream from Foster Bridge, and spotted knapweed *(Centaurea maculosa)* in a variety of small patches along the river trail between Dillon Falls and the City of Bend.

As noxious weeds are often spread by human travel, roads, recreation sites, and old timber sales units account for almost 75% of the known sites in the Deschutes National Forest (Grenier 2002). Most of the noxious weed infestations in the Deschutes Forest are found along highly traveled roads. Spotted knapweed, for example, is a "road runner" that is dispersed primarily by vehicles and people along road corridors. Bend and Redmond are both "hubs" for spotted knapweed; knapweed now dominates nearly every disturbed location in the city of Bend. It is found in vacant lots, along irrigation canals, and along roads. The riparian areas where noxious weeds have been documented are all locations that are easily accessible by car or trail.

There are notable quantities of Russian thistle (*Salsola iberica)*, mullein *(Verbascum thapsis)*, Canada thistle and knapweed *(Centaurea maculosa)* in some areas. The largest quantities of knapweed are found near Skyliners' lodge and just above where the Tumalo canal is buried. A large infestation of Canada thistle is located on the south side of Tumalo Creek between the upper and lower bridges (Levack 2003).

The spread of non-native plants, or noxious weeds, on BLM-managed lands is concentrated where surface soils or vegetation is disturbed. Some of the primary disturbance factors on BLM-managed lands are off-road vehicle travel, livestock grazing, logging, military training exercises, and the construction of roads. The expansion and increased density of noxious weeds appears to be increasing in direct proportion to the increase in off-road vehicle use (USDI 2001).

7.6 Impacts in Riparian Zones

Over the past 200 years, watersheds in eastern Oregon and other portions of the upper Columbia River Basin have experienced a wide range of land use practices following the influx of Euro-American settlers into the Pacific Northwest (Kauffman and Krueger 1984, Platts 2001, McIntosh et al.. 1994, National Research Council 1996). These introduced land use practices include: ranching, agriculture, the trapping of beaver, water withdrawals, forest harvesting, road building, mining, damming, and the continuing economic and industrial development of the region. As a result of these activities, impacts to riparian and stream resources have been extensive and, in some cases, relatively permanent. For example, it may not be possible to ever completely reverse the effects of some urban developments, highways, dams, and other structural modifications to stream systems. Similarly, the practice of appropriating water for out-of-stream uses is deeply ingrained in western water law. Because the alteration of watersheds, riparian systems, and flow regimes has been extensive, there exist considerable opportunities for ecological restoration of many riparian and aquatic systems. Such efforts could provide not only improved habitat for fish and other aquatics, but would also improve water quality and riparian wildlife habitat needs (Beschta 1999).

Due to the importance of riparian vegetation to the morphology and hydrologic functions of stream systems, significant reductions in the density and structure of these plant communities via land use practices can have long-term impacts on the system as a whole. Some negative effects might include long-term channel change such as channel incision, straightening, widening, and a general loss of stability (Beschta 1999)

Vegetation treatments on two miles of Odell Creek included the removal of lodgepole pine trees that were killed by the mountain pine beetle. Overstory removal of lodgepole pine has occurred on approximately 500 feet of Odell Creek stream bank upstream from Davis Lake and has altered sections of the forest adjacent to the creek ultimately leading to the loss of stream shade (Hurlocker 1999).

Livestock grazing has occurred throughout multiple riparian zones along the Upper Deschutes River. Grazing has led to trampled grasses and overpruned willows at Tetherow Meadow, Abbot Meadow, and Ryan Ranch Meadow (USDA 1996). Historically and currently, here has also been substantial grazing on BLM parcels of land between the City of Bend and Lake Billy Chinook. Over 14,000 acres of BLM land has been used for grazing in and around the riparian zones along the Deschutes in this area (USDI 2001). The Ecological Status of Riparian Determination scorecard was established by the USFS as a method of evaluating the ability of riparian communities to support continued livestock grazing and to recommend rest if necessary for ecosystem recovery. It is well documented that grazing by livestock has been a significant factor in the decline of riparian forests. Livestock can compact soils, exacerbate bank erosion, and consume seedlings and saplings of woody riparian species. Riparian degradation in the western United States has contributed to the decline of native fisheries and has prompted efforts to restore and protect these resources (Kennedy 2000).

7.7 Restoration Projects

Riparian restoration projects generally involve a combination of modifying or excluding certain land use practices that degrade the riparian zone and actively planting or replanting native vegetation that stabilizes the stream bank with its root systems. In addition to plantings, sometimes grading the stream bank, modifying the streambed, or other bioengineering techniques may be necessary.

Since the mid-1970’s, there has been substantial research focused on the role and importance of larger wood in forested catchments, particularly for areas west of the Cascades crest. However, channel gradients, sediment sizes comprising stream banks, peakflow hydrology, and the character of streamside vegetation for westside Oregon forested systems are considerably different than that found for east-side channel and riparian systems such as found in the Upper Deschutes Subbasin. For many riparian systems east of the Cascades crest, the occurrence of deciduous shrubs and trees (particularly willows, alders, and cottonwoods) and accompanying understories of sedges, rushes, and grasses have a much more important role in the ecological integrity of these systems than does the presence of large wood. For example, in many meadow systems, herbaceous plants such as sedges and rushes may have a dominant role in maintaining channel morphology (Beschta 1999).

The addition of large structural elements to degraded east-side stream systems can sometimes promote improved hydrologic functions, but not always. For example, in some situations the addition of logs or boulders can sometimes arrest or prevent natural channel dynamics. In other situations, the structural elements may greatly accentuate existing erosion and channel incision problems. These concerns are particularly acute for stream reaches in meadow and floodplain systems (Beschta 1999).

The Bend/ Fort Rock Ranger District of the Deschutes National Forest completed a stream bank restoration project just below Wickiup Reservoir in 2002. The project implemented bioengineering techniques to stabilize soils and revegetate eroded banks. Affecting multiple riparian and aquatic conditions, the objectives of the project were enhancement in three different areas. By enhancing and revegetating the riparian zone in this area, both land and aquatic conditions would benefit. The primary objectives of the project were to:

- Stabilize and revegetate the riverbanks from the waterline to the top of the slope,
- Reverse the gradual widening of the channel, thereby making the channel narrower by 3 feet and decreasing the width to depth ratio by 3%,
- Improve fish and wildlife habitat by providing resting and hiding areas for fish, creating habitat for aquatic macroinvertebrates, and enhancing habitat conditions for riparian dependent mammals and birds.

The methods and techniques used for the Deschutes stream bank stabilization project included instream placement of 35 pine trees, the construction of a new floodplain, transplanting sedge plugs to newly created floodplain, transplanting willow and spirea cuttings along toe slopes, and planting bitterbrush and pines on upslope areas (Walker 2001).

The willow survival rates at the project were monitored during the fall 2002. Approximately 50% of the cuttings were alive in reach 1 of the project, 0% were alive in reach 2, and 75% survived in reach 3. The reason for willow mortality was assumed to be beaver damage (Walker 2002).

The Upper Deschutes River Bank Stability Characterization (see Appendix I) presents findings from UDWC's 2002 field-work data collection effort on the stream bank conditions of the Deschutes River above Bend. In addition to characterizing the current vegetative and relative erosion conditions, the project documented visual assessments of stream bank restoration projects. Some of these projects appeared to be exacerbating erosion at bank toe.

Noxious weed control and weed management on BLM land between the City of Bend and Lake Billy Chinook is defined by BLM's Northwest Area Noxious Weed Control Program EIS. The Weed Control Program responds to noxious weeds with a management approach intertwining prevention, early detection, inventory, weed control through biological, mechanical, manual, and chemical methods, monitoring, and site rehabilitation. The chosen control methods are influenced by land management objectives, effectiveness of the control technique on the target species, size of the infestation, environmental concerns, land uses, and economics (USDI 2001).

7.7.1 Potential Riparian Zone Restoration Opportunities

7.7.1.1 Tumalo Creek

Tumalo Creek would greatly benefit from restoration in the two-mile riparian corridor between the Bridge Creek confluence and 4601 Road Bridge. Deschutes National Forest hydrologists have been studying the long-term impacts of the Bridge Creek fire and have determined that there has been significant erosion, land loss, and aquatic habitat loss caused by inadequate stream bank vegetation (Wasniewski 2002).

7.7.1.2 Farewell Bend Park

The Bend Metro Park and Recreation District (BMPRD) and The City of Bend have partnered together to create a 22 acre riverside park on the east side of the Deschutes River near river mile 170. The project will be directly adjacent to the river within the City of Bend's Urban Growth Boundary. An area that was historically used for logging and mill operations, the streamside area in this reach has lacked adequate riparian vegetation for decades. The Upper Deschutes Watershed Council is in the process of working with BMPRD to design and implement a restoration project that would reintegrate native riparian vegetation into the park. The project would be an opportunity to incorporate the benefits of a healthy riparian zone into an urban park. The Upper Deschutes Watershed Council will take this opportunity to educate students and city residents about the critical role riparian zone vegetation plays in watershed health and water quality.

7.7.1.3 Upper Deschutes River Bank Stability Characterization

The Upper Deschutes River Bank Stability Characterization (Appendix I) presents a general characterization of the erosive conditions on the Upper Deschutes between Wickiup Reservoir and the City of Bend. Applying this data toward identifying and prioritizing riparian restoration project locations would provide land managers with the clear direction to begin designing restoration projects. A more detailed analysis involving stream cross-sections of the channel in the areas of the highly eroding banks would also provide additional data to inform future restoration projects.

7.7.2 Limitations on Restoration Opportunities

7.7.2.1 Managed Flow Regime

Riparian vegetation restoration projects on the Upper Deschutes River are limited by the high summer and low winter flows. The high flows of irrigation season overlap with the summer growing period of riparian vegetation. High flows reaching levels above 2200 cfs out of Wickiup Reservoir (USDA 1996) during the growing period make the establishment or reestablishment of streamside vegetation very challenging if not impossible. Similarly, winter flows reaching levels as low as 20 cfs lower the water level at the bank toe, thereby decreasing root systems' access to a water source.

7.7.2.2 Private Land

Some of the highly eroding banks between Wickiup Reservoir and the City of Bend occur on private land. Downstream from Bend, an even higher percentage of riparian areas are on privately owned lands. Both data collection and restoration project implementation can be more challenging on private land.

7.7.2.3 Regulation and Permitting

70 percent of the Upper Deschutes Subbasin is land managed by the National Forest Service. While this often leads to more comprehensive and detailed data for the area, federally managed lands are also subject to multiple layers of research, analysis, and permits prior to project approval. Often, a project might be stalled for years beneath the permitting required to complete on-the-ground restoration.

7.7.2.4 Funding

Funding for riparian restoration projects can be limited and highly competitive. Additionally, in order for riparian restoration projects to be effective within the modified flow regimes of the Upper Deschutes, extensive research and analysis must be applied to the design component of the project. Funding for the research and design elements of restoration projects is very limited.

7.8 Data Gaps

- There have been no published analyses comparing the current riparian zone conditions in the Upper Deschutes to the conditions that existed prior to the establishment and operation of Wickiup dam. Similarly, there have been no published analyses comparing current riparian zone conditions with potential future conditions.
- ODEQ is currently modeling the effects of riparian loss on the TMDL parameter temperature, but that information has not yet been completed.
- There is no comprehensive inventory of the riparian zone conditions on the Upper Deschutes River. There is some information on the conditions that lie either on

the Deschutes National Forest or within the boundaries of the Upper Deschutes Wild and Scenic River designation, but the information is fragmented. Much of the land between the City of Bend and Lake Billy Chinook is privately owned and, therefore, has very little data on the current, historic, or potential riparian zone conditions in that area.

- There is no comprehensive inventory or map of the noxious weed infestations in riparian areas in the Upper Deschutes Subbasin.

7.9 Key Findings

- Upper Deschutes River banks are particularly sensitive to erosion due to the minimal natural resistance of the volcanic soils.
- The artificially high summer river flows and the low winter river flows that result from the release schedule from Wickiup Reservoir accelerate lateral erosion of the river banks on the Upper Deschutes River between Wickiup Reservoir and the City of Bend.
- Where established, riparian vegetation anchors stream bank soils with fibrous and woody root systems that resist the erosive forces of high river flows. Riparian root systems can increase bank stability, and streamside vegetation reduces the impact of the peak velocities of high flows, thereby decreasing energies that could otherwise erode banks, elevate sediment loads, and widen channels. By stabilizing soils, the root systems of healthy streamside vegetation also helps reduce or mitigate potential erosive damage from upland management activities such as logging and livestock grazing.
- Riparian vegetation is very difficult to restore on the Upper Deschutes between Wickiup Reservoir and the City of Bend due to the current managed flow levels that have significantly altered the natural hydrograph. Riparian vegetation that is planted to reach the water source in the summer is dewatered in the winter, and riparian vegetation that is planted to reach the water source in the winter is drowned in the summer.
- There have been a number of revegetation projects that have attempted to mitigate the effects of flow on eroding banks, but the disparity between the winter and summer flow regimes have made bank restoration projects very challenging, expensive, and often unsuccessful.
- The primary issue of concern in the Upper Deschutes Subbasin is the rapid rate at which the Upper Deschutes River banks are eroding. Stream bank erosion causes channel instability, land loss, diminished water quality, and riparian/aquatic habitat loss.
- Although there is no comprehensive noxious weed map, anecdotal evidence shows that current noxious weed infestations within riparian zones between Wickiup and the City of Bend appear to be concentrated only in high use areas.

7.10 Recommendations

- Initiate a multi-partner program to evaluate the impacts of the Wickiup Reservoir release schedule and seek timing and quantity of releases that ensure acceptable riparian conditions between Wickiup and Bend.
- Gather aerial photos of riparian plants between Wickiup Reservoir and Lake Billy Chinook. Create a photo repository of riparian conditions in the Upper Deschutes Subbasin to provide a point of comparison for future riparian zone conditions.
- Through Streamwalk and other programs, raise awareness among community members about the impacts of flow modification on riparian zones in order to promote a better understanding of the ways in which water conservation can improve river conditions.
- Form partnerships with landowners on the Upper Deschutes. Collaboratively research opportunities to revegetate bare and eroding banks between Wickiup and the City of Bend.
- Explore alternative riparian restoration and enhancement treatments that effectively reduce exacerbated erosion rates given the modified flow regime.
- Assist landowners with projects that replace nonnative vegetation with native riparian plants.
- Similar to the 2002 Stream bank Stability Characterization (see Appendix I), complete a characterization of the current on-the-ground conditions of the riparian zones between the City of Bend and Lake Billy Chinook.
- Address hikers, bikers, and walkers using Deschutes River trails in order to raise awareness about types and impacts of noxious weeds.
- Collaborate with Deschutes River user groups to coordinate and implement annual weed pulls.

8.0 WETLANDS

8.1 Critical Questions

1. What types of wetlands occur within the watershed?
2. What are the conditions of the wetlands within the watershed?
3. What are the effects of land use patterns on wetlands?
4. What are the limitations to restoration opportunities in wetlands areas?

8.2 Approach

There is very little data on the wetlands within the Upper Deschutes Subbasin. The National Wetland Inventory (NWI) has mapped wetlands across the United States, but the scale is too large to be usable by resource managers in the subbasin. Additionally, the NWI data is outdated. Therefore, the wetlands section presents general information regarding the value of wetlands within the watershed system as a whole. Where specific information regarding the conditions of wetlands in the Upper Deschutes Subbasin was available, such as within the City of Bend, that data is included in this section.

8.3 Wetland Habitat Types

Wetlands occur in areas where water either covers the soil, or is present at or near the surface of the soil all year or for varying periods of time during the year, including the growing season. For regulatory purposes under the Clean Water Act, wetlands are defined as" those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (EPA Regulations 40 CFR 230.3(t)). How the soil develops and the types of plant and animal communities living in and on the soil is dependent upon levels of water saturation. Wetlands support both aquatic and terrestrial species. The prolonged presence of water creates conditions that favor the growth of specially adapted plants known as hydrophytes and promote the development of characteristic wetland, or hydric, soils.

Wetlands vary widely due to local differences in soils, topography, hydrology, water chemistry, vegetation, and other factors including human disturbance. The types of wetlands that are found within the Upper Deschutes Subbasin are inland wetlands. Inland wetlands are most common on floodplains along rivers and streams, in isolated depressions surrounded by dry land, along the margins of lakes and ponds, and in other low-lying areas where groundwater intercepts the soil surface or where precipitation sufficiently saturates the soil in vernal pools and bogs. Inland wetlands in the Upper Deschutes Subbasin include marshes and wet meadows that are dominated by herbaceous plants, swamps dominated by herbaceous plants, swamps dominated by shrubs, and wooded swamps dominated by trees.

Some wetlands are seasonal and they are dry for one or more seasons every year. Particularly here in the west, they may be wet only periodically. The quantity of water present and the timing of its presences in part determines the functions of a wetland and its role in the environment. Even wetlands that are dry for parts of the year provide critical habitat for wildlife adapted to breeding exclusively in these areas (EPA 2003)

8.3.1 Current Wetlands

There are very limited data published regarding wetlands in the Upper Deschutes Subbasin. The National Wetland Inventory arm of the USGS has mapped wetlands throughout the United States, but the scale is too large to be of much assistance to land and resource managers in the Upper Deschutes. There is no current, comprehensive, and usable wetlands inventory for the Upper Deschutes Subbasin.

There is, however, one wetlands inventory completed by Ebasco Environmental as part of the relicensing agreement for PacifiCorp Electric's hydroelectric project in 1990. The survey area was along the Deschutes River starting in the south portion of the Old Mill district, through the City of Bend, to just south of the Newport Street bridge (PacifiCorp 1990). The inventory found that there was a total of 42 acres of wetlands encompassing 17 percent of the study area. Of the eight mammals observed during the survey, six depended on wetlands for food or cover. Of the 47 bird species observed, wetlands provided habitat for 29 species. Seventy percent of the wetlands were aquatic and contained one particular plant species, a non-native plant called elodea. By far the most important wetland for wildlife within the surveyed area is a 5.38 acre area just south of the Colorado Street bridge. This area has 2.2 acres of wetland shrubs such as willow and alder and possesses 20 different vegetation zones. Dominated by sedges and cattails, this wetland has a number of open water areas that provide nesting, foraging, and cover for birds.

There are a few other wetlands of this type on the Deschutes but they have not yet been inventoried. Currently, there is a wetland developing in areas of slow moving water on both sides of the river downstream from 1st Street Rapids near Newport Avenue in Bend (McNamara 1999).

8.4 Wetlands Management

Land use or land management activities in wetlands are affected by Oregon's Removal-Fill Law. The law applies to wetlands in addition to riparian areas. Across the state, Oregon currently has about 1.4 million acres of wetlands, compared to approximately 2.4 million acres of wetlands when it became a state in 1859. Oregon's policy as stated by the Division of State Lands is to "Promote the protection, conservation, and best use of wetland resources, their functions and values through the integration and close coordination of state-wide planning goals, local comprehensive plans, and state and federal regulatory programs." In addition, the state legislature has asserted that "Wetland management is a matter of this state's concern since benefits and impacts related to wetland resources can be international, national, regional and state wide in scope." The

Division of State Lands administers Oregon's wetland programs. It operates wetlands mitigation banks, which are publicly owned and operated sites created, restored, or enhanced to compensate for the adverse impacts from development activities.

8.5 Data Gaps

- There is no comprehensive inventory of wetlands in the Upper Deschutes Subbasin. Without an inventory of past and current wetland conditions, there can be no analysis of wetlands status and trends.
- The National Wetlands Inventory (NWI) for wetlands across the United States is outdated and inaccurate.

8.6 Key Findings

- Wetlands are very important in maintaining and improving water quality.
- Although there is no comprehensive wetlands inventory for the Upper Deschutes Subbasin, The 1999 Riverway study did assess and characterize the two wetlands known to be present within the City of Bend.
- The 5.38 acre wetland located along the Deschutes River just upstream of the Colorado Street Bridge in the City of Bend is a valuable wetland habitat. With 20 different vegetation zones, this area has a number of open water areas that provide nesting, foraging, and cover for birds.
- There is a wetland forming in the area downstream from 1st Street Rapids in the northern part of the City of Bend on the Deschutes River. This wetland is developing in areas of slow moving water on both sides of the river.

8.7 Recommendations

- Initiate collaboration among resource managers to collect, synthesize, and share wetlands data.
- Consolidate existing data and map the locations of wetlands in the Upper Deschutes Subbasin.
- Complete an inventory of the current conditions of wetlands in the Upper Deschutes subbasin.
- Analyze the status and trends of current wetlands' conditions in the Upper Deschutes Subbasin.
- Strengthen local and State wetland protection and restoration programs.
- Support programs that raise awareness among community members about the valuable roles that wetlands play within the watershed system.

9.0 GROUNDWATER

9.1 Critical Questions

1. What is the hydrogeologic setting of the basin and how does it influence groundwater flow in the region?
2. What are the sources and estimated amounts of groundwater recharge to the basin?
3. How do groundwater and surface water interact in the basin?
4. How has population growth impacted groundwater supplies?
5. What are the components and quantities of water identified by USGS in their water budget calculations?

9.2 Approach

The most comprehensive study completed to date on the dynamics of the groundwater flow in the Upper Deschutes Subbasin is *Ground-Water Hydrology of the Upper Deschutes Basin, Oregon,* Water Resources Investigation Report 00-4162 (USGS 2001) published in 2001 by the U.S. Geological Survey. The study-area perimeters for the USGS survey were chosen to correlate closely to natural hydrologic boundaries; therefore, the analyses presented therein examine a topographic area that is larger than the watershed boundaries of the Upper Deschutes Subbasin Assessment. The Upper Deschutes Subbasin Assessment examines 1,203 square miles of the Deschutes Basin while the USGS study area includes approximately 4,300 square miles in the Deschutes River drainage basin. Within the assessment of groundwater conditions and the interactions between surface water and groundwater in the Upper Deschutes Subbasin, the information presented will include the geologic and hydrologic USGS data.

Chemical Study of Regional Ground-Water Flow and Ground-Water/Surface-Water Interaction in the Upper Deschutes Basin, Oregon, Water Resources Investigation Report 97-4233 (USGS 1997) presents information regarding the water chemistry in the Upper Deschutes Basin. This study has compiled data for the same area of study as the USGS groundwater report. The boundaries for both studies are Jefferson Creek, the Deschutes River, and the Metolius River on the north end, the drainage divide between the Deschutes Basin and the Fort Rock and Klamath Basins on the south end, subsurface contact with the geologic John Day formation to the east, and the Cascade Range crest to the west.

9.3 Hydrogeologic Setting

The general hydrogeologic setting of the assessment area includes lava beds that sit on top of several hundred feet of volcanic and sedimentary rocks. The subsurface geology of the upper Deschutes Subbasin defines and directs the storage and flow of groundwater.

The type of subsurface rock and the levels of porosity and permeability within underground rocks direct how and where groundwater will flow. Porosity is based on the percentage of a rock that consists of air pockets or open space. Permeability is a measure of water's ability to move through the soil or rock. Geologic features that have large interconnected open spaces have little resistance to groundwater flow and are considered highly permeable. Rocks with very few, small or poorly connected open spaces have low permeability as they create blockages that stop or redirect groundwater flow (UDWC 2002).

Newberry Volcano, topographic sinking in the La Pine Basin, glacial and post-glacial deposition of sediments, and the expansion of the Mt. Bachelor chain of volcanoes have all contributed to the shaping of the upper Deschutes River. As Newberry Volcano grew, lava from the volcano relocated the river farther west than its original location east of Benham Butte. Simultaneously, the topography in the areas of La Pine, Crescent, Wickiup Reservoir, and Mt. Bachelor gradually sank about a half mile down (USDA 1996). In areas where the lava depth was great, the cooling was slower and tall vertical cracks, or columnar jointing, formed (Bastasch 1998). Although basalt itself is not very permeable, the fractures and joints between flows do allow a substantial amount of water to pass through (Bastasch 1998).

With the eruption Newberry Volcano 6,200 years ago came the Lava Butte Lava Flow. The lava flow created a high dam against Benham Butte, thereby impounding the water of the Deschutes River behind the lava dam. Water filled up a lake that extended back almost to Pringle Falls until the water topped out and began to flow through a lower portion of Benham Butte. Consequently, Benham Falls were formed and the river followed a channel along the west edge of the lava flow to Lava Island Falls. The old channel above Benham Falls was 60 feet deeper than the current channel and has slowly filled with sediment (USDA 1996).

The Deschutes River is primarily a spring-fed system. The springs that provide the Deschutes its water are the consequence of volcanic lava flows and the sedimentation from volcanic events and glacial activity. The volcanic rocks in the area have a high level of permeability that allows precipitation to sink easily into the ground and eventually reach the water table. As the groundwater reaches the sediments of the La Pine Basin, however; the low permeability of those sediments cause the water to rise back up to the surface, spilling out as springs (USDA 1996).

Several alluvial units have been identified in the project area, both along the river and overlying older rock units in places on the west side of the river. The alluvial units typically consist of varying amounts of sand, gravel, cobbles, and silt. Alluvial deposits west of the river are believed to be outwash from Pleistocene glaciers in the Cascades, deposited by ancestral streams flowing out of the Cascades, and are a source of much of the sand and gravel used in construction in the Bend area. Alluvial deposits along the riverbed are slightly younger, also composed of sand, gravel, cobbles and silt, and were deposited by the Deschutes River.

9.3.1 Hydrogeology

Much of the hydrology of the Upper Deschutes subbasin has been formed or modified by frequent geologic events throughout history. One vivid example of the connections between geology and hydrology in the area is in the southwestern part of the subbasin at Davis Lake. Approximately 5,500 years ago Odell Creek was dammed by a lava flow several hundred feet thick and Davis Lake was created. The lake currently has no surface outlet, but drains through porous lava openings at approximately the same rate that Odell Creek flows into it. It is believed that Odell Creek was previously hydrologically linked to the rest of the Upper Deschutes subbasin due to the common indigenous fish species including redband trout, mountain whitefish, and bull trout that were historically present in Odell Creek and in the Upper Deschutes.

Cindery soils are found throughout the subbasin. These coarse soils can support some vegetation; however, the nature of this material perpetuates a high erosive potential and makes vegetative growth or reforestation challenging. Soils in the Upper Deschutes Subbasin have varying amounts of Mazama pumice and ash. Surface accumulation of litter and duff on pumice and ash soils is relatively low (Beyer 1997). This layer provides a slightly higher water holding capacity than the Mazama ash and pumice, enhancing the productivity of the site in areas where tree roots reach this layer (Beyer 1997). These porous soils then rest upon glacial till, glacial outwash, and basaltic lava. Precipitation is easily absorbed and transferred through permeable rocks into subsurface systems resulting in extensive substantial groundwater exchange (Beyer 1997).

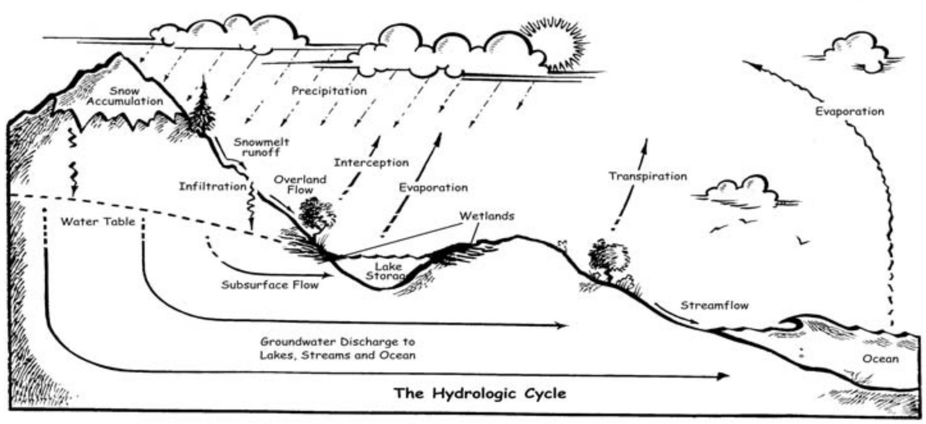
Throughout different parts of the subbasin, groundwater is recharged by Cascade precipitation, streams, and irrigation canals. Generally, groundwater flows from the High Cascades, downward through subsurface basalt fractures and volcanic and sedimentary materials, to eventually discharge into streams near Lake Billy Chinook. The High Cascades on the western side of the subbasin are a volcanic aquifer for the region. The Deschutes Basin aquifers are comprised of a sampling of late Miocene to Holocene lava flows, ignimbrites, and volcaniclastic sediments (USGS1998). Groundwater occurs in most rocks of the basin, but fractured lava, interflow zones, and coarse-grained volcaniclastic sediments are particularly productive water bearing units (USGS 1998). Groundwater recharge occurs when the water table is refilled with water percolating down from snowmelt or rain on the earth's surface. The High Cascades have a very high recharge rate from rain and snowmelt. Annual recharge is rapid, and water moves quickly down and through the aquifer. Groundwater levels also respond rapidly to changes in river levels and to irrigation canal seepage—even at depths greater than 600 feet (Bastasch 1998).

Most frequently, wells in the Bend-Redmond area tap down into the deeper volcanic and sedimentary rocks, but some are also developed through the surface lava beds. Yields from wells in the area may be as high as 2000 gallons per minute. Most municipal wells have yields in the 750 to 2000 gallons per minute range (Prowell 2003). The general water table trend ranges from approximately 500 or more feet deep at the City of Bend rising to 200-300 feet deep near Redmond. This is due to a northerly downward sloping trend in the ground surface elevation (USGS 2001).

9.3.2 Hydrologic Budget

The USGS *Ground-Water Hydrology of the Upper Deschutes Basin, Oregon 2001* report presents the most comprehensive data regarding the interactions between groundwater and surface water in the Upper Deschutes Subbasin. The report conclusively asserts that the combined hydrologic budget calculations and geologic data indicate that: "Virtually all groundwater not consumptively used in the Upper Deschutes Basin discharges to the stream system upstream of the vicinity of Pelton Dam. Moreover, virtually the entire flow of the Deschutes River at Madras is supported by groundwater discharge during the summer and early fall. Groundwater and surface water are, therefore, directly linked, and removal of groundwater will ultimately diminish stream flow" (USGS 2001).

Figure 4: A Generalized Hydrologic Cycle



Source: Watershed Professionals Network 1999

9.3.2.1 Groundwater Discharge

The main pathway through which water leaves the groundwater system in the Deschutes basin is through discharge to streams. Groundwater does discharge a small amount of water through pumping by wells, but this is almost insignificant when compared to the groundwater discharge to streams (USGS 2001). Traveling northward, a portion of the groundwater discharges to small spring-fed streams at mid-elevation and the remaining water flows in the subsurface to discharge to the Deschutes, Crooked, and Metolius rivers. Surface flow in the Deschutes River above Lake Billy Chinook is primarily groundwater discharge from April through November (USGS 1998).

Based on 1994 measurements taken by the Oregon Water Resources Department (OWRD), groundwater discharge is primarily responsible for the greater than 10-fold increase in Deschutes River streamflow from river mile 138 to 120. OWRD measured streamflow on the Deschutes River during May 1994 in an attempt to quantify natural gains and losses in the river between a stream-gaging station near river mile 164 at Bend just below Mirror Pond and a stream-gaging station near river mile 120, just downstream of the confluence of the Deschutes and Squaw Creek (OWRD, unpub. data 1994). Between river mile 164 and river mile 138, rates of flow remained rather constant with values ranging only from 35.5 cfs to 45.1 cfs. Compared to these moderate and relatively constant numbers, the 430 cfs that the streamflow in the Deschutes River increased by between river mile 138 and the stream-gaging station near river mile 120 is extremely dramatic (LaMarche 2002). Near river mile 123, Squaw Creek merges with the Deschutes and brings nearly 100 cfs of its own gained groundwater discharge (OWRD, unpub. data, 1992). Squaw Creek is responsible for most of the Deschutes River streamflow gain (126 cfs) between river mile 123.3 and the stream-gaging station near river mile 120. Contributions to streamflow in the Deschutes River from other tributaries (Tumalo and Deep Canyon Creeks) are relatively insignificant (USGS 1998). Consequently, the bulk of the 430 cfs gained in the Deschutes between river miles 138 and 120 is from groundwater discharge.

9.3.2.2 Groundwater Recharge

The groundwater flow system of the Upper Deschutes Basin is recharged by a combination of precipitation, canal leakage, infiltration of applied irrigation water that percolates below the root zone, and leakage from streams (USGS 2001). In the basin, there is a strong connection between precipitation quantity and groundwater recharge rates. Recharge from rain or snow takes place when water percolates through the soil and filters down to the groundwater flow system (USGS 2001). Due to large quantities of snowfall in the High Cascades, approximately 84 percent of recharge due to infiltration of precipitation in the Deschutes Basin occurs between November and April (USGS 2001).

Precipitation

Due to the fact that water occupies more volume as snow and ice than in its liquid form, Oregon's high annual snowpack plays an important role in defining the amount of water available for groundwater recharge. The snowpack that accumulates in the Cascades through the winter is a dense storehouse of large quantities of water. Multiple years of accumulating snows have formed glaciers on the Three Sisters in the northwestern part of the subbasin. Although they are small in area, each square foot of glacier can generate about 13 cubic feet of average annual water to contribute to ground-water recharge (Bastasch 1998).

> *The rain-enriched snowpacks melt into porous volcanic rocks and charge aquifers to the point where streams like the Metolius can spring practically full-blown from the earth* (Bastasch 1998).

The primary area of precipitation is the Cascade Range, with 30 to 60+ inches annually recharging groundwater levels. The foothills of the Cascades recharge groundwater at rates of 10 to 30 inches annually, and lower elevation areas east of the Cascades recharge groundwater at rates of less than 10 inches per year (USGS 1998). The amount of recharge from precipitation in the Upper Deschutes Basin is approximately 3800 cfs per year, or the equivalent to 5.5 Klamath Lakes (Prowell 2002).

9.3.2.3 Canals

The geology of the area surrounding and underlying a canal plays a primary role in the amount of canal leakage that will occur. The highest rates of leakage appear to take place in areas where the geology underlying canals consists of fractured basalt. Canal leakage in the Deschutes Basin accounted for 356,600 acre-feet, or 490 cfs of the 770,410 acre-feet (1,060 cfs) that was diverted into canals during the summer months in 1994. This amount is equal to 46% of the water that was diverted into canals of the upper Deschutes Basin that year (USGS 2001). Combined with on-farm losses, canal leakage may contribute almost 13% to annual groundwater recharge in the area (USGS 1998).

Canal Leakage

Moving east away from the Cascade Range, the area becomes more arid and canal leakage plays a more significant role as a source for groundwater recharge (USGS 1998). East of the Cascades, there is very little groundwater recharge from precipitation. However, there is a substantial amount of recharge from leaking irrigation canals north of Bend. Where the elevation of a stream is above that of the water table in adjacent aquifers, water can leak from the stream to the underlying strata and recharge the groundwater system (USGS 2001). So, a stream or a canal that is higher than the water table can recharge groundwater with leakage, or *seepage.*

The effects of canal leakage are found in the streamflow records for the Upper Deschutes Subbasin. The August mean flows of the lower Crooked River increased between the early 1900s and the early 1960s by approximately 400 to 500cfs. This amount paralleled the increase in the estimated canal leakage that occurred just north of Bend at the same time. A large proportion of the water lost from leaking irrigation canals north of Bend is discharging to the lower Crooked River upstream of the Opal Springs gage. This finding is consistent with the hydraulic-head distribution and the direction of groundwater flow in the area (USGS 2001).

On-Farm Losses

Evaporation, wetted canopy, wind drift, runoff, and deep percolation can all contribute to a loss of irrigation water, or what is referred to as an on-farm loss. Exact amounts of on-farm losses are difficult to calculate, but approximately 20% of water loss in the USGS study area was attributed to on-farm loss (USGS 2001).

One substantial contribution to on-farm losses in the Upper Deschutes Subbasin is the deep percolation that results from flood irrigation techniques. On-farm losses from deep percolation contribute to groundwater recharge. The mean annual recharge from deep percolation throughout the study area in years 1993-1995 was approximately 49,000 acre-feet (USGS 2001). However, the quantities of recharge vary greatly from district to district due to different irrigation methods. In areas where crops are irrigated by flood (surface) irrigation, the average irrigation application efficiency is approximately 40 to 50%. The average irrigation application efficiency for sprinkler irrigation is approximately 60 to 65%. Low pressure center pivot systems can attain 75 to 85% efficiency when properly managed (Ross 2003). Areas where flood irrigation is used tend to have a greater amount of groundwater recharge from on-farm water loss than do areas where sprinklers are the primary method for distributing irrigation water. For example, North Unit Irrigation District is almost entirely irrigated by sprinkler; and there is virtually no ground-water recharge from deep percolation on-farm losses in that area (USGS 2001). However, areas where flood irrigation is the primary method for delivering water to crops can have groundwater recharge rates up to 10 inches per year.

9.4 Groundwater and Surface Water Interactions

Measuring the effects of groundwater withdrawal on surface water flows is challenging, if not impossible, due to the large amount of natural variability in groundwater discharge. However, both hydrologic and geologic assessments in the area indicate that groundwater and surface water are inherently connected. From April to November, a majority of the flow in the Deschutes River just upstream from Lake Billy Chinook is due to groundwater discharge (USGS 1998).

9.4.1 Interbasin Transfer

In addition to recharge from precipitation, some groundwater recharge into the area occurs as a result of subsurface flow from adjacent basins. Groundwater inflow occurs along the Cascade Range crest in the Metolius River drainage and in an area northeast of Newberry Volcano. Approximately 50 cfs flows into the southeastern parts of the basin from the Fort Rock Basin (USGS 2001).

9.5 Population Growth and Water Supplies

Population growth is occurring generally alongside the expansion of Urban Growth Boundaries (UGB) of established cities throughout the Basin. The current land use planning laws of Oregon require a 20-year “supply” of buildable land to meet the projections of growth within a UGB. The availability of buildable land is contingent on being able to supply the necessary water and wastewater services. Therefore, growing Oregon cities need to plan on a secure 20-year horizon for municipal water supplies.

Surface water in the Deschutes subbasin has been allocated since the early 1900's and none is available for municipal supply. Groundwater is the water choice for new growth but it has recently been limited in the Deschutes Basin—it has been conditioned with providing mitigation water in equal amounts before any new groundwater is allowed to be certificated. Therefore, in order to meet the 20–year water supply law, water previously used for agriculture will need to be shifted to meet the needs of the new urban designations as they occur on formerly agricultural land. This can transpire in various ways including: 1) recapturing inefficiently used water through the conserved water statue by completing on- farm conservation projects, piping, and lining projects, or 2) expanding UGB's into existing irrigated land and transferring water rights of former agricultural use. The City of Bend's calculations show less water used per acre of urban land versus the same amount of irrigated agricultural land with current rate and duty allowances for agriculture in the Deschutes subbasin. Due to canal leakage and the extra water needed to charge canals and propel water to the end of long laterals, approximately 50% extra water currently needs to be diverted for agricultural water use (Griffiths 2002).

9.6 Data Gaps

- The Upper Deschutes Subbasin is one of the many subbasins located upstream from the Lake Billy Chinook region. Although both groundwater discharge and recharge for the entire region are known, values specific to the Upper Deschutes Subbasin have not been identified from the most recent USGS study. Similarly, groundwater flow between the subbasins within the region has not been characterized.
- Exactly how much, where, and when canal leakage returns to the river is not known.
- There are no close analyses of the spatial and temporal resolution of the channel gains and losses from the canals.

9.7 Key Findings

- Groundwater recharge occurs directly and indirectly from precipitation falling predominantly in the upper elevations of the subbasin. Subsequently, groundwater generally flows from the Cascades and Newberry Volcano areas of high elevation, precipitation, and permeable soils towards lower elevation and low precipitation areas.
- Groundwater discharge occurs where canyons intersect the water table, or where the groundwater encounters low permeability formations. This occurs near the basin outlet near Lake Billy Chinook and at the western boundary of the La Pine structural basin.
- Groundwater and surface water are directly linked as all groundwater eventually discharges to surface water either within the subbasin or into adjacent subbasins.
- Groundwater withdrawals will affect surface flows both within the subbasin and in neighboring subbasins. However, these effects are difficult to detect due to inherent complexity and measurement error and the large amount of natural variability in groundwater discharge compared to current groundwater withdrawal.
- Some groundwater discharged to surface water re-enters the groundwater system via infiltration of applied irrigation water and from channel leakage in stream and canals.
- Due to the porous geology of the subbasin, unpiped or unlined canals may leak approximately 50% of their water. Therefore, canals are a conveyance mechanism in which surface water is converted back to groundwater. This groundwater is then discharged in its entirety in the Lake Billy Chinook area.
- A large proportion of the water lost from leaking irrigation canals north of Bend is discharging to the lower Crooked River upstream of the Opal Springs gage.

Therefore, waters that would otherwise contribute to the instream flows of the Upper Deschutes River are actually contributing to the Crooked River flows.

- The City of Bend's current Urban Growth Boundary and the corresponding 20-year water supply plan will require additional water resources to meet growing urban needs. Increased groundwater use availability through surface water conservation and exchange, and stream restoration and mitigation projects are key to increasing the municipal water supply.

9.8 Recommendations

- Complete synoptic measurements at a finer spatial resolution to identify losses in canals. Combine this with other existing information on flow and loss data for streams and canals.
- Use the existing USGS groundwater model to identify the specific recharge and discharge values in the Upper Deschutes Subbasin.
- Conduct analysis and ongoing monitoring of the effects of groundwater pumping on the flows of nearby stream reaches.
- Raise awareness among community members about the interconnections between groundwater and surface water in order to promote the conservation of both.

10.0 SURFACE WATER QUANTITY

10.1 Critical Questions

1. What is the flood history in the watershed?
2. What impact have land uses in the basin had on high and low flows?
3. What was the historical flow regime?
4. What studies have been done on the relationship between flow and critical habitat conditions? What are the key findings in those studies?
5. What canals are located in the watershed?

10.2 Approach

Surface waters in the Upper Deschutes Subbasin are inherently valuable for multiple users and resources. Surface water supplies are also very limited and, therefore, close attention must be paid to the appropriate allocation of those resources for the needs of fisheries and fish habitat, municipal water supplies, irrigation, recreation, and watershed health.

This section will begin by examining the current and historic hydrology of the primary surface waters in the subbasin. The surface waters in the subbasin have been altered, managed, and diverted for irrigation and municipal use for the past century and the management regime of the surface waters in the area has played a role in affecting water quality, water quantity, and the overall health of the watershed. The hydrologic and biologic effects of water diversion and management will be discussed. The surface water quantity section will examine the minimum flows necessary to meet the parameters set by the *Upper Deschutes Wild and Scenic River Management Plan* as well as for the ongoing health of fisheries, other aquatic species, and the watershed as a whole.

10.3 Surface Water

10.3.1 Current Conditions

The primary surface water condition facing land, water, and resource managers in the Upper Deschutes Subbasin is the timing and quantity of minimum and maximum flows in the Deschutes River. The current flow regime as managed and controlled by the Oregon Water Resources Department is dramatically different than the natural historic river flows.

The Deschutes River is a spring-fed system that has historically had very stable flows. As opposed to river systems that are dominated by surface runoff, a spring-fed river like the Deschutes has an incredibly stable natural hydrologic regime in which daily, monthly, and even annual fluctuations in water flows are minimal. A 1914 U.S. Reclamation Service report refers to the Deschutes River as "one of the most uniform of all streams in the United States, not only from month to month, but also from year to year. The extreme minimum is usually in midwinter when it occasionally drops, for a few days only to (approximately) 1,100 cfs" (USDA 1996). A spring-fed system with such a stable flow regime, the Deschutes River and its tributaries have not been greatly affected by floods throughout history. There exists a high level of permeability within the volcanic rocks in the subbasin and this permeability allows rain and melting snow to quickly sink into the ground and recharge the water table. Therefore, flooding is much less common in the Upper Deschutes than in other less stable, less permeable systems.

Little Lava Lake is the source or the headwaters of the Deschutes River. The elevation at Little Lava Lake is 4,739 feet and the substrate varies from detritus to bedrock. Water in the lake is supplied by subsurface flows and springs on the north side of the lake. In extremely wet years, there is a surface connection between Little Lava and Lava Lake through an open channel (ODFW 1996). The source of recharge into the lake is primarily from the upslope groundwater. The groundwater originates in the snowfields of Mt. Bachelor and the Three Sisters mountains (Nielson et al. 1986).

The few tributaries on the upper Deschutes are Fall River, the Little Deschutes, Spring River, Tumalo Creek, and Squaw Creek. Fall River contributes 90 to 160 cfs, the Little Deschutes usually contributes between 140 and 350 cfs, and Spring River combines with nearby springs to add 180 to 210 cfs to the flow of the upper Deschutes (USDA 1996).

The historically stable flows of Deschutes River have been greatly altered in the past sixty years. Crane Prairie Dam regulated flows as early as 1922 and Wickiup Dam began influencing flows in 1945. Since that time, the Deschutes River has been a system modified and regulated in its water releases and flows. The river is managed year-round; water is stored in Wickiup and Crane Prairie during the winter in order to ensure sufficient water quantity for irrigation in the summer. Therefore, the amount of surface flow and the seasonal fluctuations of flow in the Deschutes River are directly related to the water needs and demands of the irrigation season. As managed and released out of Wickiup Reservoir, the average minimum flows during the summer is between 1,500 and 1,600 cubic feet per second (cfs) at Bend (USDA 1996).

10.3.2 Water Rights

The "Prior Appropriation Doctrine" governs the water laws in Oregon. It became apparent very early in the 1900's that water use and water appropriation were important and contentious issues. The Prior Appropriation Doctrine was passed in 1909 and asserted some basic guidelines and principles for the governance of water. This doctrine asserts that water rights are hierarchical in nature; the earlier a water right was allocated, the more senior that right is. The premise the doctrine is based on is "first in time, first in right," with all water ultimately belonging to the state. The Prior Appropriation Doctrine basically asserts that:

- Water belongs to the public.
- The state assigns the right to use water.

- Water rights follow a strict hierarchy: Those with earlier priority dates get their water before any junior right.
- Water permits are issued only for beneficial uses without waste (McNamara 1999).

Therefore, in the event that there is a low water year and there is insufficient water to go around, someone holding a junior water right might not receive water that year. Water rights are considered appurtenant to the land for irrigation or for domestic, municipal, or industrial uses but may be severed from the land if allowed by the Oregon Water Resources Department (OWRD). Instream flow rights may be protected by the State by reservation. Oregon's current water code contains the following basic provisions:

- Surface water or groundwater may be legally diverted only if used for a beneficial purpose.
- The more senior a water right, the longer water is available during a time of shortage.
- A water right is attached to the land where it was established, as long as the water is being used. If the land is sold, the water right goes with the land to the new owner.
- A water right is valid as long as it is put to beneficial use once every 5 years. After 5 years of non-use, the right is considered forfeited (USDI/OWRD 1997).

Water rights to divert and use waters of the Deschutes River were allocated until 1913. In 1913 the State Engineer, now the Oregon Water Resources Department, withdrew the Deschutes River above Bend from further appropriation.

In 1987, the passage of the Instream Water Rights Act (ORS 537.348) recognized instream water flows as being a beneficial use of water. The Act provides three ways to create instream water rights. Two of these options are initiated by state agencies and result in the creation of instream water rights with relatively junior water rights. The third option allows private parties to create instream rights by purchasing, leasing, or accepting a donation of existing water rights for conversion to instream rights, with the same priority date as the original rights. The older the priority right, the better the chance that the water will remain instream during the irrigation season.

Table 20 presents each irrigation district that currently draws water out of the upper Deschutes River. Arnold, Central Oregon, Swalley, and North Unit draw water directly out of the Deschutes, Walker Irrigation District draws water out of the Little Deschutes River, a major tributary of the Deschutes, and Lone Pine receives water from North Canal, which draws directly from the Deschutes (OWRD 2001).

With some exemptions allowed for specific minor uses, water right permits are required for all surface water and groundwater use in the Upper Deschutes Subbasin. Exemptions for surface water use include: the use of a natural spring that does not form a natural channel that flows off the land, stock watering when used directly from the source without any modifications to the source, and water use for salmon egg incubation projects. Exemptions for groundwater use include: stock watering, lawn irrigation for less than one-half acre, domestic water use under 15,000 gallons per day, industrial or commercial uses not exceeding 5,000 gallons per day, heat exchange uses, and school ground watering under 10 acres (USDI/OWRD 1997).

Water rights also allow for domestic and stockwater runs during the winter months for irrigation districts. A 1930 Supreme Court decision allows simultaneous winter runs on some irrigation canals (Nielson 1986).

Table 20 lists the water rights, priority dates, quantity of water diverted, and dates of usage for the water diversions above the City of Bend.

Table 20: Water Rights for Diversions Above the City of Bend

	Period------------->>>>	1	2	3	3	3	3	3	4	5
District & Date	*Description*	*April 1-30*	*May 1-14*	*May15-31*	*June*	*July*	*Aug*	*Sept 1-14*	*Sept 15-30*	*Oct 1-31*
Lone Pine 1900	Max Rate (cfs)	25	31	38	38	38	38	38	31	25
	Volume/Period (ac-ft)	1458	916	1215	2279	2355	2355	1140	916	1506
	Total for Month (ac-ft)	**1458**	**2132**		**2279**	**2355**	**2355**	**2056**		**1506**
Swalley 1899	Max Rate (cfs)	55	73	121	121	121	121	121	73	55
	Volume/Period (ac-ft)	3255	2163	3827	7176	7415	7415	3588	2163	3363
	Total for Month (ac-ft)	**3255**	**5990**		**7176**	**7415**	**7415**	**5751**		**3363**
Arnold 1905	Max Rate (cfs)	87	113	136	136	136	136	136	113	87
	Volume/Period (ac-ft)	5147	3362	4316	8093	8362	8362	4046	3362	5319
	Total for Month (ac-ft)	**5147**	**7678**		**8093**	**8362**	**8362**	**7408**		**5319**
North Unit 1913	Max Rate (cfs)	1101	1101	1101	1101	1101	1101	1101	1101	1101
	Volume/Period (ac-ft)	65514	32757	34941	65514	67698	67698	32757	32757	67698
	Total for Month (ac-ft)	**65514**	**67698**		**65514**	**67698**	**67698**	**65514**		**67698**
COID 1900	Max Rate (cfs)	564	752	989	989	989	989	989	752	564
	Volume/Period (ac-ft)	33560	22374	31386	58850	60811	60811	29425	22374	34679
	Total for Month (ac-ft)	**33560**	**53760**		**58850**	**60811**	**60811**	**51798**		**34679**
COID 1907	Max Rate (cfs)	0	0	401	401	401	401	401	0	0
	Volume/Period (ac-ft)	0	0	12726	23861	24657	24657	11931	0	0
	Total for Month (ac-ft)	**0**	**12726**		**23861**	**24657**	**24657**	**11931**		**0**
Walker 1897	Max Rate (cfs)	9	9	14	19	19	16	10	10	10
	Volume/Period (ac-ft)	564	282	428	1129	1167	973	283	283	584
	Total for Month (ac-ft)	**564**	**710**		**1129**	**1167**	**973**	**565**		**584**
Walker 1900	Max Rate (cfs)	1	1	1	2	2	2	1	1	1
	Volume/Period (ac-ft)	60	30	44	104	108	92	30	30	61
	Total for Month (ac-ft)	**60**	**74**		**104**	**108**	**92**	**60**		**61**
Walker 1902	Max Rate (cfs)	8	8	12	16	16	13	8	8	8
	Volume/Period (ac-ft)	476	238	381	952	984	820	238	238	492
	Total for Month (ac-ft)	**476**	**619**		**952**	**984**	**820**	**476**		**492**

Source: La Marche 2001

10.3.3 Irrigation Districts

The irrigation season generally runs from April 1 through October 31. Each irrigation district has water rights that vary in amount and priority. There are six irrigation districts that divert water near Bend to irrigate 94,340 acres in and outside of the subbasin. Table 21 presents each of the primary irrigation canals in the subbasin, the quantity of water diverted in each district, the acreage for irrigated areas in the districts, the mean water requirement per district, the quantity of crop water needs, the mean irrigation efficiency per district, the estimated quantity of water deliveries per district, and the amount of water lost due to canal seepage in each district. As of 1994, North Unit Irrigation District's canal had the highest percentage of irrigation efficiency at 94%, followed by Lone Pine at 89% efficiency, Tumalo Irrigation District at 60%, Swalley Irrigation District at 51%, Arnold Irrigation District at 50%, and finally Central Oregon Irrigation District's main canal with 43 % and their Pilot Butte Canal with 43% efficiency (USGS 2001). It is significant to note that a total of 313,930 acre-feet of water was lost through canal leakage in these canals in 1994.

Table 21: Canals, Irrigated Acreage, On-farm Deliveries, and Canal Leakage

Canal diversions, irrigated acreage, on-farm deliveries, and canal leakage in 1994
(Adapted from 2001 USGS Groundwater Study)

	A	B	C	D	E	F	G
Canal	**Canal diversions (acre feet)**	**Irrigated area (acres)**	**Mean crop-water requirement (ft/yr)**	**Crop-water needs (acre-feet)**	**Mean irrigation efficiency (percent)**	**Estimated Deliveries (acre feet)**	**Canal losses (acre feet)**
Arnold	**26,570**	**2,310**	**2.25**	**5,200**	**0.5**	**10,400**	**16,170**
Central Oregon	**181,500**	**22,500**	**2.37**	**53,330**	**0.43**	**124,020**	**57,480**
North Unit	**196,700**	**45,000**	**2.03**	**91,350**	**0.94**	**97,180**	**99,520**
Tumalo	**42,600**	**4,890**	**2.31**	**11,300**	**0.6**	**18,830**	**23,770**
Pilot Butte	**165,800**	**14,800**	**2.36**	**34,930**	**.43**	**81,230**	**84,570**
Lone Pine	**10,640**	**2,390**	**2.13**	**5,090**	**0.89**	**5,720**	**4,920**
Swalley	**38,700**	**2,450**	**2.33**	**5,710**	**0.51**	**11,200**	**27,500**
Total	**662,510**	**94,340**		**206,910**		**348,580**	**313,930**
Average			**2.25**		**0.61**		

**** All values in acre-feet unless otherwise noted.***
Source: USGS 2001

The irrigation district canals that are located in the Upper Deschutes Subbasin are Arnold Canal, Central Oregon Canal, Bend Feed Canal, Columbia Southern Canal, Tumalo Feed Canal, North Unit Main Canal, North Canal, and Swalley Canal. Only a part of Columbia Southern Canal is still used by Tumalo Irrigation District. Figure 5 presents the primary irrigation diversions located in Central Oregon.

10.3.3.1 Conservation Projects

There have been many conservation projects proposed and undertaken as ways to conserve water in the subbasin. One of the irrigation districts in the subbasin is Tumalo Irrigation District (TID). TID withdraws water from Tumalo Creek. The first diversion ditch for TID was built in 1914 and operates between July and October of most years. Diversion of water for irrigation purposes and municipal water use have altered the natural flow regimes in both Bridge Creek and Tumalo Creek. In order to address the high water losses that are linked to the fractured basalt and lava tubes that are a part of

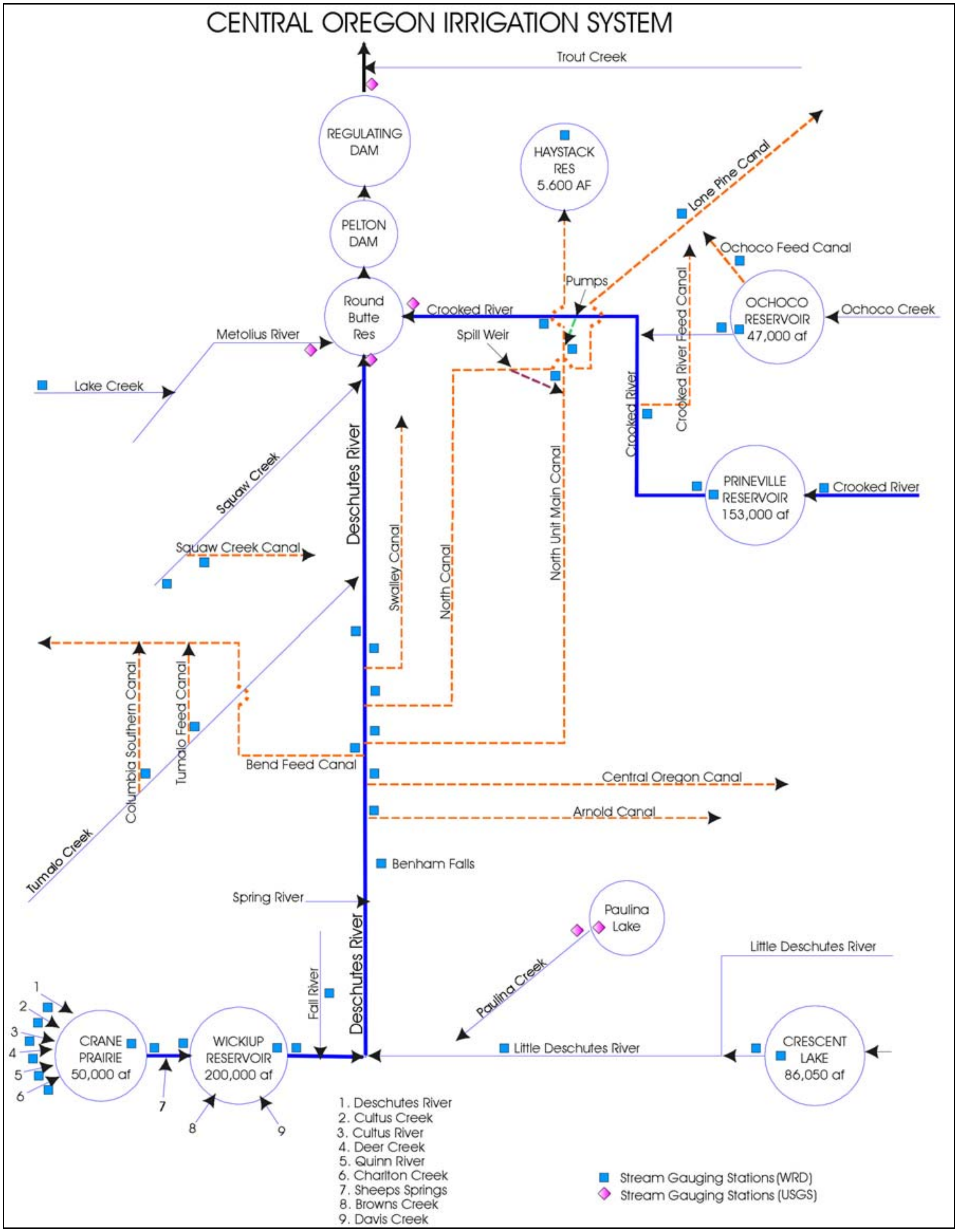


Figure 5: Central Oregon Irrigation System
Source: OWRD 2001

the geology of the area, TID has been converting its open distribution canals to underground pressurized pipelines. The purpose of these pipelines eliminate water seepage, reduce delivery time, provide enough water to meet irrigation needs in drought years, and guarantee minimum instream water levels in Tumalo Creek. The piping projects will assist TID in putting 5.8 cfs of senior water rights back into Tumalo Creek and 11 cfs of junior water rights that will be placed instream when enough water is available. TID's conservation piping projects won the U.S. Bureau of Reclamation Regional Director's Water Conservation Award for 2001. The funding for TID's conservation projects came from a variety of sources including the Deschutes Resources Conservancy, U.S. Bureau of Reclamation, Oregon Watershed Enhancement Board, and Tumalo Irrigation District.

Oregon state law contains the Conserved Water Statute. This is a voluntary program that provides incentives for water rights holders to conserve water. The statute allows water users who file a conservation proposal with the state to use, sell, or lease up to 75 percent of the water they conserve. The statute requires that at least 25 percent of the conserved water be allocated to the state and legally protected for instream use. Before the passage of the Conserved Water Statute, water laws basically applied the "use it or lose it" premise to water rights.

10.3.4 Irrigation Management

The Deschutes Soil and Water Conservation District (SWCD) has as its mission: "to make available to local landowners and the general public the technical, educational, and financial assistance needed to provide for the conservation of the district's natural resources." In order to attempt to do this effectively, the SWCD is developing a working partnership with local landowners to create and Irrigation Water Management (IWM) Program. The objectives of the IWM are to provide greater on-farm irrigation efficiency, improve on-farm and irrigation delivery systems, and eventually dedicate a portion of the saved water to instream flows (Ross 2003).

Expressed as a percentage, the ratio of the depth of irrigation water used by the plant to the depth of irrigation water applied is referred to as irrigation efficiency. Efficiency rates range from 60 to 65% efficiency when sprinklers are used down to 35 to 50% efficiency with flood irrigation. (Appendix III).

The Deschutes SWCD estimates that a 25% water use reduction can occur with on-farm irrigation improvements in the Deschutes Basin. Improvements in distribution facilities, equipment and hardware, and operations and management can include: improving delivery and distribution facilities, converting surface irrigation to sprinklers, modifying irrigation system operation, scheduling irrigation more efficiently, and providing adequate maintenance to sprinkler system hardware. Some very specific suggestions made by the Deschutes SWCD are to:

- Replace worn nozzles that discharge greater than design flows
- Use appropriate operating pressure at the sprinkler head
- Replace non-functioning sprinkler heads

- Use flow control nozzles on fields with elevation differences greater than 20-40 feet
- Use a flow meter or weir to measure delivery flows
- Maintain trash screens to prevent plugging pumps and nozzles
- Line existing ponds and sump pumps that have high seepage losses
- Convert surface, or flood, irrigation systems to sprinkler irrigation

10.3.5 Hydroprojects

Central Oregon Irrigation District currently owns and operates a hydroelectric plant on the Upper Deschutes River. The project was completed in 1989 and supplies 6 megawatts of electricity, or enough electricity to power roughly 2,200 homes. Deschutes river water is diverted from the Central Oregon Canal into the hydroplant to generate the electricity. Once the water has been run through the plant, the water is returned to the river.

10.3.6 Streamflow

In the Upper Deschutes Subbasin, during the irrigation season, stream flows are impacted more by water withdrawals than by natural run-off. Although several tributaries add flow to the Upper Deschutes River, most of the mainstem flow is regulated by releases from Crane Prairie Reservoir and Wickiup Reservoir. Additionally, a large amount of flow is diverted from the Deschutes River via the six canals previously discussed. Since the majority of flows are released from the reservoirs, the Upper Deschutes River does not exhibit the same gradual diminishment in flows over the summer as one sees in streams which are recharged from snowmelt.

Low flows as released from Wickiup Reservoir occur in the Upper Deschutes River during the fall, winter, and early spring in the reaches below the storage facilities. Water diversions from the Deschutes River irrigate agricultural lands far beyond the subbasin boundary, extending even as far as Lone Pine to the northeast, in the Crooked River Watershed. Because of these highly manipulated water releases during the summer, the Deschutes River experiences high flows as well as large fluctuating daily and monthly flows. From November to March, the storage season, flows in the Deschutes River just below Wickiup Reservoir can drop to as little as 20 cfs. Conversely, during the irrigation season from April to October, the river averages approximately 1200 cfs as water is released from Wickiup Reservoir (Breuner 2003).

Table 22 shows the median monthly discharge measured at two gauges between the years 1970 and 2000, one above and one below major water diversions. The percentage of median monthly flow describes the amount of water diverted from the Deschutes River in a given month for irrigation use. The flows measured at the Benham Falls gauge are the highest summer time flows for this segment of the river because they include the combined releases from both reservoirs and the flows from the tributaries. In contrast, the flows measured at the OWRD gauge below Bend represent the lowest flow conditions observed on this reach of the Deschutes River (Breuner 2003).

Table 22: Median Monthly Discharge (cfs) of the Deschutes River.

Gauge station	APR	MAY	JUN	JUL	AUG	SEP
Deschutes River at Benham Falls (river mile 182)	1360	1890	2222	2330	2150	1810
Deschutes River below Bend (river mile164)	93	39	34	33	31	34
Percent diverted flow	63%	85%	90%	91%	92%	89%

Source: Breuner 2003

On average, 90% of the water is diverted from the Deschutes River during the high withdrawal months of June through September.

Between the City of Bend and Lake Billy Chinook, the Deschutes River exhibits a flow regime that is essentially opposite of the Upper Deschutes River above Bend. Stream flows in this reach are impacted by both the upstream water withdrawals in Bend and by inflows from two tributaries and springs. The two tributaries, Tumalo Creek and Squaw Creek are located at RM 160.2 and RM 123 respectively. There is a large spring complex, beginning at Steelhead Falls at RM 127.8 and continuing to the inflow of Lake Billy Chinook, which adds a significant amount of groundwater into the Deschutes River (Breuner 2003).

Lower than natural flows occur in the summer for the Deschutes River below Bend and Tumalo Creek below Tumalo Feed Canal (TFC). The current minimum target flows set by the Oregon Water Resources Department for the reaches depleted of water are a mixture of water rights, inter-district agreements, and instream leases. There are some *instream* water rights, or rights for water to remain in the stream or river, for some of the depleted reaches, but these rights are of junior priority so they do not have any current effect on instream flows.

Target minimum flows in the Deschutes River below Bend are based on the irrigation districts verbal agreement to maintain flows 35 cfs. Target minimum flows for the Deschutes below Crane Prairie are 30 cfs and are based on irrigation district verbal agreements and instream leases. For Tumalo Creek below the Tumalo Feed Canal, the target minimum flow is 2.5 cfs and is also based on verbal irrigation district agreements and instream leases. Target flows below Wickiup Reservoir are set at a minimum of 20 cfs for fisheries under the Wickiup Reservoir storage right (OWRD 2001). These minimum flows are quite a bit lower than those recommended by the Upper Deschutes Wild and Scenic River Record of Decision to protect river values. The adaptive management minimum flow selected as the long-term instream flow target is 300 cfs released out of Wickiup Reservoir (USDA 1996).

10.3.7 Impacts on Water Quality and Fish

The unnatural extremely low winter flows and sustained high summer flows are of hydrologic and biologic concern. The low flows, or dewatering of the river in the winter can lead to the degradation of fish habitat, exposure of redds, decrease in water supply for macroinvertebrates, limitation of water access for vegetation, and streambed exposure that can lead to a dramatic increase in sedimentation and turbidity upon water releases. When the flows are ramped up in the spring, the rapid increase of flow and water quantity force large amounts of sediment into and down the river by scouring the dry stream banks.

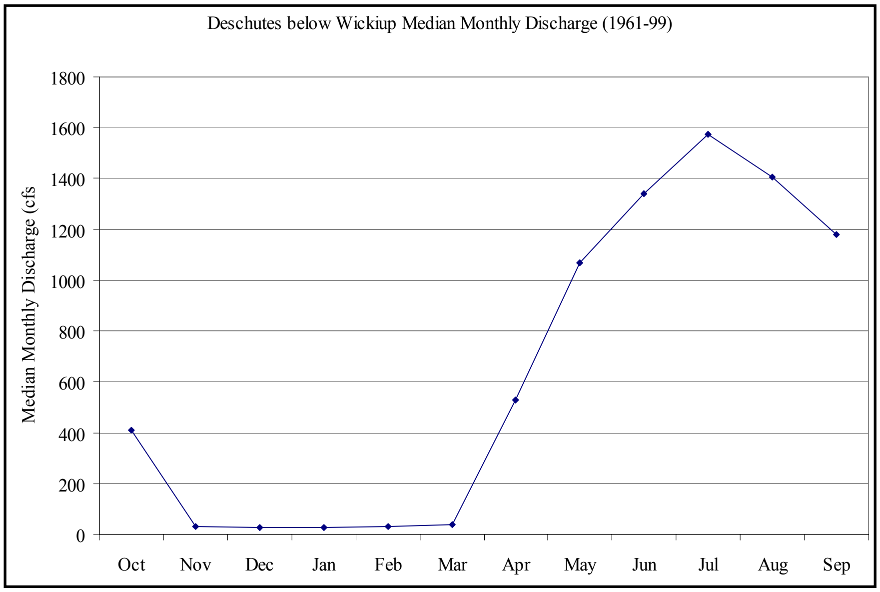
Lower flow levels in the upper Deschutes River occur during the winter months at the same time that pumice soils are vulnerable to frost heave and loosening. The sustained, above-normal flows in the summer months create velocities that contribute to stream bank erosion of the previously loosened soils and move eroded bank material downstream. In addition, the longer sustained duration of higher-than-normal flows during the irrigation season means that the bank area is subject to the forces of moving water for a longer period of time than under natural conditions. The upper Deschutes River above the City of Bend is a low energy or low gradient reach of the river so sediment transport capability is minimal and the stream responds to the increased sediment load through deposition and accelerated lateral migration.

A stream bank erosion survey conducted in 1978 from Wickiup Dam downstream to below Benham Falls estimated that stream bank erosion rates generally range from zero to two inches per year. At many locations, however, rates jumped up to eight inches per year. No attempt was made in the survey to quantify how much of the stream bank erosion is the direct result of the altered flow regime (Nielson et al. 1986).

The Oregon Water Resources Department (OWRD) and the U.S. Bureau of Reclamation (BOR) partnered together to create *The Upper and Middle Deschutes Basin Surface Water Distribution Model, Open File Report #SW02-001.* The report characterizes the historic and current condition of stream flow and water storage in addition to modeling the optimum allocation of water for both irrigation and instream flows.

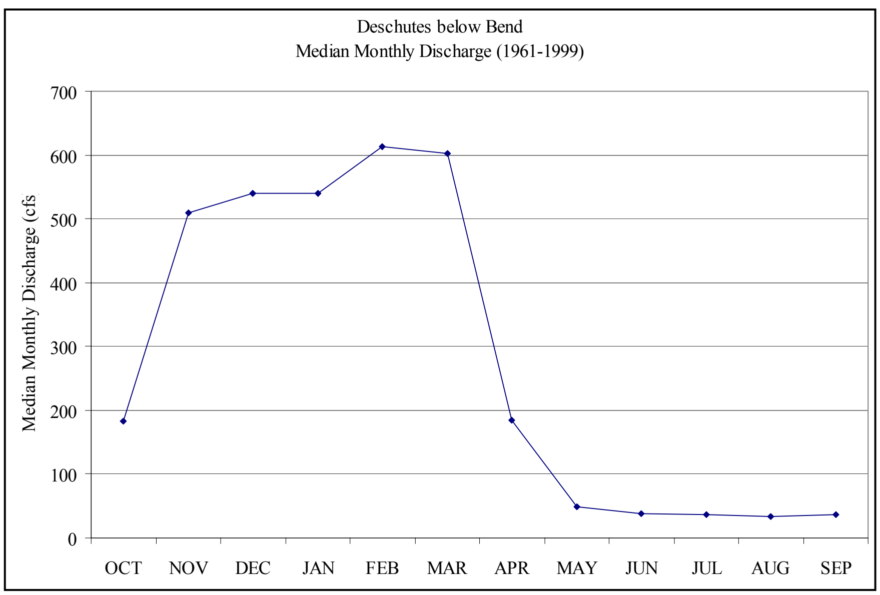
The median ratio of summer to winter flows from 1961 through 1999 is 1500 to 30 cfs below Wickiup reservoir (Figure 6) and roughly 30 to 600 cubic feet per second (cfs) below Bend (Figure 7). The swing between the maximum and minimum flows in these sections of the Deschutes is dramatic when compared to the natural stable hydrograph of the river. As currently managed, the minimum flows are substantially lower than they were historically. According to the Oregon Water Resources Department, "increasing flows in these reaches during low flow periods would benefit both the aesthetics and ecology of the river." (OWRD 2001).

Figure 6: Median Monthly Discharge Below Wickiup Reservoir



Source: OWRD report #SW02-001

Figure 7: Median Monthly Discharge Below Bend



Source: OWRD report #SW02-001

10.3.8 Adaptive Flow Management Strategy

The Upper Deschutes Wild and Scenic River Management Plan presents an adaptive flow management strategy that seeks to maintain off-stream beneficial uses while improving instream beneficial uses of the waters of the upper Deschutes River (USDA 1996). The river values that the management strategy seeks to protect and improve include the quality of the water instream, but also the quality of the stream banks and wildlife habitat in the adjacent riparian zone. Specifically, the long-term goal of the Wild and Scenic Management Plan is to maintain instream water quantity at flow levels that preserve and enhance the Outstandingly Remarkable Values defined within the Wild and Scenic Rivers Act. These values and the goals identified for achieving them are to:

- Preserve the geologic values of the Deschutes by maintaining erosion rates along the stream banks that more closely resemble a natural range.
- Enhance aquatic and riparian vegetation to both protect the river channel from erosion and to provide cover and food for fish and macroinvertebrates.
- Enhance the hydrologic value by improving water quality within the river.
- Enhance fisheries with an increase in sustained annual water quantity and habitat quality.
- Improve wildlife values by maintaining stream flow adequate for osprey and eagle prey, enhancing habitat conditions for waterfowl, songbirds, and furbearers.
- Improve the winter scenic value of the river by keeping more water instream.
- Increase recreation values on the Deschutes by maintaining flow levels that open the river up to year-round navigation (USDA 1996).

10.3.9 Municipal Water Use

For it's municipal water supply, the City of Bend uses surface water from Bridge Creek and spring water that would otherwise flow into the Middle Fork of Tumalo Creek. The Bridge Creek watershed is 3,200 acres of spring-fed drainage area. The spring water is diverted through a ¼ mile earthen canal into Bridge Creek.

The City of Bend began using surface water from Bridge Creek in 1926 with the construction of Overturf Reservoirs and the intake structure. In 1955, in response to community growth a small diversion was constructed to divert water from a major spring complex into Bridge Creek along with the construction of an additional pipeline and the 5 million gallon underground concrete reservoir on Awbrey Butte. There have been no increases in surface water sources since 1955. The City of Bend holds rights to 13.6 millions gallons per day from Bridge Creek. Hydraulic constraints of the intake pipes and receiving reservoirs limit daily withdrawal to 10.6 million gallons per day. The City uses about 4.6 million gallons per day of surface water in the winter and 10 million gallons per day in the summer for a yearly average of nearly 6 million gallons per day. Surface water makes up about 50% of the total water delivered by the City (Prowell 2003).

Municipal water is withdrawn just upstream of the confluence with Tumalo Creek. The withdrawn water is piped into storage tanks where it is treated with chlorination before it is delivered to city users. Before chlorination treatment occurs, any surplus water in the municipal system is released into Tumalo Creek near Shevlin Park. In order to protect the water supply, access in the Bridge Creek watershed is restricted to trails only. There are no motorized vehicles, no camping, no fires, no bicycles, and no domestic animals allowed.

In addition to its surface water supply from Bridge Creek, the City of Bend also utilizes six groundwater well fields. With well depths ranging from 400 to 1,000 feet, the groundwater from these wells is also of very high quality. The wells are primarily used to meet increased demands during high usage in the summer. The wells are also used as a source of municipal water at times when the surface water quality is unacceptable due to snowmelt or precipitation (City of Bend 2001).

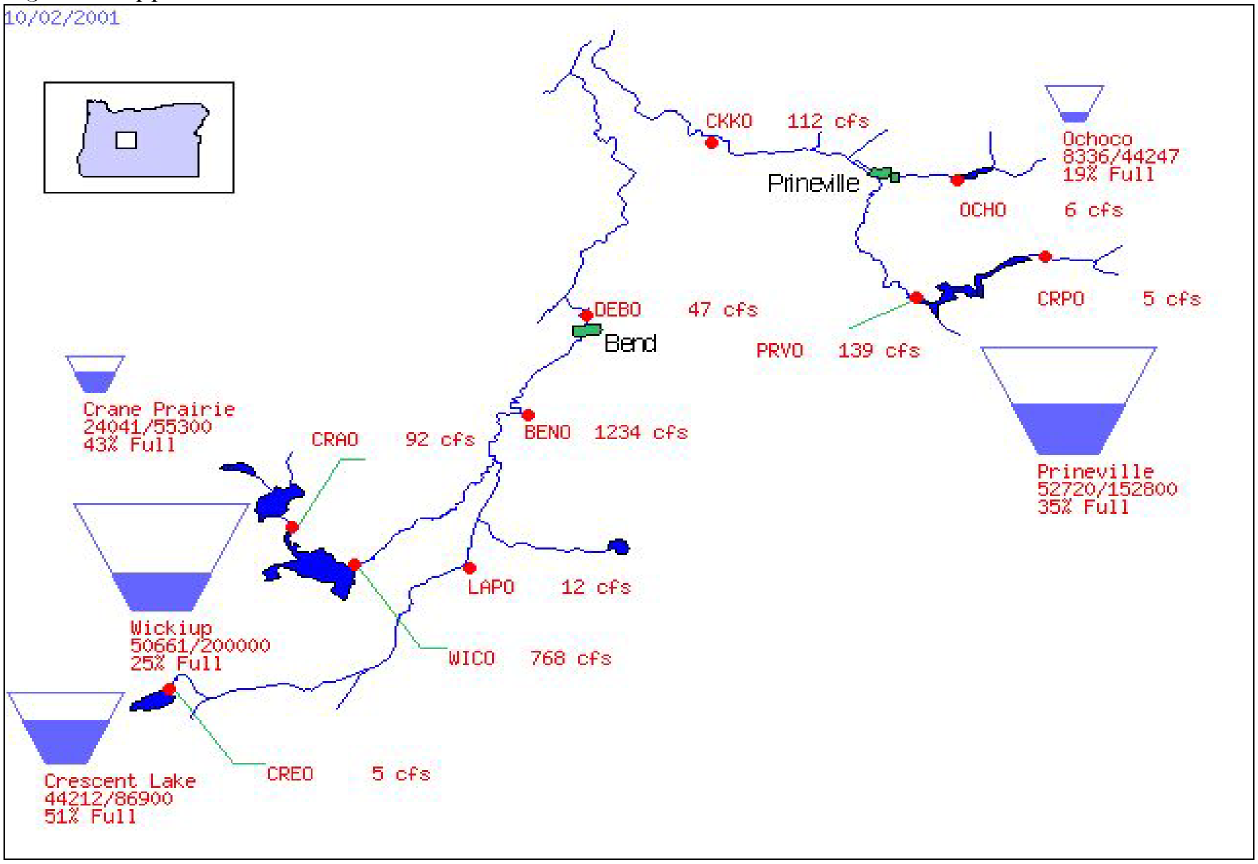
The City of Redmond uses groundwater exclusively for its municipal water supply. Average use in the winter is 1.7 million gallons per day and in the summer is 5.5 million gallons per day. A peak day in the summer might reach 10 million gallons used (Dorning 2002).

10.3.10 Water Storage

Crane Prairie and Wickiup are two reservoirs that sit near the headwaters of the Deschutes River. Crane Prairie is located 13 river miles downstream from Little Lava Lake and Wickiup Dam is an additional 15 river miles down from Crane Prairie. Crane Prairie is an earthfill dam that is 285 feet long and 36 feet high. The reservoir can hold 55,300 acre-feet of water (BOR 2003). The larger of the two, Wickiup Reservoir began filling in 1942 with 20,000 acre-feet originally impounded. The capacity of the reservoir was increased until the maximum storage capacity of 200,000 acre-feet was reached in 1949. The water is stored for irrigation purposes and water storage rights belong to the North Unit Irrigation District. Wickiup Dam is a 2.5 mile long, 100 foot tall earthfill structure with a rock-face (BOR 2003).

Figure 8 displays the primary reservoirs impacting the Upper Deschutes River flows. The depiction was a created for a modeling report by the Oregon Water Resources Department at the end of irrigation season in 2001. In October of that year Crane Prairie held 24,041 acre-feet (43% of its capacity) and Wickiup held 50,661 acre-feet (25% of its capacity). Not shown in Figure 8 are the City of Bend's thirteen storage reservoirs for municipal water use.

Figure 8: Upper and Middle Deschutes Basin Reservoirs



Source: OWRD 2001

10.4 Data Gaps

- More research is needed regarding the shallow hydrogeologic interaction between the river and canals near the canal diversion points.
- A close analysis of how much canal leakage enters the groundwater system to later return to the river is needed.
- There are no close analyses of the spatial and temporal resolution of the channel gains and losses both from the river and the canals.

10.5 Key Findings

- Low wintertime stream flow levels play a major role in impacting the resource conditions of the Upper Deschutes River between Wickiup Reservoir and the City of Bend by degrading riparian conditions, reducing high quality fish habitat, and diminishing water quality.
- Low summertime flow levels play a major role in impacting the water quality and aquatic resource conditions of the Deschutes River between the City of Bend and Lake Billy Chinook by dewatering fish habitat and increasing stream temperatures.

- High water springtime releases from Wickiup Reservoir can scour sediment from loose stream banks to increase the turbidity levels in the river.

10.6 Recommendations

- Initiate a program that will work to improve and increase minimum wintertime flow levels as identified by the Oregon Department of Fish and Wildlife in the Upper Deschutes River between Wickiup Reservoir and the City of Bend.
- Initiate river mitigation programs to assist the cities of Deschutes County in obtaining future municipal groundwater supplies and maintain minimum summertime flow levels in the Middle Deschutes river below the City of Bend that are consistent with the levels identified by the Oregon Department of Fish and Wildlife as necessary to protect fish and wildlife habitat.
- Support current and future methods to improve the efficiency of water delivery systems. Support canal piping projects that comply with Oregon's conserved water statute.
- Continue to increase public understanding of the connections between water quantity and water quality conditions.
- Research connections between water conservation measures and water storage in Wickiup Reservoir.

11.0 SURFACE WATER QUALITY

11.1 Critical Questions

1. What are the designated beneficial uses for streams in the watershed?
2. What are the water quality criteria that apply to streams in the watershed?
3. Are there any 303 (d) listed streams in the watershed?
4. What role does water management play in water quality in the watershed?
5. Are any stream reaches identified as high-quality waters or Outstanding Resource Waters?
6. Do any current water quality studies or evaluations indicate that water quality in the watershed has been degraded or is limiting beneficial uses?

11.2 Approach

The surface water quality section presents the factors contributing to or being affected by water quality in the Upper Deschutes Subbasin. The majority of the information is derived from documents and research from the Oregon Department of Environmental Quality Natural Resources Specialist Bonnie Lamb, and Water Quality Specialist Nancy Breuner. The primary water quality concern in the majority of the water bodies of the Upper Deschutes Subbasin is temperature. Stream temperatures that are higher than normal create inhospitable fish habitat conditions and can create or exacerbate additional water quality issues.

11.3 Water Quality

Water quality is affected by many factors: natural background levels of nutrients and sediment, soil types, hydrology, geomorphology and anthropogenic causes such as point and non-point sources of pollution. Past and present forest, agricultural and urban land use practices have contributed to poor water quality conditions (Breuner 2003). These conditions resulted in the listing of many stream segments on ODEQ's water quality impaired list.

11.3.1 Water Quality Standards and Beneficial Uses

Passed in 1972, the Federal Water Pollution Control Act, also referred to as the Clean Water Act, aims to restore and preserve the chemical, physical, and biological integrity of the nation's waters. Oregon has integrated the goals of the federal Clean Water Act into state Water Quality Standards. Implementation and enforcement of the Clean Water Act now rests with the U.S. Environmental Protection Agency (EPA).

The Federal Clean Water Act with the goal of restoring and preserving the chemical, physical, and biological integrity of the nation's waters. The Act directs the states to adopt and review water quality criteria as necessary to protect beneficial uses of waters of the state. Each state is then supposed to evaluate water bodies in the state and compile a list of all of the water bodies that do not meet the state's water quality standards. These standards are described using both numeric criteria and narrative statements. The water bodies that do not meet the standards are considered to be *water quality limited* and are placed on the state's 303(d) list (called the 303(d) list from Section 303(d) of the Clean Water Act). Each state must then set Total Maximum Daily Load (TMDL) allocations for each waterbody included on the 303(d) list. The TMDLs describe the maximum amount of pollutants (from all sources) that may enter a specific water body without violating water quality standards.

In an attempt to achieve the goals of the Clean Water Act, the Oregon Department of Environmental Quality (ODEQ) acts as the state arm of enforcement and regulation for the EPA. ODEQ has defined certain water quality standards which include the beneficial uses for streams, the criteria needed to protect beneficial uses, and the methods and policies that should be used to implement the standards. The beneficial uses listed in Table 23 are the specific uses for which water should be protected in the Deschutes. Aquatic life, particularly salmonid spawning and rearing, is considered one of the most sensitive beneficial uses in the subbasin (Lamb 2003).

Table 23: Beneficial Uses of Water Protected in the Deschutes Basin.

Beneficial Uses: Deschutes River Basin (OAR 340-41-562)	
Public Domestic Water Supply*	Resident Fish & Aquatic Life
Private Domestic Water Supply*	Wildlife and Hunting
Industrial Water Supply	Fishing
Irrigation	Boating
Livestock Watering	Water Contact Recreation
Anadromous Fish Passage	Aesthetic Quality
Salmonid Fish Rearing	Hydro Power +
Salmonid Fish Spawning	

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

\+ Applies to the Deschutes mainstem from the Pelton Reregulation dam to the Bend Diversion dam.

Source: ODEQ 2003

As a way to protect the beneficial uses of state's water, certain water quality criteria have been defined. These criteria are described using both numeric criteria and narrative statements. Numeric criteria are established when it is feasible to identify specific numbers or limits that will protect these uses. Narrative criteria are applied when it is illogical to set specific numeric targets at a regional or statewide level. Therefore, the criteria for nutrients and sedimentation are defined narratatively, while the criteria designed to protect fish and fish habitat are specific numeric limits for stream temperature, toxics, and other parameters. A summary of the water quality criteria used in the Upper Deschutes Subbasin is presented in Table 24.

Table 24: Summary of Applicable Water Quality Criteria

Parameter (Beneficial Use Affected)	Criteria Type/ Measurement	Criteria *
Aquatic Weeds or Algae (Water contact recreation, aesthetics, fishing)	Narrative Criteria (biological monitoring)	Growth of fungi or other growths having a deleterious effect on aquatic life or which are injurious to public health, recreation, or industry are not allowed. See also Nutrients.
Bacteria (Water contact recreation)	Numeric Criteria *Escherichia coli*	126/100 ml. (30 day log mean) 406/100 ml. (Single sample)
Biological Criteria (Resident fish and aquatic life)	Narrative Criteria (measured using macroinvertebrates)	Waters of the state shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.
Dissolved Oxygen (Resident fish and aquatic life, salmonid spawning and rearing)	Numeric Criteria Dissolved oxygen (mg/L)	Salmonid Spawning: Greater than 11 mg/L Cold Water Aquatic Life: Greater than 8.0 mg/L. (Several conditions apply, see standards for details.)
Habitat & Flow Modification (Resident fish and aquatic life, salmonid spawning and rearing)	Narrative Criteria (Habitat measurements, flow assessment)	Waters of the state shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.
Nutrients (Aesthetics)	Narrative Criteria (phosphorus, nitrates, ammonia)	No criteria for the Deschutes Basin. Suggested screening criteria from OWEB Manual (WPN 1999). Total Phosphorus 0.05 mg/L Total Nitrate 0.30 mg/L
PH (Resident fish and aquatic life, water contact recreation)	Numeric Criteria (pH)	pH: 6.5 – 8.5
Sedimentation (Resident fish and aquatic life, salmonid spawning and rearing)	Narrative Criteria	Formation of bottom deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry are not allowed
Temperature (Resident fish and aquatic life, salmonid spawning and rearing)	Numeric/ Narrative Criteria (temperature)	No measurable temperature increase resulting from anthropogenic activities is allowed if any number of narrative or numeric criteria are exceeded. Two of the most commonly applied criteria are for: Salmonid fish rearing: 64 ° F. Salmonid spawning: 55 ° F.
Toxics (Resident fish and aquatic life)	Numeric Criteria	Numeric criteria are identified for 120 organic and inorganic toxic substances in Table 20 in the Oregon Water Quality Standards (ODEQ 2001).
Turbidity (Resident fish and aquatic life, water supply, aesthetics)	Narrative/ Numeric Criteria (turbidity (NTU))	Not greater than 10% increase over natural stream turbidity. Suggested screening criteria – 50 NTU (WPN 1999)

* The criteria have been abbreviated for this table. Most criteria have associated conditions and exceptions that apply. Obtain the full text of the regulations (ODEQ, 2001a) for specific applications. Table adopted from UDWC's Little Deschutes River Subbasin Assessment, 2002.

Source: ODEQ 2003

11.3.2 Upper Deschutes Subbasin 303(d) List

The federal Clean Water Act requires states to maintain a list of all of the streams that do not meet water quality standards. The rivers or streams that do not meet water quality standards are called *water quality limited streams* and they are placed on the state's

303(d) list. The 303(d) list of water quality limited segments received its name from the 303 (d) section of the Clean Water Act that identifies water quality requirements.

In 2002, stream reaches and lakes were included on the state's 303(d) list for not meeting water quality standards for temperature (Map 11.1), pH (Map 11.2), dissolved oxygen (Map 11.3), chlorophyll-a (Map 11.4), sedimentation (Map 11.5), and turbidity (Map 11.6). In addition to the listings shown in Table 22 below, two water bodies were noted as having water quality of potential concern: Fall River for temperature (salmonid spawning) and Odell Lake for chlorophyll-a. Additional data is needed to verify these concerns (Lamb 2003). For a detailed description of the specific water bodies in the subbasin which are found on ODEQ's 2002 303(d) list, see ODEQ's website, http://www.deq.state.or.us/wq/303dlist/303dpage.htm. This site also describes the water quality data used to support the listing of specific waterbodies and stream segments.

The ODEQ 303 (d) list of rivers, creeks, and lakes in the Upper Deschutes Subbasin includes sections of the upper Deschutes River, Fall River, Odell Creek, and Odell Lake. Table 25 lists the quantity of river miles or lake surface area that have been listed for varying 303 (d) parameters in DEQ's 2002 draft 303(d) list.

Table 25: 303 (d) Parameters for Rivers and Lakes in the Upper Deschutes Subbasin

Parameter	Upper Deschutes River Miles	Odell Lake Area	Odell Creek Miles
Temperature (Rearing) 64*F	59.6		11
Temperature (Spawning) 55*F	95.8		11
pH (summer)	5.6	5.3	
pH (spring/summer)	36.2		
pH (winter/spring/fall)	36.2		
Dissolved Oxygen (7/1 to 8/31)	21.2		
Dissolved Oxygen (10/1 to 6/30)	32.8		
Dissolved Oxygen (year round)	21.2		
Chlorophyll a (6/1 to 9/30)	21.2		
Sedimentation	54		
Turbidity (spring/summer)	54		

Note: Some river segments are listed for multiple parameters

Source: ODEQ 2002 303(d) list

11.3.3 Total Maximum Daily Load

ODEQ's water quality standards identify the beneficial uses and criteria that provide the basis for a Total Maximum Daily Load (TMDL) for each stream or river segment. The TMDL is the maximum pollutant load that can exist in a waterbody and still allow the river, stream, or lake to meet water quality criteria. A TMDL is a strategy for bringing the waterbody back into compliance with the water quality standards. Pollutant loads that are above water quality criteria levels are required to be reduced over time using pollution control technology for point sources and using best management practices (BMP) for non-point sources (UDWC 2002).

TMDLs for the Upper Deschutes Subbasin are scheduled for completion in 2005. TMDLs will apply on all listed water bodies and on any water bodies feeding into the listed water body. In order to effectively establish appropriate TMDL levels, ODEQ is working with local stakeholders to assess additional monitoring needs and water quality conditions in the subbasin.

A large amount of water quality data has been gathered over the years by several natural resource agencies and entities. This data has been compiled and analyzed by the Upper Deschutes Watershed Council and is presented in two separate technical reports (Breuner, 2003a, 2003b).

11.3.4 Upper Deschutes Subbasin Water Quality

In addition to the river miles that are listed for varying 303(d) parameters, Odell is a lake in the Upper Deschutes Subbasin that is on ODEQ's 303 (d) list for exceeding the pH standard of 6.5-8.5 as a result of phytoplankton blooms (ODFW 1996) during the summer. Odell Lake is especially susceptible to cultural eutrophication due to the increased human use and development around the lake and the porous soil in the watershed that cannot absorb and hold nutrients (Hurlocker 1999). There are two resorts and approximately 70 private homes on the lake (ODFW 1996). The lake is relatively large and deep, so surface temperatures rarely exceed 68 degrees Fahrenheit.

The water quality in the Deschutes River between Crane Prairie Reservoir and Wickiup Reservoir deteriorates during mid-summer due to warm water releases out of Crane Prairie Reservoir. Algae is released with the water from Crane Prairie. The algae discolors the water and triggers algal blooms in Wickiup Reservoir (ODFW 1996).

In the southwestern corner of the subbasin, Davis Lake is a shallow body of water that has recorded temperatures as high as 84 degrees Fahrenheit. The alkalinity of the lake ranges from 7.6 to 8.7 and, due to the quantities of chlorophyll and phosphorous in addition to the water transparency, the lake is considered mesotrophic (ODFW 1996).

The primary water quality issues of concern identified in the Upper Deschutes subbasin include: water quantity (stream flow), water temperature, pH, dissolved oxygen, turbidity and sediment transport, nutrients and bacteria (Anderson 2000).

11.3.4.1 Stream Flow

As previously discussed, stream flows in the upper Deschutes River and many of its tributaries are managed year-round. Surface water is stored in Crane Prairie and Wickiup reservoirs during the winter months to ensure sufficient water quantities for irrigation purposes. Due to water storage, there are extremely low flows in the river below the reservoirs during the winter months. However, during the irrigation season when water is released from the reservoirs, there are very high flows.

High and low flow extremes impact both the geomorphology and the biological integrity of the river. In the upper Deschutes, streambeds and stream banks are dewatered and exposed during the winter. Then, when large amounts of stored water are released from Wickiup Reservoir in the spring, sedimentation and turbidity increase due to erosion from freeze and thaw action on the exposed stream banks. Riparian vegetation loses its connection to a continuous water source during low winter flows. Fish and macroinvertebrate habitat conditions are diminished during low flows and fish redds can be exposed to near freezing temperatures.

11.3.4.2 Water Temperature

The growth and survival of aquatic organisms is affected by water temperature. All aquatic species have preferred ranges within which they flourish during their various life history stages. Increased temperature typically increases an organism's metabolic rate which can lead to increased growth when enough food is available. However, increased temperatures above a certain point can also cause fish mortality, either directly or indirectly. The most common and widespread cause of thermally induced fish mortality is attributed to interactive effects of decreased or lack of metabolic energy for feeding, growth or reproductive behavior, increase exposure to pathogens (viruses, bacteria and fungi), decreased food supply (impaired macroinvertebrate populations) and increase competition from warm water tolerant species. This mode of mortality, termed indirect or sub-lethal, exhibits a delayed response in the fish, typically occurring weeks to months after the onset of the elevated temperatures. For most cold water species this usually occurs in the temperature range of mid-60^{o}F's to low 70^{o}F's. At temperatures above this, fish can succumb to direct thermal stress resulting from the breakdown of physiological regulation of respiration and circulation. The exact temperature at which different fish succumb depends on the temperature that the fish is acclimated and on particular development life-stages (Breuner 2003a).

Increased temperature can also indirectly affect pH and dissolved oxygen concentrations in the water column. With increased temperature, photosynthesis of aquatic plants increases, which can affect the oxygen/carbon dioxide balance in the water, which in turn can affect pH and dissolved oxygen concentrations.

Water temperature varies considerably on both a daily and seasonal basis. Daily fluctuations are usually the result of the continuous changes in solar radiation which warms a water body's surface. Fluctuating water withdrawals and diversions also impact downstream temperatures. Seasonal changes in water temperature are a response to differences in climate and solar aspect and to variable amounts of stream flows from both natural (i.e. snowmelt) and manipulated (reservoir) sources. The warmest stream temperatures are typically observed during the summer months from June through September (Breuner 2003a).

Stream heating processes can either be natural or caused by human activity. Riparian vegetation, stream morphology, stream flow, climate and geographic location can all influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and stream flow can all be affected by land use activities. Human activities that can contribute to degraded water quality conditions include: the removal of stream bank (riparian) vegetation thus reducing the shading it provides; decreased stream flows due to water diversions; increased stretches of shallow water due to sedimentation or changes in channel morphology (straightening and widening); and water impoundments (e.g. dams). Conversely, water temperatures can decrease as a result of groundwater inflows (springs), the inflow of cooler tributaries, and cooling water discharges.

To protect salmonid and resident fish and aquatic life, ODEQ has established a temperature standard which states that "no measurable temperature increase resulting from anthropogenic activities is allowed" if any of a number of narrative or numeric criteria are exceeded. The numeric criteria are based on the seven day average of daily maximum stream temperatures and are as follows: 64°F (17.8°C) for salmonid rearing; 55°F (12.8°C) for salmonid spawning and 50°F(10.0°C) for native Oregon bull trout. If any of these are exceeded in a subbasin or watershed, as they are in the Upper Deschutes Subbasin, then the standard would suggest that the human activities contributing to stream heating should be eliminated or reduced as much as possible (Lamb 2003).

The mainstem of the Deschutes River, from above Steelhead Falls upstream to Sunriver, is listed for exceeding the temperature criterion for salmonid fish spawning between September 1 and June 30. Most of this same reach, from above Steelhead Falls to Bend, is also listed for exceeding the temperature criterion for salmonid rearing. This section is heavily impacted by the withdrawal of water for irrigation purposes, and water withdrawals have been identified as raising stream temperatures by decreasing stream flows (Lamb 2003). Eleven miles of Odell Creek are also listed for exceeding both the rearing and spawning criteria.

An extensive temperature monitoring network exists in the Upper Deschutes Subbasin, with data collected every year by a number of agencies and organizations including: the Deschutes National Forest, BLM, the Upper Deschutes Watershed Council, ODFW, PGE, OWRD. In addition, ODEQ coordinated a major water quality study in 2001 as part of their TMDL data collection efforts. This study included the collection of Forward Looking Infrared Radiometry (FLIR) data on most of the major tributaries in the Upper Deschutes Subbasin, including the Deschutes River, Fall River, Tumalo Creek, and Odell Creek (Lamb 2003).

11.3.4.3 pH

pH is a measure of the hydrogen ion concentration in water, using a logarithmic scale of 1.0 to 14.0. Low pH water (pH less than 7.0) is considered acidic while high pH water (pH greater than 7.0) is basic. Water pH can have both direct and indirect effects on the aquatic ecosystem. In general aquatic organisms do best in a pH range of 6.5 to 8.5.

Water pH can impact both aquatic insect populations and salmonids by affecting egg and embryo development and egg hatching (Breuner 2003). Elevated pH levels can affect the availability and toxicity of certain pollutants such as heavy metals and ammonia, and can consequently lead to fish kills (Lamb 2003).

Like temperature, pH naturally varies both daily and seasonally. Daily fluctuations in pH are usually the result of the photosynthetic activity of aquatic plants. During daylight hours when aquatic plants consume carbon dioxide and produce hydroxide the water becomes more basic and pH values increase. Conversely, during the night when plants are producing carbon dioxide, pH values drop as the water becomes more acidic. The daily peak in pH values occurs around mid to late afternoon while the lowest values occur just before sunrise (Oregon Plan 1999). Seasonal fluctuations in pH are also due to the differences in the photosynthetic activity of aquatic plants, with the highest production occurring during the summer and low to no production during the winter (Lamb 2003).

pH values can be altered by increased aquatic plant growth due to the introduction of nutrients into the stream or lake system from a variety of human or natural sources. The human sources include nutrients from failing septic systems, agricultural runoff, stormwater runoff or sewage spills. Natural sources which may affect pH include the chemistry of the local substrate and atmospheric deposition from acid rain.

ODEQ has set general numeric criteria for pH to protect beneficial uses for resident fish, aquatic life, and water contact recreation throughout the entire Deschutes Basin. These criteria are:

- pH shall not fall outside the range of 6.5 to 8.5.
- For water bodies specific to the Cascade Lakes, the pH range is 6.0 to 8.5.

The mainstem Deschutes River is included on the State's 303(d) list for exceeding the pH standard from RM 126.4 (near Steelhead Falls) to RM 168.2, (upstream of Bend). Odell Lake, parts of Odell Creek which drains from Odell Lake, and Lake Billy Chinook are also listed. Odell Lake is especially susceptible to eutrophication due to increasing human recreational use and recreational residence development around the lake (Hurlocker 1999). ODEQ and the Deschutes National Forest cooperated in an intensive water quality study of nutrient and pH conditions in Odell Lake in 2001. They are hoping to do a more detailed study of Odell Lake in 2004 as part of continued TMDL monitoring. ODEQ also routinely collects pH data every other month at four locations on the Deschutes River as part of its state-wide ambient monitoring program. These locations are: Lower Bridge, Mirror Pond Footbridge, Harper Bridge, and Pringle Falls Bridge (Lamb 2003). More comprehensive pH data was also collected by ODEQ throughout the Upper Deschutes Subbasin in 2001 as part of their TMDL data collection efforts (see Breuner, 2003b for more information).

11.3.4.4 Dissolved Oxygen

A natural stream system both produces and consumes oxygen. Water gains oxygen from plant photosynthesis and from exposure to the atmosphere through splashing and turbulence (aeration). Water loses oxygen through the respiration of aquatic organisms, the decomposition of plant and animal material, and through various chemical reactions that consume oxygen (Breuner 2003b).

Oxygen in the water is measured in its dissolved state, at a given water temperature and a given atmospheric pressure. The most common means of measuring dissolved oxygen (DO) is the Winkler Titration method, which results in DO values expressed as mg/l (Oregon Plan 1999).

If more oxygen is consumed than produced in water, DO levels decrease and aquatic organisms can be affected. High concentrations of DO in the water column are essential to support aquatic life, but particularly for fish species. Salmon and trout, especially in their early life stages as eggs and alevins, are very susceptible to low DO concentrations. Dissolved oxygen is important to a stream's biological community and to the breakdown of organic material.

Like temperature and pH, dissolved oxygen levels fluctuate both daily and seasonally. Cold water holds more oxygen than warm water, and water holds less oxygen at higher altitudes (less atmospheric pressure). Aquatic organisms are most vulnerable to lowered dissolved oxygen levels in the early morning hours on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have been consuming oxygen since sunset (Breuner 2003b).

Other water quality parameters can impact dissolved oxygen. For example, increased water temperatures can reduce DO concentrations. Sedimentation within the gravels of fish redds can reduce the availability of dissolved oxygen necessary for egg viability. Nitrates, algae, and decomposition of organic matter place a high demand on in-stream oxygen and can cause a critical reduction in DO.

ODEQ has set a minimum level of dissolved oxygen to protect the most sensitive beneficial uses, Resident Fish and Aquatic Life and Salmonid Fish Rearing and Spawning, throughout the entire Deschutes Basin:

- Spawning: not less than 11mg/l or 95% saturation
  Season: September 1 - June 30

- Cold water: not less than 8mg/l or 90% saturation
  Season: July 1 - August 31

The mainstem of the Deschutes River is listed on the 2002 303(d) list for exceeding the DO criterion for spawning, from RM 168.2 (upstream of Bend) to RM 222.2, (just below Wickiup Reservoir). The river is also listed for exceeding the cold water DO criterion from RM168.2 (upstream of Bend) to RM 189.4 (below Sunriver). Lava Lake, near the headwaters of the Deschutes River, is on the 2002 303(d) list for exceeding the cool water DO criterion.

Monitoring for dissolved oxygen in the Upper Deschutes Subbasin is primarily conducted by ODEQ at their four ambient monitoring stations, with additional data collected during TMDL monitoring efforts in 2001 (see pH discussion).

11.3.4.5 Sedimentation and Turbidity

Sediment is produced by the erosion of rock and soil particles that are carried to a water body and either dissolve (dissolved solids), remain suspended (suspended solids), or settle out on the streambed (deposited solids or sediment). While sediment such as sands and gravels are an important component of healthy stream systems, too much sediment in the water column or deposited on a streambed can be harmful to bottom-dwelling aquatic organisms and the fish that feed on them. Suspended in the water column, increased amounts of sediment can reduce light penetration causing decreased beneficial instream productivity. Feeding and growth of fish are adversely affected and studies have indicated that gill tissue, with prolonged exposure to increased levels of sediment, becomes less efficient in the uptake of oxygen. As suspended material settles, it can cover the stream bottom, smothering fish eggs and bottom-dwelling aquatic organisms. Fine sediments can also serve as carriers of toxic chemicals which tend to attach to suspended particles (Breuner 2003b).

Turbidity is a measure of water clarity using light penetration through a water sample. It is directly affected by material suspended in water such as soil particles, leaf litter, algae, plankton that decreases the passage of light through the water. In many streams, turbidity is used as a surrogate for measuring suspended sediment because it is easy and relatively inexpensive. However, it cannot distinguish between suspended sediment and other material suspended in the water sample nor does it address the sources of sediment or the rates of deposition of sediment.

The local geology, soils, slope, vegetative cover, precipitation, streamflow, and adjacent land management practices such as construction, logging, and agricultural activities can all influence the rate of sedimentation in a stream. Sources of turbidity and dissolved sediment can include: stream bank erosion caused by flow fluctuations and boat wakes; upland soil erosion from roads, constructions sites, forest lands, and bare agricultural lands; return flow from eroding irrigation canals; municipal and industrial wastewater discharges; winter sanding of roads and parking lots; and bottom feeders that disrupt sediments through their feeding habits. Turbidity can additionally be caused by excessive algal growth.

Measuring sedimentation can be a complex process, taking many forms depending on the scale and purpose of the sediment study. Along the Upper Deschutes River, bank pin placement and subsequent monitoring has been conducted by forest service hydrologists to determine site-specific erosion rates. McNeil core sampling, which is a very small-scale determination of the amount of fine sediments present in fish redds, is a common yet time intensive method used by fisheries biologists.

The ODEQ narrative criteria for sedimentation states that: "The formation of appreciable bottom or sludge deposits, or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation or industry shall not be allowed." The beneficial uses which are impacted by sedimentation are salmonid fish spawning and rearing and resident fish and aquatic life.

Turbidity is frequently used substitute for measuring the transport of suspended particles because it is easy and relatively inexpensive to measure. Turbidity is usually measured by a turbidity meter that measures the intensity of light scattered by the particles in the water sample. Turbidity is expressed in nephelometric turbidity units or NTUs. Below Wickiup Reservoir, the Upper Deschutes River experiences higher than normal turbidity levels following the spring release of stored water.

The ODEQ standard for turbidity allows no more than a 10 percent cumulative increase in natural stream turbidities, as measured relative to a control point immediately upstream of the turbidity causing activities. This is not a terribly useful standard for evaluating the possible effects of nonpoint sources of pollution which can occur across the landscape rather than just at one point. The Oregon Watershed Enhancement Board suggests an evaluation criterion of 50 NTU for turbidity, because values above this level are known to interfere with the sight-feeding of salmonid fish.

The mainstem Deschutes River is on the ODEQ 2002 303(d) list for exceeding both the State's sedimentation and turbidity standards from RM 168.2 (just upstream of Bend) to RM 222.2 (Wickiup Reservoir). Turbidity monitoring in this reach during peak water releases from Wickiup Reservoir has shown that the timing, volume and duration of released flows has contributed to increased sedimentation and turbidity. The Upper Deschutes River downstream from Wickiup Reservoir has reaches where the flow alterations have eroded the stream banks and bottoms, increasing sedimentation and turbidity and causing degradation of both riparian and aquatic habitat.

Turbidity monitoring has been conducted on the Deschutes River between Wickiup and Bend by both the Deschutes National Forest and ODEQ. Suspended sediment and turbidity monitoring is also conducted by ODEQ at their four ambient monitoring stations, with additional data collected during TMDL monitoring efforts in 2001 (see pH discussion).

11.3.4.6 Chlorophyll a

Chlorophyll is the green pigment found in plants which allow them to photosynthesize. The measurement of chlorophyll is an indirect measurement of the amount of photosynthesizing plants including both algae and phytoplankton found in water.

The amount of algae and phytoplankton in a stream directly influences other water quality parameters such as dissolved oxygen and pH, and indirectly affects temperature and turbidity. This occurs when photosynthesizing organisms produce oxygen and increase the pH of water during daylight hours, then consume oxygen thus decreasing pH at night. pH is also affected when plants decompose. Excessive suspended algae can increase water column turbidity which in turn can increase water temperature. The photosynthetic production of algae and phytoplankton can be stimulated by excessive levels of nutrients and fertilizers such as nitrogen and phosphorous. Algal growth is also affected by streamflow, available light and water temperature (Breuner 2003b).

ODEQ's standard for chlorophyll-a states that, in natural lakes which do not thermally stratify, reservoirs, rivers and estuaries, chlorophyll-a concentration greater than 0.015 mg/L may impair beneficial uses. Beneficial uses which may be affected by chlorophyll a levels include: water contact recreation, aesthetics, resident fish and aquatic life, water supply and livestock watering. The season of concern in the Upper Deschutes Subbasin is June 1 – September 30 (Lamb 2003).

The mainstem Deschutes River is listed on ODEQ's 2002 303(d) list for exceeding the chlorophyll a criterion, from the north end of Bend up to below Sunriver. Lake Billy Chinook is also listed for exceeding the chlorophyll a levels due to occurrences of blue-green algal blooms during the summer months. In addition to those beneficial uses described above, chlorophyll a values in Lake Billy Chinook may also affect water contact recreation, fishing, water supply and livestock watering.

Monitoring for chlorophyll-a in the Upper Deschutes Subbasin is primarily conducted by ODEQ at their four ambient monitoring stations, with additional data collected during TMDL monitoring efforts in 2001 (see pH discussion).

11.3.4.7 Nutrients

The two main nutrients of concern for water quality are nitrogen and phosphorus because they can both stimulate algae and plant growth in water. Algae and aquatic plants process sunlight into food for aquatic insects and other organisms and are an important part of the stream ecosystem. However, excessive inputs of nutrients can over-stimulate plant growth and harm beneficial uses by: causing elevated levels of pH and dissolved oxygen, causing nuisance algal blooms, and adversely affecting water contact recreation and aesthetics (Oregon Plan 1999). Excessive nitrogen in the form of nitrates can also cause hypoxia, or low levels of dissolved oxygen, which can be toxic to warm blooded animals at higher concentrations.

Phosphorus and nitrogen are the principal growth-limiting nutrients in water. Potential sources of these nutrients from human activities include: wastewater discharges, runoff from fertilized lawns and cropland, failing septic systems, manure storage areas, disturbed lands, and commercial cleaning solutions, and soil erosion. There are also natural sources of phosphorus from soil and rocks, such as the volcanic soils found in the Upper Deschutes Subbasin (Lamb 2003).

ODEQ does not have any nutrient standards for the Upper Deschutes Subbasin. The closest standard that might apply is the narrative standard for aquatic weeds and algae which states that: "the development of fungi or other growths having a deleterious affect on stream bottoms, fish, or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed." The potentially affected beneficial uses include: resident fish and aquatic life, water contact recreation and aesthetics.

Although there are no water bodies specifically listed for exceeding nutrient standards within the subbasin, nutrients need to be monitored to prevent human health impacts. There is rather dated evidence that some stream reaches have seasonal problems with eutrophication, especially in those reaches with low DO concentrations or high pH values. Algal blooms are commonly observed in these reaches; for example, the mainstem Deschutes River from the north end of Bend to just downstream of Steelhead Falls. The past decade's significant growth in human population and subsequent increased recreational activity on and near many of the lakes in the region may be adding unhealthy levels of nutrients into local water bodies. Crane Prairie Reservoir and Wickiup Reservoir may be a larger source of nutrients into the mainstem of the Deschutes River than previously measured.

Monitoring for nutrients in the Upper Deschutes Subbasin is primarily conducted by ODEQ at their four ambient monitoring stations, with additional data collected during TMDL monitoring efforts in 2001 (see pH discussion).

11.3.4.8 Bacteria

Escherichia coli (*E. coli*) bacteria are a form of fecal coliform bacteria found specifically in fecal material from humans and other warm-blooded animals. Coliform bacteria in general are used as indicators of possible sewage contamination. Although E. coli are not themselves harmful, they indicate the possible presence of other disease-causing bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, the presence of fecal coliform bacteria in surface water indicates that pathogenic microorganisms might also be present, and that there is a risk to human health. The presence of high levels of bacteria may be the result of sewage spills, failing septic systems, feedlot contamination, or human use of a common water source for both sanitation and drinking water (Breuner 2003b).

Water contact recreation is the beneficial use most directly affected by bacterial contamination of surface waters.

There are currently no stream reaches or water bodies within the Upper Deschutes subbasin that are listed for exceeding ODEQ's *E. coli* standards. Bacteria data is collected by ODEQ's four ambient water monitoring sites and by local public and private utilities on a continuous basis to protect drinking water supplies. Water contact recreation is quite common during the summer months throughout the subbasin. Water bodies where bacteria contamination might be a concern include 'urban stream segments' such as the mainstem of the Deschutes River through Bend and lakes and reservoirs with resort development or extensive lakeside campgrounds such as Odell Lake or Elk Lake (Breuner 2003b).

11.3.4.9 Stormwater runoff

A number of pipes drain streets into the Deschutes River in the City of Bend. One estimate noted that ten percent of the stormwater in Bend drains into the river. Approximately 50 to 100 cubic yards of cinders (used on icy streets) wash into Mirror Pond annually via the storm drains. Although this runoff is a small amount compared with other sources of sediment upstream, it is still a water quality concern (Winzler 1981).

11.3.5 Municipal Water Quality

The City of Bend receives its municipal water supply from Bridge Creek. The purity of the spring water in Bridge Creek lends itself to making the water quality among the best of surface water in the United States. The turbidity of Bridge Creek is usually between 0.2 and 0.3 NTUs, and the City ceases withdrawing water if the NTUs exceed 1.0 (Moscosco 1995). There are usually between 45-55 days per year when the turbidity exceeds 1.0 as a result of sediment run-off from snowmelt or thunderstorms (Moscosco 1995). When the turbidity is in excess of 1.0 the City relies on its groundwater for municipal water needs. City of Bend municipal water supplies are stored in thirteen storage reservoirs that are cleaned annually to remove accumulated sediment. The surfaces and joints of the tanks are also inspected and repaired annually for leaks (City of Bend 2001).

The City of Redmond relies exclusively on groundwater for its municipal water supply. Although they have consistently met EPA drinking water quality requirements, they use chlorine in their water supply as a protective measure (Dorning 2002).

11.4 Impacts on Fish

When water is first released from Wickiup in the spring, water quality is initially good, but quality begins to deteriorate rapidly in the first few miles below the dam. The turbidity level, a measure of water clarity, is increased as much as 30 times after the spring water releases for irrigation (Forest Service Turbidity Monitoring Study, 1991-1993 data). These initial spring water releases from Wickiup send a rush of elevated flows down a channel that had been dewatered for the majority of the winter months. The exposed sediments along the stream banks are highly vulnerable to erosion and are easily released and eroded downstream by high flow levels (see Appendix I for greater detail). As the summer progresses the turbidity levels remain elevated to nearly twice the background level until late July.

While many reservoirs can decrease turbidity by trapping sediment behind dams, Wickiup Reservoir contributes to spring erosion due to ramped up water releases and mid and late season turbidity by enhancing primary productivity in the reservoir. The sunlight that reaches the unshaded waters of the reservoirs warms the still waters and the growth of microorganisms known as “primary productivity” flourishes. The millions of organisms cloud the water by creating “algae blooms.” In mid-summer these clouds of organisms are released from the reservoir and begin to appear in the river and become the dominant determinant of turbidity. As a result of the combination of spring erosion and summer primary productivity, turbidity levels in the Upper Deschutes do not meet the Oregon water quality standard. The water quality standard defines a water quality violation for turbidity as an increase in excess of 10% over background levels (ODFW 1996).

Fish and other aquatic species can be adversely impacted by high levels of turbidity. Turbidity can have negative effects on aquatic invertebrates and newly emerged trout fry by interfering with their food supply and ability to feed efficiently. Gravel that houses trout eggs can become plugged with sediment, consequently suffocating the eggs or forming a sediment cap over the redds which can prevent trout from emerging. Adult fish may experience gill tissue damage from excessive turbidity that lasts between 5 and 10 days (ODFW 1996).

Additionally, high concentrations of DO in the water column are essential to support fish species. Salmon and trout, especially in their early life stages, are very susceptible to low DO concentrations. Dissolved oxygen is important to a stream’s biological community and to the breakdown of organic material.

The growth and survival of fish and other aquatic species are affected by water temperature. Increased water temperatures above a certain point can also cause fish mortality, either directly or indirectly.

11.5 Data Gaps

- The Upper Deschutes Watershed Council has been implementing a water quality monitoring program. In its initial stages, the program has focused on collecting and synthesizing the water quality data from all of the participating agencies in the area. The past water quality data for the Upper Deschutes Subbasin has been inconsistent. There needs to be more consistent and long term monitoring and data gathering for water quality parameters in the Upper Deschutes Subbasin.
- ODEQ is setting TMDLs for temperature and evaluating what is needed to reestablish temperature regimes, but this information is not yet available.

11.6 Key Findings

- Water quality conditions in the Upper Deschutes Subbasin are inextricably linked to water quantity and flow levels. The water quality parameters monitored by the Oregon Department of Environmental Quality including temperature, dissolved oxygen (DO), and pH are affected by low flow conditions in the subbasin.
- As a result of channel erosion, the flow release schedule from Wickiup Reservoir, and summer primary algae productivity in Wickiup Reservoir, turbidity levels in the upper Deschutes River do not meet the Oregon water quality standard.

- Multiple sections of the upper Deschutes both above and below the City of Bend do not meet Oregon water quality standards.

11.7 Recommendations

- Decrease sedimentation and turbidity levels in sections of the Upper Deschutes River between Wickiup Reservoir and the City of Bend by maintaining the target winter minimum flow level of 300 cfs set by the Upper Deschutes Wild and Scenic River Management Plan.
- Reduce erosion and subsequent turbidity and sedimentation by maintaining springtime ramping rates (0.1 ft/ 4hrs rising) that are consistent with the Upper Deschutes Wild and Scenic River Management Plan.
- Improve water quality and reduce algal blooms and nutrient loading between the City of Bend and Lower Bridge by maintaining higher summer flows.
- Monitor water quality parameters including: temperature, DO, pH, turbidity, bacteria, and chlorophyll a, as a way to improve understanding of changes and impacts on water quality.
- Support and initiate interagency water quality monitoring activities such as the Upper Deschutes Watershed Council's effort to implement the regional coordinated water quality monitoring plan.
- Research and model the location of erosion and sedimentation in the upper Deschutes River between Wickiup and Bend. Quantify the amount of sediment loss and the sediment bedload levels.

12.0 FISHERIES AND AQUATIC HABITAT

12.1 Critical Questions

1. What resident or anadromous fish species were historically present in the subbasin?
2. What is the current distribution of fish species?
3. What are the aquatic habitat conditions throughout the subbasin?
4. How have fish been affected by land or water management?
5. What other key aquatic species are found in the subbasin?
6. What impact does flow regime have on fish habitat?

12.2 Approach

The current and historic fisheries and aquatic habitat information for the Upper Deschutes Subbasin will be presented in this section. The distribution of both native and non-native fish will be described, as will the watershed conditions that either contribute to or detract from healthy aquatic habitat conditions.

The section begins with a discussion regarding the historic and current fish species in the subbasin and the scope and range of their current distribution. Maps depicting the historic and current distribution of bull trout, brown trout, redband trout, and brook trout will accompany narrative descriptions for each species. Specific attributes of both native and non-native species will be described, followed by discussions on interactions, fish stocking, and fish management policies. Other subbasin aquatic species will be presented along with a list of aquatic species of concern and aquatic habitat conditions in the area. Finally, a brief discussion regarding the impact of modifications to the natural flow regime and the consequences to aquatic species will be presented. Most of the information and data presented in this section comes from the Oregon Department of Fish and Wildlife (ODFW), the United States Forest Service (USFS), and the United States Fish and Wildlife Service (USFWS).

12.3 Fish

The waters of the Upper Deschutes Subbasin contain an interesting blend of indigenous and introduced species of fish. Fish stocking, water management, dams and diversions, and excessive harvesting have combined together over the past hundred years to cultivate a subbasin that supports many non-indigenous species of fish. Species such as Pacific lamprey, bull trout, and steelhead that were historically native to the area have been almost completely extirpated from the subbasin.

Table 26 lists the historic and current fish species found in the waters of the Upper Deschutes Subbasin. Both common and scientific names for each species are listed, as well as whether the species is native or non-native to the area, the current status of the species, whether or not the species is still stocked, and the relative abundance according to the Oregon Department of Fish and Wildlife's 1996 Upper Deschutes River Subbasin Fish Management Plan.

Table 26: Historic and Current Fish Species in the Waters of the Upper Deschutes Subbasin

Common Name	Scientific Name	Origin	Status	Abundance
Pacific lamprey	*Entosphenus tridentatus*	Native	Extinct	
Summer steelhead	*Onchorhynchus mykiss*	Native	Extinct	
Chinook salmon	*Onchorhynchus tshawytscha*	Native	Extinct	
Coho salmon	*Onchorhynchus kisutch*	Introduced	Present	Locally abundant
Kokanee	*Onchorhynchus nerka*	Introduced *	Present	Abundant
Atlantic salmon	*Salmo salar*	Introduced *	Present	Rare
Redband trout	*Onchoryhnchus mykiss gairdneri*	Native	Present	Moderate
Bull trout	*Salvelinus confluentis*	Native	Present	Very rare
Mountain whitefish	*Prospium williamsoni*	Native	Present	Very abundant
Rainbow trout	*Onchorhynchus mykiss*	Introduced	Present	Abundant
Brown trout	*Salmo trutta*	Introduced	Present	Abundant
Brook trout	*Salvelinus fontinalis*	Introduced *	Present	Abundant
Cutthroat trout	*Oncorhynchus clarki lewisi*	Introduced *	Present	Moderate
Lake trout	*Salvelinus namaycush*	Introduced	Present	Low
Largemouth bass	*Micropterus salmoides*	Introduced	Present	Moderate
Smallmouth bass	*Micropterus dolomieui*	Introduced	Present	Low
White crappie	*Pomoxis annularis*	Introduced	Present	Low
Black crappie	*Pomoxis nigromaculatus*	Introduced	Present	Low
Brown bullhead catfish	*Ictalurus nebulosus*	Introduced	Present	Locally abundant
Bluegill	*Lepomis macrochirus*	Introduced	Present	Moderate
Shorthead sculpin	*Cottus confuses*	Native	Present	Locally abundant
Reticulate sculpin	*Cottus perplexus*	Native	Present	Unknown
Longnose dace	*Rhinichthys cataractae*	Native	Present	Low
Chiselmouth	*Acrocheilus alutaceus*	Native	Present	Moderate
Largescale sucker	*Catostomus macrocheilus*	Native	Present	Locally abundant
Bridgelip sucker	*Catostomus columbianus*	Native	Present	Moderate
Northern squawfish	*Ptychocheilus oregonensis*	Native	Present	Moderate
Three-spined stickleback	*Gasterosteus aculeatus*	Introduced	Present	Very abundant
Tui chub	*Gila* (Siphateles) *bicolor*	Introduced	Present	Very abundant
Blue chub	*Gila* (Gila) *coerulea*	Introduced	Present	Locally abundant

Source: ODFW 1996
*Indicate species that are still stocked annually in the subbasin

As Table 26 indicates, the Upper Deschutes Subbasin is home to a wide variety of fish species, many of which are not native to the waters of the area. Many of the most prevalent and widespread species such as tui chub and the three-spined stickleback found throughout the subbasin were introduced either legally or illegally at some point in the last century. Alternately, many of the fish species that are native to the subbasin are now relatively rare. Bull trout *(Salvelinus confluentus)* and redband trout *(Onchorhyncus mykiss)* are two native fish species that historically thrived throughout the subbasin, but today are limited and fragmented in abundance (ODFW 1996). Currently, native bull trout have been effectively eradicated from much of the subbasin by dams acting as migration barriers, lack of year-round instream water, warm water temperatures, and over harvesting (ODFW 1996). Similarly, the current distribution of redband trout throughout the subbasin is limited due to natural barriers, severe stream flow alterations from irrigation development, dams lacking any or adequate fish passage, chemical treatment projects, and the competition from introduced non-indigenous trout stocks (ODFW 1996). Redband trout previously inhabited most of the waters connected to the Deschutes River.

12.3.1 Distribution

12.3.1.1 Historic

The native fish that were originally distributed throughout the Upper Deschutes Subbasin are believed to have been bull trout, redband trout, mountain whitefish, and sculpins. Summer steelhead, Chinook salmon, and pacific lamprey were also historically present up to Big Falls.

Historically, bull trout *(Salvelinus confluentus)* flourished throughout the majority of the Upper Deschutes Subbasin. From the headwaters of the Deschutes River down to Big Falls, bull trout existed all along the mainstem of the Deschutes. Bull trout were also historically found in Fall River, Davis Lake, Odell Lake, and Odell Creek (Buchanan 1997).

In 1913, the Oregon Department of Fish and Wildlife, which was at that time referred to as the Oregon Fish and Game Commission, allowed the construction and operation of a fish hatchery on Odell Creek. The Odell Creek hatchery cultivated rainbow trout and non-indigenous brook trout and consequently supplied fish not only for Odell Creek, but also for many other waters in the subbasin. Increased demands for recreational fishing throughout Central Oregon prompted the introduction of additional fish species including Kokanee salmon *(Oncorhynchus nerka)* and lake trout, also called mackinaw (*Salvelinus namaycush).* Both species were introduced from1910 through the 1920's to provide a recreational fishery in Odell Lake. It has also been documented that anglers used chub as baitfish and illegally introduced them into Odell and Davis Lakes in the 1920's (Hurlocker 1999).

The distribution of bull and redband trout throughout the subbasin will be depicted in Maps 12.1 and 12.2. Based on data from ODFW's 1996 *Upper Deschutes River Subbasin Fish Management Plan*, the historic distribution of native bull and redband trout was much more extensive than it is currently. The data for the graphical presentation of the distribution of fish species originated as textual descriptions from ODFW'S management plan.

12.3.1.2 Current

The composition of the fishery in the Upper Deschutes Subbasin today is remarkably different that the fish presence of 100 years ago. Fish harvesting, the construction of Crane Prairie and Wickiup dams, the modification and regulation of water flows, the introduction of non-native fish species, and the removal of instream large woody material have all played a role in altering the fish species composition and fish habitat conditions throughout the subbasin.

Due to changes in habitat conditions, bull trout are no longer present in the majority of the Deschutes River. In their place, introduced brown trout are the prevalent species throughout much of the Deschutes. Currently, bull trout exist only between Big Falls and Lake Billy Chinook and in Odell Lake (Buchanan 1997).

Just as in the Deschutes River, Tumalo Creek is also now a host to many introduced species of fish. At 97 feet high, Tumalo Falls previously acted as a natural fish barrier; however, fish introductions above the falls have allowed the distribution of non-native rainbow and brook trout populations to establish. Rainbow trout have also been documented downstream of Tumalo Falls, near the headwaters of Bridge Creek, and in the South Fork of Tumalo Creek. Introduced brook trout have been documented as occurring in all of the following streams: Tumalo Creek, the Middle Fork of Tumalo past the confluence with Bridge Creek canal, the North Fork up to Happy Valley, Tumalo Lake and Tumalo Lake Creek which drains it, the South Fork up to the junction of the two channels, and in Bridge Creek up to the diversion dam. Brook trout are also found in many of the small springs and beaver ponds in the flood plain. Due to the presence of the Bridge Creek dam, fish are unable to migrate further upstream on Bridge Creek (Lee 1998).

The current distribution of brown trout and brook trout are depicted in Maps 12.3 and 12.4. These species were mapped due to either their importance or prevalence throughout the subbasin. As with the historic distribution maps, the current fish distribution maps come from the textual descriptions within ODFW's *Upper Deschutes River Subbasin Fish Management Plan*.

12.3.2 Native Fish

Historically, the Deschutes River from Lake Billy Chinook upstream to Big Falls supported native anadromous runs of summer steelhead and spring Chinook salmon. Pacific lamprey are also believed to be native to the lower sections of the Deschutes River. Redband trout, bull trout, mountain whitefish, sculpin and dace species, chiselmouth, sucker species, and the northern squawfish are also fish species that are native to the Upper Deschutes Subbasin area.

12.3.2.1 Summer Steelhead

Historically, anadromous summer steelhead *(Onchorhynchus mykiss)* were found in the Deschutes River. Steelhead could make it past Steelhead Falls during high winter or early spring flows and in 1922 a fish ladder was constructed that they could navigate their way up. A minimum of 300 cfs in the Deschutes at Bend was determined to be an adequate amount of water for the effectiveness of the fishway. After 1930 a minimum of 300 cfs was maintained only during the non-irrigation season-- November through April. Therefore, during the irrigation months of lower flows, summer and fall migrating fish may have been prevented from moving upstream above Steelhead Falls (ODFW 1996). Summer steelhead were found trapped in the Steelhead Falls fishway in 1953, 1954, and 1955 (Nehlsen 1995). There were additional fishways constructed at Big Falls and Cline Falls in the 1920's, but no steelhead were known to have passed either falls (Nehlsen 1995).

12.3.2.2 Chinook Salmon

Chinook salmon *(Onchorhynchus tshawytscha)* are native to the subbasin and were historically present in the Deschutes River up to both Steelhead Falls and Squaw Creek. Currently, there is believed to be a remnant population of spring Chinook in Lake Billy Chinook.

Spring Chinook spawn in the gravel areas of streams or rivers during late summer and early fall. Hatching occurs in late winter, until which point eggs will remain in the gravel. Juvenile Chinook salmon remain in the streams for about 3 months until they begin to migrate downstream to Lake Billy Chinook. Spring Chinook and summer steelhead have been blocked from Steelhead Falls, Big Falls, and Squaw Creek on the upper Deschutes River since 1968. The completion of Round Butte Dam in 1964 did include some fish passage facilities, but they were ineffective in moving smolts downstream. Upstream migration usually begins around April and May, with adults remaining in large, deep pools until they begin to spawn during August and September (ODFW 1996).

12.3.2.3 Pacific Lamprey

Pacific lamprey *(Entosphenus tridentatus)* is an anadromous parasitic species with the period of parasitism occurring while they are in the ocean. The mouth of the lamprey is down-turned and adapted for clinging and sucking. The lamprey has a round, elongate, flexible cartilaginous body. Lamprey have no scales and are smooth and slimy to the touch. Pacific lampreys are either dark bluish gray or dark brown in color and they can be up to 30 inches in length. Lampreys were historically in Lake Billy Chinook and up the Deschutes River near the confluence with Squaw Creek. There is very little known about the specific history of Pacific lamprey in the Upper Deschutes Subbasin.

12.3.2.4 Bull Trout

Bull trout *(Salvelinus confluentus)* were historically found throughout most of the Upper Deschutes Subbasin. A major Native American and Euro-American pioneer fishery thrived at Pringle Falls and there are many historical photos of large bull trout taken near Bend (Buchanan 1997). They are known to have been present in the mainstem of the Deschutes from Lake Billy Chinook to the headwaters, as well as in Odell Creek, Odell Lake, and Davis Lake. They are suspected to have been present in other Deschutes tributaries such as Squaw Creek, but documentation of other streams is limited (ODFW 1996). Currently, native bull trout have been effectively extirpated from much of the subbasin by dams acting as migration barriers, lack of year-round instream water, warm water temperatures, and over harvesting (ODFW 1996).

The bull trout in Oregon have three life-history patterns represented by the differences between resident, fluvial, and adfluvial fish. Resident juvenile bull trout are believed to confine their migrations to and within their natal stream, while fluvial populations generally migrate between smaller streams used for spawning and early juvenile rearing and larger rivers used for adult rearing. Fluvial populations have been known to switch to adfluvial pattern under some conditions. Adfluvial populations generally migrate between smaller streams used for spawning and juvenile rearing and lakes or reservoirs used for adult rearing. In Oregon, adfluvial bull trout have been known to exceed 20 pounds. (Buchanan 1997).

Odell Lake contains the last natural adfluvial population of bull trout in Oregon. The only known spawning and rearing habitat to occur in the Odell Lake subwatershed is in 0.8 miles of Trapper Creek (Hurlocker 1999). Since 1995, redd counts have been conducted in Trapper Creek from the mouth to the second falls. Table 27 shows a summary of the findings of redd counts completed by the USFS and ODFW.

Table 27: Summary of Bull Trout Redds Detected in Trapper Creek

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Number of Redds	1	0	8	1	12	6	12	11	4

Source: Dachtler 2002

Bull trout spawn in cold tributary streams in September and October. They deposit their eggs in a redd and the juvenile bull trout then rear in their natal stream for two years. After two years, the juveniles migrate in the spring to larger waters for rearing to adulthood. At age 5 they migrate back to their natal tributary to spawn.

Bull trout was first classified by the American Fisheries Society (AFS) as a species "of special concern" in 1989. This classification was the result of destruction of habitat, hybridization, predation, and competition from non-native species (Williams 1989). The species was listed by the Oregon Department of Fish and Wildlife (ODFW) as a sensitive/critical species in 1993 (Buchanan 1997). Following a series of petitions by conservation groups throughout the Western states, in 1994 the United States Fish and Wildlife Service (USFWS) declared that, although listing bull trout as a threatened or endangered species was reasonable, due to limited resources and other higher priority species, bull trout would not be listed under the Endangered Species Act (ESA) at that time. Challenging the USFWS finding, Friends of the Wild Swan and Alliance for the

Wild Rockies filed a lawsuit to the Oregon Federal District Court. In November 1996, the Court directed the USFWS to reconsider the 1994 finding. Finally, on June 10, 1997, the USFWS declared that Klamath Basin bull trout be proposed for endangered status and the Columbia Basin bull trout be proposed for threatened status (USFWS 1997). On June 10, 1998 the species was listed by the USFWS as Threatened in the conterminous United States.

The USFWS has proposed to designate sections of the Deschutes River and Odell Lake as critical habitat for bull trout. The final decision will be made in October 2003 following a public comment period and a series of informational hearings. The term “critical habitat” refers to specific areas that have been determined to be essential for the conservation of a threatened or endangered species.

If portions of the Deschutes River Subbasin are listed as critical habitat for bull trout, those areas would receive protection under Section 7 of the Endangered Species Act. With regard to actions carried out, funded, or authorized by a federal agency, any destruction or adverse modification of critical habitat will be prohibited. The Act does not apply to activities on non-federal lands that do not involve federal funding or federal permits (USFWS 2002).

12.3.2.5 Redband Trout

Redband trout (*Oncorhynchus mykiss)* are native inland resident fish. Redband were historically found throughout the Upper Deschutes Subbasin in the mainstem of the Deschutes and its tributaries. Redband is actually the common name for an inland subspecies of rainbow trout found throughout the Columbia Basin. Upper Deschutes Subbasin redband trout are a subspecies of rainbow trout and steelhead that are well adapted to the arid conditions east of the Cascades. It has been concluded that the inland redband trout represent a more primitive evolutionary stage than the Oregon coastal rainbows. This analysis was based on patterns of coloration, the presence of trace cutthroat markings, and vestigal basibranchial teeth (Behnke 1992).

The current distribution of redband trout in the Upper Deschutes is fragmented due to the ongoing impacts of dams, inadequate fish passage, natural barriers, severe stream flow modifications from irrigation development, chemical treatment projects, and the introduction of non-indigenous trout stocks. Redband populations are believed to be in a depressed status. They are currently found in the Deschutes from Lake Billy Chinook upstream to Little Lava Lake, in Tumalo Creek, and in Odell Creek, but samples of redbands in these areas are currently being tested to determine if they have been genetically influenced by hatchery stocks (ODFW 1996).

Redband trout spawn in rivers and streams during the spring months of March, April, and May. Cool, clean, well-oxygenated water is necessary for the eggs to survive. Redband trout fry emerge from the gravel in June and July. Redbands generally live near where they spawned. Maturity is reached at 3 years with size varying depending on the productivity of individual waters. On average, redband in the Upper Deschutes Subbasin do not exceed 10 inches in length (ODFW 1996).

Table 28 shows the findings of redband trout redd counts performed by ODFW and the USFS on specific sections of the Deschutes River. The redd counts were completed within habitat enhancement project areas between Wickiup and Crane Prairie reservoirs. Specifically, the redd counts were conducted where gravels were added 200 yards downstream from Crane Prairie Reservoir and at Brown's crossing on the Deschutes River (Dachtler 2003).

Table 28: Summary of Redband Trout Redd Counts in the Deschutes River Between Crane Prairie and Wickiup Reservoir

Year	1991	1996	1997	1998	1999	2000	2001	2002
Number of Redds	7	29	No Survey	121	43	214	No Survey	116

Source: Dachtler 2002

12.3.2.6 Mountain Whitefish

Mountain whitefish *(Prosopium williamsoni)* are members of the salmonid family. Whitefish are native to streams and lakes in the Upper Deschutes Subbasin and throughout Oregon. Their distribution is currently very similar to what it historically was. Whitefish are found in Little Lava Lake, the Deschutes River from Lake Billy Chinook to the headwaters, Wickiup and Crane Prairie Reservoirs, Odell Lake, Odell Creek, Davis Lake, Fall River, Spring River, lower Tumalo Creek, and the Cultus Lake basin (ODFW 1996).

Whitefish prefer cold spring-fed streams for spawning. Unlike salmon and trout, whitefish do not dig a redd to bury their eggs, but broadcast spawn instead. Juvenile whitefish hatch in the spring and reach sexual maturity around ages 3 to 4. Whitefish generally eat bottom dwelling aquatic insects in streams (UDWC 2002). Consuming similar insects, they can directly compete with trout for food. Whitefish are very abundant; they appear to more successfully respond to adverse environmental conditions than trout do (ODFW 1996).

12.3.3 Non-Native Fish

12.3.3.1 Atlantic Salmon

Atlantic salmon *(Salmo salar)* were initially stocked into many lakes in the subbasin, specifically into Hosmer Lake in 1958. The Atlantic sea-run salmon eggs that were used came from Gaspe Bay, Quebec, Canada in 1951. Of all of the lakes stocked, the eggs survived and produced fisheries only in Hosmer Lake. In 1984, the Gaspe Bay Atlantic salmon stock was replaced with a landlocked stock from Maine (ODFW 1996). Atlantic salmon from Maine are still currently stocked in Hosmer Lake.

12.3.3.2 Kokanee

Kokanee *(Oncorhynchus nerka)* are a landlocked sockeye salmon that have been introduced into the Upper Deschutes Subbasin. Presently, they are found in Odell, Davis, and Elk Lakes as well as in Wickiup and Crane Prairie Reservoirs. Kokanee have been stocked throughout the subbasin and fingerlings are currently still stocked in Crane Prairie Reservoir (ODFW 1996).

Kokanee spawn in cold spring-fed tributaries between September and October. They build redds in the gravel and spawn at age 3-4 and then die shortly after spawning. The fry emerge from the gravel during mid-winter, at which point they immediately migrate to larger waters (ODFW 1996).

12.3.3.3 Brown Trout

Brown trout *(Salmo trutta)* are fish that are native to Europe. They were introduced into the subbasin in the early 1900's (ODFW 1996). They are known to be piscivorous, they prey on other fish, and efficiently compete with other trout species in altered, warm water habitats (UDWC 2002). Although they are not currently stocked in any streams of the subbasin, brown trout are found throughout the Upper Deschutes River from Crane Prairie Reservoir downstream to Lake Billy Chinook. They are also found in Wickiup Reservoir, Spring River, Fall River, and Tumalo Creek.

Brown trout spawn from mid-September to mid-November in the Deschutes River and can grow to an average of 15 inches. Brown trout up to 15 pounds have been taken from the Deschutes River. They are currently not stocked in any streams in the subbasin, but they maintain their numbers through natural reproduction (ODFW 1996). ODFW inventory results for the population status of brown and redband trout on the Upper Deschutes are shown in Table 29.

Table 29: Status of Deschutes River Brown and Redband Trout

Section	Population	Status	Inventory method	Year
	Brown	Redband		
Wickiup to Fall River	Fair	Low	Drift boat electrofish	90,91
Fall River to Benham Falls	Good	Low	Drift boat electrofish	90,91
Benham Falls to Bend	Low	Excellent	Drift boat electrofish	90,91

Source: ODFW 1996

ODFW has identified the current condition of the Deschutes River between Wickiup and Sunriver as being better suited to brown trout than to redband. This area has a low gradient and few riffle areas. There is a lack of winter holding habitat and competition from brown trout and mountain whitefish might be affecting redband populations (ODFW 1996).

12.3.3.4 Cutthroat Trout

A non-native species to the subbasin, westslope cutthroat trout *(Oncorhynchus clarki lewisi)* are currently stocked by ODFW into Sparks Lake and several small high elevation wilderness lakes (Dachtler 2003). The cutthroat eggs that are used for stocking come from Lake Chelan in Washington State. The Lake Chelan eggs are referred to as Twin Lakes stock. The Twin Lakes stock of cutthroat eggs have had very successful survival and spawning rates in the Upper Deschutes Subbasin. Due to the popularity of angling for cutthroat trout in the area, ODFW is looking into expanding the use of cutthroat into other waters (ODFW 1996).

12.3.3.5 Lake Trout

Lake trout *(Salvelinus namaycush)* were introduced into Odell Lake in 1917. Later, hatchery raised lake trout were stocked into Odell and Cultus lakes from 1951 through 1965 (ODFW 1996). Like brown trout, lake trout are piscivorous. They are known to eat whitefish, kokanee, tui chubs, other trout and crayfish. They can live up 20 years and reach extremely large sizes. The largest lake trout in Oregon reached 36 pounds 8 ounces and was caught in Odell Lake (ODFW1996).

12.3.3.6 Brook Trout

Brook trout *(Salvelinus fontinalis)* is a charr. Brook trout are native to the eastern United States but were introduced into the Upper Deschutes Subbasin and across the country in the early 1900's (ODFW 1996). They are currently distributed widely across the subbasin, from high Cascade lakes through all stream systems in the area. They are the most prevalent fish in both wilderness and non-wilderness high lakes (ODFW 1996). ODFW still stocks brook trout into some of the Cascade high lakes that are not connected to rivers or streams (Wise 2003).

Brook trout readily hybridize with and out-compete bull trout. Tissue samples were collected from suspected hybrid species found in Trapper Creek in 2001 and tests at the University of Montana genetic lab confirmed that they were in fact hybrids (Dachtler 2002). Brook trout are no longer stocked in the Upper Deschutes Subbasin and they are not protected by harvest regulations (Runyon 2002). In 1996, ODFW and USFWS targeted brook trout for removal from Trapper Creek. Between 1996 and 2002 ODFW and USFWS used dip nets and electrofishing techniques to reduce the brook trout population in Trapper Creek (Dachtler 2002).

12.3.3.7 Three-spined Stickleback

Three-spined stickleback *(Gasterosteus aculeatus)* were first discovered in Spring River in the 1980's; since that time, they have spread both upstream and downstream in the Deschutes River. They have been present in Crane Prairie Reservoir since the early 1990's. Stickleback were illegally introduced into Crane Prairie to provide forage for other illegally introduced warmwater species in the reservoir (ODFW 2001).

Stickleback are a small fish reaching 3 inches in length. They primarily eat small plankton including water-fleas and copepods. They also eat aquatic insect larvae, small crustaceans, and other bottom dwelling organisms (ODFW 1996). The three-spined stickleback present in Crane Prairie Reservoir are known to commonly have the *schistocephalus solidus* tapeworm parasite. ODFW asserts that the high productivity of the reservoir and presence of conditions favorable for completing the tapeworm life cycle contribute to a high incidence of occurrence of the tapeworm in stickleback (ODFW 2001). *Schistocephalus* parasites and three-spined stickleback parts have also been found in the digestive tracts of trout, thereby revealing that trout had ingested stickleback that had parasite infestations. Largemouth bass diet studies have also shown secondary ingestion of *schistocephalus* due to their consumption of stickleback (ODFW 2001).

The ultimate impact of the parasite on fish is that the tapeworms can eventually make up a large portion of the total volume or weight of the host. Fish infested by the tapeworms can be identified by a swollen abdomen. Impaired movement and swimming ability of the infested fish may make them vulnerable to a higher predation rate. When piscivorous birds including mergansers or blue heron consume the infested fish, the larval tapeworm will attain sexual maturity within a few days, produce eggs and then die. Tapeworm eggs are expelled from the bird in fecal matter. Eggs that reach the water can be taken up by small crustaceans or copepods and the first larval or procercoid stage develops. The life cycle of the parasite is complete when the copepods are then eaten by fish (ODFW 2001).

12.3.3.8 Largemouth Bass

Largemouth bass *(Micropterus salmonides)* were illegally introduced into Crane Prairie Reservoir during the late 1970's and 1980's. Abundant food, including insects and tui chub, combined with ideal habitat conditions to lead to high survival and good growth rates of largemouth bass. Five and six pound bass were fairly common (ODFW 1996). Concerns about the interactions between largemouth bass and trout have been raised by many people in the subbasin.

12.3.4 Fish Stocking

In the early 1900's, hatchery stocking programs were common and abundant throughout the Upper Deschutes Subbasin. Early stocking endeavors included packing rainbow and brook trout on ODFW and USFS horse and mule pack strings into the high Cascade lakes. Most major waters in the subbasin had been stocked by 1930 (ODFW 1996).

As of 1996, an estimated 100,000 legal-size and 733,000 fingerling-size trout and salmon were stocked annually throughout the subbasin. The majority of the hatchery stocking programs occur in standing waters. Stream stocking is limited to Fall River and the Deschutes River between Wickiup Reservoir and Sunriver. The majority of stocking is with fingerling-size rainbow, brook and cutthroat trout, kokanee, and coho salmon. Stocking of legal-size Atlantic salmon is done in Hosmer Lake, and legal-size brown trout are stocked in Wickiup Reservoir (ODFW 1996). Additionally, 90 high mountain lakes are stocked with 67,000 fingerling brook, rainbow, or cutthroat trout every two years. All of the trout that are used to stock waters in the subbasin are produced at either Wizard Falls, Fall River, Oak Springs or Klamath fish hatcheries (ODFW 1996).

The Oregon Fish and Wildlife Commission adopted the Trout and Warmwater Fish Plans in 1987. The hatchery programs in the subbasin are currently being reviewed for compliance with the state fish plans and the Wild Fish Policy (ODFW 1990). The focus of the review processes is on potential genetic and disease impacts on indigenous trout stocks (ODFW 1996). Stocking of non-native fish throughout many rivers in Oregon has been discontinued due to wild fish genetic concerns. Table 30 presents a list of the waters of the Upper Deschutes Subbasin that are currently stocked with hatchery fish.

Table 30: Current Fish Stocking in the Upper Deschutes Subbasin

Upper Deschutes Subbasin waters that are stocked annually with hatchery fish

Water Body	Species	Size	Number
Deschutes River	Rainbow	Legal	25,000
Fall River	Rainbow	Legal	7,500
	Brook	Legal	7,500
Three Creeks Lake	Rainbow	Legal	4,000
Devils Lake	Rainbow	Legal	5,000
Little Cultus Lake	Brook	fingerling	8,000
Cultus Lake	Rainbow	Legal	6,000
Sprague Pond	Rainbow	Legal	1,000
Century Gravel Pond	Rainbow	Legal	1,000
Fireman's Pond	Rainbow	Legal	500
Shevlin Pond	Rainbow	Legal	1,000
North Twin Lake	Rainbow	Legal	6,000
	Rainbow	fingerling	15,000
South Twin Lake	Rainbow	Legal	6,000
	Rainbow	fingerling	20,000
Crane Prairie Reservoir	Rainbow	fingerling	200,000
	Kokanee	fingerling	20,000
Wickiup Reservoir	Brown	Legal	6,000
	Coho	fingerling	100,000
Lava Lake	Rainbow	fingerling	100,000
	Brook	fingerling	25,000
Little Lava Lake	Rainbow or brook	fingerling	10,000
Hosmer Lake	Atlantic salmon	Legal	2,000
	Brook	fingerling	5,000*
Elk Lake	Brook	fingerling	20,000
Sparks Lake	Brook	fingerling	30,000
Davis Lake	Rainbow	fingerling	35,000

Fingerlings are 2-4 inches long

Legal-size fish are 8-12 inches long

* Brook trout are stocked every few years to maintain a small population of large fish

Source: ODFW 1996

The introduction of non-native lake trout into Odell Lake is one reason given to explain why bull trout in this lake are at a "high risk" of extinction. Introduced lake trout have been known to displace and eventually eliminate native bull trout. There is a public campground on Trapper Creek in the only identified bull trout spawning area in the Odell subbasin and high public access there may put spawning bull trout at risk from illegal harvest and harassment (Buchanan 1997).

12.3.5 Management

Early fish management activities in the Upper Deschutes Subbasin were undertaken by the Oregon State and Game Commission in the 1940's. Fish management throughout the west at that time focused time and energy on the chemical control of "undesirable" fish populations, angler harvest and catch studies, monitoring anadromous fish runs, stocking waters, and biological and physical surveys. In 1940, the first comprehensive physical and biological surveys of standing waters in the subbasin were conducted by Oregon State Game Commission biologists. Prior to that time, fish stocking was the primary fish management activity. After World War II, only limited fish management occurred on a few major lakes until 1950 when the Central Region Office of the Oregon State Game Commission was established in Bend. Since that time, waters of the area have been managed by biologists in both Bend and Klamath Falls (ODFW 1996).

In the Upper Deschutes Subbasin, the primary undesirable fish species that was targeted with chemical treatments was the introduced tui chub. Most of the chemical treatments in the area consisted of the use of the piscicide and insecticide Rotenone in an attempt to eradicate entire populations of tui chubs (Marx 2003). Rotenone has been used widely throughout the Upper Deschutes Subbasin and throughout the country as one method for fisheries managers to control fish populations. Rotenone, or the application of any chemical piscicide, is the only method other than complete dewatering that will extirpate entire populations of fishes. The use of rotenone is increasingly a concern due to its widespread impact on ecosystems.

Most work in the early days of fish management looked primarily at standing waters because they were most in abundance, generated the most fishing activity, and contained the populations of undesirable fish species (ODFW 1996). Between 1940 and 1987, multiple chemical treatments were used to control undesirable fish populations throughout the subbasin. Total chemical treatments were done on Lava Lake from 1941 through 1980 and South Twin Lake was totally treated multiple times between 1941 and 1987. Davis Lake and its tributaries received a total treatment with the controversial agricultural chemical toxiphene in 1961. Little Cultus Lake was treated in 1949, and Hosmer Lake was treated in 1957. Periodic spot treatments have been also conducted on Lava and Davis between the 1940's and 1980's.

The only documented stream treatment occurred on Fall River in 1973 when all fish were killed with chemicals in order to stop the spread of bacterial kidney disease (BKD) and infectious pancreatic necrosis (IPN) virus (ODFW 1996). Both diseases were found present in the Fall River hatchery rainbow trout that had been stocked in the river and

IPN was found occurring in brook trout. 1.8 million fingerling rainbow and brook trout, 71,000 legal-size rainbow trout, and any wild trout present in the river at that time were killed (ODFW 1996). Neither disease has appeared in the river since the treatment.

ODFW's current objectives and policies for fish management, the implementation of commercial and sport fishing regulations, hatchery operations, and the Natural Production and Wild Fish Management Policies are adopted as Oregon Administrative Rules (OARs). ODFW's Natural Production and Wild Fish Management policies (OAR 635-07-521 through 635-07-529) outline suggestions and guidance on the development of fisheries management options throughout the state (Fies et al. 1996). ODFW states their mission as one to: *Protect and enhance Oregon's fish and wildlife and their habitats for use and enjoyment by present and future generations.*

Oregon's Wild Fish Management Policy [OAR 635-07-527 (6) (a)] sets a minimum of 300 breeding fish as necessary to maintain genetically viable populations. Recommendations made by the Oregon Department of Fish and Wildlife assert that protection strategies for harvest and habitat management should be designed to meet or exceed this standard.

Fisheries management has evolved over the past 20 years due to the implementation of the Wild Fish Management Policy. Most stocking has been reduced or eliminated due to concerns for wild trout, lack of public access, habitat alterations, and poor returns of stocked fish to the angler. In order to protect wild trout, protect spawning fish, and respond to the impacts of low water conditions, fishing regulations have become more restrictive (ODFW 1996).

12.3.5.1 Fish Passage

Fish passage and migration through the waters of the Upper Deschutes Subbasin often requires maneuvering over or around dams and other barriers. There are some falls in the subbasin that act as natural barriers to fish migration, but there are also multiple diversions and dams that have modified the historic migrations of fish.

Since the mid-1800's, the state of Oregon has had fish passage laws on record. When the Oregon Territory was first established in 1848, its constitution explicitly addressed the need for fish passage facilities and prohibited people from blocking salmon streams. The first game laws passed in 1872 also required fishways to be built over dams. Currently, ODFW may require dam owners or operators to install and maintain fish passage facilities at all artificial in-channel obstructions in fish-bearing streams (Bastasch 1998).

Diversions and Fish Screens

When water diversions are unscreened, the effects on fish can be devastating. Fish can be sucked into or against pump intakes or eventually stranded in irrigation canals and ditches. Many surface water diversions throughout the state still remain unscreened. ODFW estimates that the majority of Oregon's three thousand high-priority diversions that still need fish screens are located in the eastern part of the state. The regulations enforced by ODFW assert that any person diverting water from a fish-bearing stream at a rate of 30 or more cfs must install, operate, and maintain a fish screening or by-pass device (Bastasch 1998).

The Bend Riverway project closely inventoried the diversions and fish screens within the City of Bend's urban growth boundary. The fish screen findings from the Riverway project are the most detailed and up to date in the subbasin. The Riverway findings catalogue five diversions in Bend's urban growth boundary - four of these diversions currently have fish screens. Three of the screens are slated to be replaced in the near future. Fish screens on diversions are critical to fish health. They are essential in order to move fish safely around a canal diversion. An adequate and effective screen is important so fish are not injured. There are two types of screens used in the subbasin. A drum screen provides a physical barrier to the fish preventing it from entering the canal. A louvered screen deters the fish by altering the fish's behavior. Fish approach the louvered screen, but its appearance causes them to swim away. The louvered screens are less harmful to fish because they don't physically contact the screen (McNamara 1999). Table 31 lists the locations of the diversions and the fish screens inventoried in the Riverway project.

Table 31: Diversions and Fish Screens Within Bend's Urban Growth Boundary

Diversion	Diversion Location	Fish Screen	Typical Summer Maximum Flows
Central Oregon Canal	East side of river below Elk Meadow Elementary school	Yes. Perforated plate screen. Fixed panel with self-cleaning brush. Black paint has camouflaged this screen.	550 cubic feet per second
Tumalo Irrigation District Bend Feed Canal or DCMID Canal	West side of river at 1st Street Rapids	There is a louvered fish screen at present. A new screen is being designed. (DCMID is the Deschutes Co. Municipal Improvement Dist.)	140 cubic feet per second
Swalley Irrigation Canal	East side of river at North Canal dam	Yes. Louvered. Improved screen proposed by ODFW.	115 cubic feet per second
North Canal or Pilot Butte Canal	East side of river at North Canal dam	No. Proposed by ODFW.	550 cubic feet per second

Source: McNamara 1999

In addition to the diversions and fish screens assessed by the Riverway project, there is the Arnold Irrigation District Canal located at river mile 174.5 on the Deschutes, the DAW Mill diversion at river mile 168 on the Deschutes, and Pacific Power and Light's (PPL) Bend Hydroelectric diversion at river mile 166.2. Arnold diverts as much as 135 cfs and has no fish screen, the DAW Mill has been shut down but still allows no upstream fish passage, and PPL diverts as much as 1,325 cfs and allows no upstream fish passage. The intake structure at the Bend Hydroelectric plant is improperly screened and thereby allows fish migrating downstream to be injured or killed as they pass through the turbines (ODFW 1996).

Natural Barriers

Steelhead Falls is located at river mile 128 on the Deschutes River. It is 15 feet tall and is a barrier to fish passage during low water years or at times during the irrigation season when Deschutes River flows are greatly reduced due to water withdrawals.

Big Falls is another natural fish barrier located at river mile 132 on the Deschutes River. It is 30 feet tall and has always acted as a natural blockade to fish migrating upstream.

Fall River falls on Fall River is a 12-foot high barrier to upstream fish migration (ODFW 1996).

At 97 feet tall, Tumalo Falls on Tumalo Creek is a daunting natural barrier to upstream fish movement.

Dams

Wickiup dam was constructed by the Bureau of Reclamation in 1949. The reservoir is located above river mile 226 on the Deschutes River. The dam is an earthfill structure that is used to store water during the winter for irrigation uses in the summer. The holding capacity of the dam is 200,000 acre-feet of water. The water releases are currently managed by the Oregon Water Resources Department (OWRD). The reservoir is not part of the municipal water supply and the dam serves no hydropower function. The reservoir's purpose is to store water for irrigation use in the summer. There are no fishways, fish ladders, or means for fish passage up through Wickiup dam. There are also no fish screens, and kokanee and coho salmon have been documented to be transient outmigrants from Wickiup Reservoir (ODFW 1996).

Crane Prairie is an earthfill dam built by the Bureau of Reclamation in 1922. It is located on the Deschutes River at river mile 239 and is 285 feet long and 36 feet high. Crane Prairie Reservoir can hold up to 55,300 acre-feet of water. Its primary purpose is to store water during the winter to supplement irrigation demands in the summer. The dam and the reservoir are operated by Central Oregon, Arnold, and Lone Pine Irrigation Districts. There is a fish screen on the outlet structure to prevent fish losses; however, holes in the screen have been noted by ODFW on at least two occasions (ODFW 1996). There are no means of fish passage on the dam.

Three dams within the City of Bend's UGB have no fish passage facilities. The Pacific Power and Light dam is located at river mile 166 on the Deschutes River and is a complete barrier to fish attempting to move upstream. Additionally, the North Canal dam is also a total barrier to upstream fish migration while the Colorado Street dam is a partial barrier to the upstream movement of fish. Except for some downstream movement, these upstream barriers may have created four potentially isolated groups of fish. They may pass fish only at certain flows or, quite likely, may be complete barriers (ODFW 1996).

Round Butte dam was completed in 1964. Since its inception, the Pelton Round Butte Project has affected the fish runs and upland recreation and wildlife values of the Metolius, the Crooked, and the Deschutes River. When the project was initially approved by the Federal Energy Regulatory Commission (FERC), the Project applicant claimed that fish would continue to move through the system using either the fish ladder or backup trap and haul methods (FUSP 2002). There were some fish passage facilities installed in the dam, but they were not effective for moving smolts downstream. In the late 1960's, fish passage efforts were abandoned as a failure.

According to the Final Unified State Position on the current federal re-licensing of the Pelton/ Round Butte dams:

> *The Pelton Round Butte Project continues to damage resident and anadromous fish populations, as well as aquatic, terrestrial and riparian habitat by the continued inundation of wetlands, riparian and upland habitats, by blocking passage of fish and wildlife between river systems above and below the Project, and by adversely impacting water quality. The Project also intercepts intermittent and perennial streams and blocks movements of animals across reservoirs. In addition, human access and disturbances resulting from the Project have caused additional fish and wildlife fragmentation and modified river flows* (FUSP 2002).

In order to mitigate for Pelton Round Butte's impacts on fish, a summary of the recommendations made by ODFW that affect the Deschutes River above the project is as follows:

- That the joint applicants implement a fish passage program that will establish sustainable native anadromous and resident fish runs. The joint applicants will fund and implement a fish passage plan for effective upstream and downstream fish passage of Chinook salmon, summer steelhead, sockeye salmon, Pacific lamprey, bull trout, rainbow trout, and mountain whitefish.

- Limit ramp rates except during extraordinary circumstances to reduce adverse impacts on spawning, incubating eggs, and juvenile rearing.

- In the event that passage efforts are eventually abandoned by all the resource agencies due to lack of sustainable anadromous fish populations, or risks of disease are considered too great in the upper basin, the Joint Applicants will re-open the license and develop a settlement agreement with the resource agencies with detailed alternative plans. These plans will include restoration of fish populations above and below the Project in consultation with federal and state fish and wildlife resources agencies and the Natural Resources Department of the Confederated Tribes of Warm Springs. This plan will include off-site mitigation commitments such as substantial riparian and riverine land acquisition, improvement or passage barriers and habitat improvement.

- Habitat quality for fish and wildlife above and below the Project must be improved, commensurate with the ongoing impact to riparian, riverine, wetland, and upland habitat. The Joint Applicants shall mitigate for ongoing losses via purchase and acquisition of riparian/riverine habitats or implement habitat obligations which include either projects or a habitat fund that mitigates for continuing impacts to high quality spawning and rearing habitat (FUSP 2002).

12.3.6 Interactions

Many organizations have researched the impacts of interactions between wild fish and hatchery fish. Recently, The National Research Council, the Independent Multidisciplinary Science Team, and the Independent Scientific Advisory Board have concluded that the hatchery system is in need of major reform. Jim Myron, the Conservation Director of Oregon Trout, has stated that hatchery and harvest programs in Oregon "should be separated from wild fish populations and limited to areas where harvest can be carefully controlled to eliminate adverse impacts to wild fish" (Myron 2002).

12.3.7 Temperature Standards for Fish

The ODEQ has set the following temperature criterion to protect native salmonids:

- 17.8^{o}C (64^{o}F) where salmonid fish rearing is a designated beneficial use
- 12.8^{o}C (55^{o}F) where salmonid fish spawning is a designated beneficial use (September 1 to June 30)
- 10.0^{o}C (50^{o}F) in waters determined by ODEQ to support or to be necessary to maintain the viability of native Oregon bull trout

12.4 Other Aquatic Species

12.4.1 Crayfish

Crayfish (*Pacifastacus leniusculus)* are crustaceans that are indigenous to the subbasin and are widely found throughout the streams, reservoirs, and lakes of the Upper Deschutes. Crayfish inhabit benthic environments down to 60 feet deep. Mating occurs during either the summer or the fall. Female crayfish extrude 100-300 eggs shortly after mating. The eggs are then carried through the winter to hatch in late spring. The young molt twice while remaining with the female for several weeks. Sexual maturity occurs between 18 and 30 months and at a nose-to-tail length of 2.5 inches. Some large crayfish with rapid growth rates may mate during their first fall. Crayfish are substantial food and prey for piscivorous fish and a variety of birds and mammals in the subbasin (ODFW 1996).

12.4.2 Aquatic Invertebrates

A sampling of the bottom of Crane Prairie Reservoir produced an average of 27.9 insects per square foot. The most prevalent invertebrates in the reservoir are the Diptera (two-winged flies), Hirudinea (leeches), Emphemeroptera (mayflies), Gastropoda (snails), and Annelida (worms). Extensive hatches of Odonata (dragonflies, damselflies) occur frequently. Bottom sampling in 1962 showed invertebrate production to be as high as 102 pounds per acre (ODFW 1996).

Studies completed by ODFW in Odell Lake show that the most common aquatic invertebrates present in the lake are midges and crayfish. Additionally, ODFW research staff found the composition of zooplankton to be 73% *Cyclops* and 23% *Daphnia* (ODFW 1996).

Bottom samples were collected by ODFW in Lava Lake to determine organisms present and results showed a composition of 60% Diptera (true flies), 28% Annelids (worms), and 8% Hirudinea (leeches). Also identified were members of the mayfly and caddisfly families. The total organisms present were quantified at 11.5 pounds per acre (ODFW 1996).

Aquatic macroinvertebrate samples collected at three sites from Bend at the COID Diversion area upstream to Wickiup dam indicated moderate organic enrichment by nutrients, sediment, dissolved oxygen, or thermal impacts and one sample indicating organically polluted. These designations were attributable to high sediment loads throughout the section. Abundance summaries showed only that species sensitive to changes in riparian condition represented between 0.6 and 1.5% of the total abundance. Species that fed on fine particulate organic matter represented 83.5 to 98.2% of the total abundance and were dominated by members of the black fly, midge, and tubifex worm families. Species of mayfly, stonefly, or caddisfly that are pollution intolerant represented 13.3% of the total abundance. Species that exhibited life cycles greater than 1 year were few and ranged from 0 to 3 taxa per sample. Overall, macroinvertebrate analysis indicated high amounts of sediment and fine material in the system with good water quality (ODFW 1996).

Sampling and analysis in Tumalo Creek has shown that macroinvertebrate diversity is high and abundance is moderate (Moscoso 1995).

12.4.3 Amphibians

Table 32 presents the 2001 list of known or suspected amphibian species of the Deschutes National Forest.

Table 32: Amphibian Species on the Deschutes National Forest

List of known and suspected amphibian species on the Deschutes National Forest

Common Name	Scientific Name
Northwestern Salamander	*Ambystoma gracile*
Long-toed Salamander	*Ambystoma macrodactylum*
Tiger Salamander	*Ambystoma tigrinum*
Pacific Giant Salamaner	*Dicamptodon tenebrosus*
Clouded Salamander	*Aneides ferreus*
Oregon Slender Salamander	*Batrachoseps wrighti*
Ensatina	*Ensatina eschscholtzii*
Rough-skinned Newt	*Taricha granulosa*
Western Toad	*Bufo boreas*
Pacific Chorus Frog	*Pseudacris regilla*
Tailed Frog	*Ascaphus truei*
Great Basin Spadefoot	*Scaphiopus intermontanus*
Cascades Frog	*Rana cascadae*
Bullfrog	*Rana catesbeiana*
Oregon Spotted Frog	*Rana pretiosa*

Source: USDA 2001

12.5 Aquatic Species of Concern

There are a variety of aquatic species of concern residing throughout the Upper Deschutes Subbasin. Table 33 lists the species, species status, listing agency, and occurrence in the subbasin.

Table 33: Upper Deschutes Subbasin Aquatic Species of Concern

Species of Concern	USFWS	USFS R6	State of Oregon	Occurrence
Bull Trout	Threatened	Threatened	Sensitive	Adfluvial
Redband Trout	Candidate	Sensitive	Sensitive	Resident/ fluvial
Cascade Apatanian Cadisfly	Candidate	Sensitive	Sensitive	Unknown
Tailed Frog	Species of Concern	-	Sensitive	Present
Cascade Frog	Species of Concern	-	Sensitive	Present
Oregon Spotted Frog	Candidate	-	Sensitive	Present

Source: USFS 1999

12.5.1 Oregon Spotted Frog

The Oregon spotted frog *(Rana pretiosa)* historically thrived from southwestern British Columbia down to the northeast corner of California. Currently, their range is dramatically decreased; they can now be found only through the Oregon Cascades and dipping into the northeast corner of California (Green 1997). They are known to currently occur in emergent wetland vegetation within the Upper Deschutes Subbasin near Wickiup Reservoir.

Oregon spotted frogs breed during the late winter or early spring. The male frogs have very soft calls that are similar to the sound of the distant tapping of a woodpecker. Females lay their eggs in traditional communal oviposition sites that are areas of shallow, still or slow-moving water and sparse, emergent wetland vegetation. Spotted frog eggs take from18 to 30 days to hatch and the tadpoles grow and develop for 13 to 16 weeks prior to metamorphosis in mid-summer. In two to three years, Oregon spotted frogs mature and begin breeding (Green 1997).

12.6 Aquatic Habitat Conditions

Fish require certain habitat conditions for their continued health and survival. Channel stability, substrate composition, cover, temperature, and migratory corridors all play a major role in creating habitat conditions that impact fish distribution and abundance (Buchanan 1997).

Recent studies on the variables that are important for adequate bull trout habitat can be used to understand what factors are necessary components of high quality habitat for all fish in the Upper Deschutes Subbasin. In a 1997 study, Dambacher and Jones closely examined 103 reaches of 32 Oregon streams to compare possible or potential bull trout habitat. They found seven habitat variables that played a significant role in the presence of juvenile bull trout (Dambacher 1997). These are:

- high levels of shade,
- high levels of undercut banks
- large woody debris volume
- large woody debris pieces
- high levels of gravel in riffles
- low levels of fine sediment in riffles
- low levels of bank erosion

In their research, Dambacher and Jones found juvenile bull trout residing only in areas of quality habitat containing the listed habitat variables (Buchanan 1997). It has also been documented that any increase in fine sediment reduced the survival rates for bull trout (Weacer and Fraley 1991).

In addition to specific habitat characteristics, bull trout are a stenothermal species, meaning they require a narrow range of cold temperatures to rear and reproduce (Buchanan and Gregory 1997). Bull trout distribution can be limited by water temperatures that are higher than 15 degrees Celsius (Rieman and McIntyre 1993). Water temperatures represent a critical habitat characteristic for bull trout (Mc Phail and Murray 1979, Shepard et al. 1984, Buchanan 1997). Summer maximum temperatures are considered a limiting period for juvenile and adult bull trout; fall temperatures are a limiting period for bull trout spawning; fall, winter, and spring can be limiting for egg incubation; and spring temperatures can be limiting for spring fry growth (Buchanan 1997).

Changes in habitat that reduce or isolate segments of populations can increase bull trout's' vulnerability to processes such as natural death rates, sex ratios, or chronic or catastrophic environmental events. It has been estimated that the likelihood of bull trout extinction will increase if there are much fewer than 100 redds or 2,000 total fish in an area (Rieman and Mc Intyre 1993). As the number of individuals will be smaller and the population less diverse in structure or distribution, a loss of genetic diversity might reduce fitness and thereby increase sensitivity to environmental variation (Rieman and McIntyre 1993).

Recommendations for bull trout habitat improvement projects have been made by the Oregon Department of Fish and Wildlife. Some of these improvements include:

- fencing projects to better manage livestock use in riparian areas
- planting projects to restore riparian vegetation
- road obliteration and decommissioning
- screening water diversions
- instream habitat improvement projects that increase the volume and abundance of large woody material, restore channels to proper functioning condition, or restore fish passage at artificial barriers that block migratory access to historic bull trout habitat (Buchanan et al. 1997).

Large woody material has historically been removed from the Deschutes River in order to facilitate the transportation of logs down to mill sites. Currently, large woody material is often removed from the river in an attempt to enhance navigation for anglers, rafters, and kayakers. The ongoing removal of wood has eliminated cover for trout and has diminished critical habitat for macroinvertebrates. In portions of the river that naturally lack rock outcroppings or rubble substrates, large woody material is likely to be the only source of suitable cover for aquatic life ranging widely from tiny insects to 30 inch long brown trout (USDA 1996). The presence of large woody material also helps prevent bank erosion by decreasing water velocities and armoring the channel. When large woody material is moved to the river's margins by high irrigation flows and is later dewatered in the winter, the wood provides little cover for fish and cannot successfully interact with the aquatic environment (ODFW 1996).

12.6.1 Habitat Descriptions and Limitations

Located between Crane Prairie Reservoir and Wickiup Reservoir, Browns Creek, Davis Creek, Sheep Springs, and the Deschutes River provide spawning habitat for brown and rainbow trout, kokanee, whitefish, and brook trout. A stream survey completed by the Oregon Game Commission in 1967 showed 2,315 square yards of spawning gravel present in 2.25 stream miles of Browns Creek. Of the stream miles containing spawning gravel, 1,314 square yards was rated as good and 1,001 square yards was rated as marginal. Almost 20 years later, ODFW and volunteers from Central Oregon fishing clubs worked together to add 40 cubic yards of spawning gravel to the upper sections of Browns Creek (ODFW 1996).

In 1990, a stream survey by the Deschutes National Forest was completed on 0.65 miles of the Deschutes River between Crane Prairie and Wickiup. The survey revealed that the dominant streambed substrate was cobble and the subdominant substrate consisted of small boulders. Spawning gravels were found only at the beginning and end of the section and the gravels and cobbles were not embedded. Due to the fact that the section was nearly all riffle, trout cover was rated poor overall. The surveyor also noted that Crane Prairie dam had prevented the recruitment of spawning gravel from upstream sources. It is also likely that gravel was washed out of this section by high irrigation flow releases out of Crane Prairie (ODFW 1996).

The habitat limitations identified by ODFW for this section of the Deschutes River are:

- No minimum flow release below Crane Prairie for aquatic life.
- Crane Prairie dam has blocked recruitment of spawning gravel from upstream sources
- Stream surveys have noted a lack of trout cover, pool area, and spawning gravel.
- Flow fluctuations below Crane Prairie dam can significantly alter the amount of useable spawning gravel and trout rearing cover.
- Water temperatures rise in the summer due to the release of warm surface water from Crane Prairie Reservoir (ODFW 1996).

Wickiup Reservoir is a popular fishing and boating destination in the Upper Deschutes Subbasin. The bottom of Wickiup Reservoir is covered with the tree stumps that were left when the reservoir site was logged. The stumps provide both fish cover and valuable habitat for aquatic insects and crayfish. Some of the tree stumps are lost each year due to the water level fluctuations with the irrigation season. Many of the stumps dry out and float up as the reservoir fills again, eventually piling up on the dams. According to ODFW, the quantity of stumps lost each year increases with drought conditions due to longer exposure to the air (ODFW 1996). The water temperature and water chemistry in Wickiup are suitable for aquatic production. The conductivity is 51 umhos/cm and the phosphorus concentration is 0.033 mg/l, both of which are higher than in many other Cascade lakes. The pH of the reservoir is 7.6 (ODFW 1996). Wickiup offers abundant quantities of aquatic worms, clams, larval flies, dragonflies, damselflies, mayflies, and caddisflies as fish food (ODFW 1996). ODFW has identified the following habitat limitations at Wickiup Reservoir:

- Severe water storage drawdown in some years—occurs during the fish growing season, reduces aquatic food production, and increases competition between and among fish species.
- No legal minimum pool for aquatic species.
- Loss of pine and lodgepole stumps reduces fish cover and aquatic food production.

- Outlet of reservoir is unscreened, allowing substantial loss of fish from reservoir, especially during severe drawdown years (ODFW 1996).

The fish habitat limitations on the Deschutes River between Wickiup dam and Benham Falls have been identified by ODFW as being caused by the alteration of natural flow patterns. Irrigation development has impacted this section of the river by altering flows to range from almost complete dewatering in the winter to above-normal flows in the summer. The modification of flows results in degradation or loss of fish and fish habitat. The specific impacts on fish habitat as related to flows between Wickiup and Benham Falls are detailed in section 12.6.2 Flow Regime.

The fish habitat limitations identified by ODFW for Fall River are:

- Lack of natural spawning gravel. Gravel is embedded with naturally occurring fine sediment.
- Lack of large woody material for trout cover.
- Lack of pool habitat.
- Average daily water temperature at Fall River hatchery was 45 F for the period between 1990-1994. This cold water reduces the growth rates of trout (ODFW 1996).

ODFW has identified some aquatic habitat deficiencies on the Deschutes River between Benham Falls and Bend. This section of the river has a more stable flow regime than upstream sections due to the inflow from the Little Deschutes River, Fall River, Spring River, and as assortment of springs.

The habitat deficiencies between Benham Falls and Bend are:

- A lack of spawning gravel and large woody material.
- High stream gradient and high water velocities limit spawning and rearing of trout.
- Although the flow regime in this section is improved by the influence of upstream tributaries, flow fluctuations averaging 1,695 cfs annually result in loss and disturbance of fish habitat and fish loss from stranding.
- Natural water loss through basalt formations result in a 7% flow reduction in this section of the Deschutes.
- Benham, Dillon, and Lava Island Falls may be barriers at certain flows to upstream migrating trout.
- Existing water rights allow maximum total diversions from this river section of 2,773 cfs during the irrigation season. These diversions cause disturbance and loss of fish habitat. (ODFW 1996).

12.6.2 Habitat Restoration Projects

The USFS Crescent Ranger District completed a restoration project on .4 miles of Trapper Creek in 1992. Trapper Creek is located in the far southwest corner of the Upper

Deschutes Subbasin adjacent to Odell Lake. The goal of the project was to create a minimum of 26 new habitat structures in order to restore fish habitat for Bull trout (*Salvelinus confluentas)* and restore stream channel diversity. Trees, rootwads, and boulders were placed in the stream to provide pool-forming material for fish habitat. Unfortunately, the 1992 project did not attempt to improve the hydrologic balance of the creek, so many of the habitat structures were washed away during flooding in 1996 (USDA 1999).

In 2002 the Upper Deschutes Watershed Council partnered with the United States Forest Service to restore Trapper Creek. In line with the USFS Environmental Impact Assessment, the project focused on creating an improved hydrologic balance in the system by re-contouring the existing channel and banks, excavating a new stream channel, and restoring natural channel features using large woody material, riparian vegetation, and rocks. The restoration design emphasized increasing the stream's ability to access its floodplain, increasing channel sinuosity, improving sediment balance, and reducing potential for loss of bull trout habitat. Instream habitat was increased and channel banks were stabilized and revegetated with native plants. The project design and implementation was consistent with the Oregon Watershed Enhancement Board Oregon Aquatic Habitat Restoration and Enhancement Guide.

12.6.3 Flow Regime

Low flows in the Upper Deschutes River during the winter storage season increases competition among native and introduced trout, concentrates trout, and limits useable spawning and cover opportunities. Similarly, low flows in the Middle Deschutes below Bend during summer irrigation season result also result in negative impacts to fish.

The construction of Wickiup Reservoir in the upper reaches of the Deschutes cut off access to the primary spawning gravel utilized by trout inhabiting the river above Pringle Falls. Spawning gravels below Wickiup became even more limited when the construction of the dam curtailed the recruitment of gravel from upstream sources. The stream banks below Wickiup provide only limited quantities of gravel. The gravel that is available below the dam is of rather poor quality, becomes highly embedded with fines from stream bank erosion, and is usually pushed toward the margins during high flows (USDA 1996).

As flows are severely reduced below Wickiup in early October, small fish as well as aquatic invertebrates are stranded in pools and side channels where they will soon perish. Aquatic invertebrates are important fish food items and it takes time to recolonize once their habitat has been dewatered. Populations of all aquatic organisms are forced to exist in restricted habitats only a fraction of their historical size.

Low winter flows and freezing weather result in extremely cold water temperatures with the river occasionally freezing solid in the lowest flow section between Wickiup dam and Fall River. Obviously, freezing eliminates habitat for all fish and aquatic invertebrates. Eggs deposited in redds by fall spawning fish, such as brown trout, can be lost during severe ice conditions. In severe winters, trout survival is dependent on a small number of deeper pools. Low winter flows exposes much of the stream bank to "frost heave" with loosened soil washing downstream when flows are increased in the river during the beginning of irrigation season in April. At a flow of 30 cfs, about 50% of the stream channel is exposed to frost action cycles (USDA 1994).

ODFW has pointed to the alteration of natural flow patterns as one of the primary factors limiting fish habitat conditions on parts of the Deschutes River. The 1996 ODFW Upper Deschutes River Subbasin Fish Management Plan asserts that, "detrimental impacts of irrigation development on the Deschutes River are due to alteration of natural flow patterns. Flows now range from almost complete dewatering to above-normal flows which result in degradation or complete loss of fish and fish habitat" (ODFW 1996). Some of ODFW's identified impacts on fish habitat due to regulated high flows during the irrigation season are:

- Increases in the rate of bank erosion and sediment load. Higher flows are causing changes in the meander sequence of the river.
- Spawning gravels are moved to stream margins and become imbedded with sediment. Flow regulation has eliminated the short-term spring "flushing" flows that clean spawning gravel under natural flow conditions.
- Increased bank erosion and sedimentation makes it difficult to maintain riparian and aquatic vegetation and breaks down the chain of primary food production, especially aquatic insects and the vegetation they depend on.
- Reduces bank angling opportunity due to an increase in flow velocity, increased turbidity, and increased depths.
- Inundation of stream banks during the growing season impacts growth of vegetation (ODFW 1996).

And, during the non-irrigation season, fish habitat is impacted as regulated low flows:

- Exposes areas of spawning gravel which directly impacts potential trout production.
- Reduces trout cover used for rearing, feeding, and hiding.
- Exposes the stream channel and results in a loss of aquatic invertebrate production.
- Forces trout to concentrate in a few deeper pools, increasing their vulnerability to predation and harvest.
- Increases ice-induced mortality of trout during severe cold periods.
- Dewaters adjacent wetlands and riparian areas whish provide trout food and cover.
- Exposes stream banks to freeze-thaw action resulting in breakdown and eventual loss when flows are increased.
- Increases foot access to river sections not fishable at high water levels and concurrently reduces the ability to boat the river (ODFW 1996).

12.7 Data Gaps

- Although the Deschutes National Forest recently compiled the data for the fish distributions throughout the Upper Deschutes Subbasin, the current distribution of sculpin species through the subbasin is unknown.
- A specific analysis of the impacts that the low winter flows have on fish and fish habitat between Wickiup and the City of Bend is needed.
- A close analysis of the impacts that low summer flows have on fish and fish habitat below the water diversions downstream from the City of Bend is needed.

12.8 Key Findings

- On June 10, 1998 the Columbia River population of bull trout was listed by the USFWS as a Threatened species.
- The goal for the United States Fish and Wildlife Service Recovery Plan for bull trout in the Deschutes Recovery Unit is to ensure the long-term persistence of self-sustaining complex interacting groups of bull trout distributed throughout the species native range so that the species can be delisted.
- The United States Fish and Wildlife Service has proposed to designate sections of the Deschutes River and Odell Lake as critical habitat for bull trout. The final decision will be made in October 2003 following a public comment period and a series of informational hearings.
- Bull trout are indigenous to the Upper Deschutes Subbasin but their numbers rapidly declined in the 1950's following the construction and operation of Wickiup and Crane Prairie Reservoirs. While they were previously abundant throughout the subbasin, currently, bull trout are found only in Trapper Creek, Odell Lake, and Lake Billy Chinook.
- The remnant population of bull trout in Odell Lake is the only resident non-reservoir adfluvial population remaining in Oregon.
- Redband trout are indigenous to the Upper Deschutes River and its tributaries. Redbands have been listed as a state and federal sensitive species. They were historically found throughout almost all of the streams and lakes within the subbasin, but their current range includes only the mainstem of the Deschutes, Odell Lake, Davis Lake, Wickiup Reservoir, and Crane Prairie Reservoir.
- Introductions of non-native fish species have competed with native fish populations for resources in the subbasin.
- Fish habitat conditions and successful fish spawning between Bend and Lake Billy Chinook have been severely reduced since the construction and operation of Wickiup Reservoir.
- The Oregon Department of Fish and Wildlife has stated that fish screens, minimum flow releases, and modifications to flow release timing at Wickiup and Crane Prairie Reservoirs are necessary to improve downstream conditions for fish and other aquatic species.

12.9 Recommendations

- Support ongoing monitoring of fish habitat restoration and enhancement projects such as the Trapper Creek bull trout habitat restoration project.
- Collaborate with the Odell Lake Bull Trout Working Group and use outreach activities to develop a bull trout recovery plan for Odell Lake.
- Initiate and participate in monitoring activities as a way to understand the limiting factors affecting native fish populations in the subbasin.
- Initiate and support efforts such as fine sediment sampling projects to monitor and address the changing habitat conditions on the mainstem of the Deschutes.
- Support fish species that are wild and native to the Upper Deschutes Subbasin by minimizing the impacts of hatchery trout.
- Initiate collaborative and interagency enhancement and restoration projects that seek to improve both water quality and fish habitat conditions for native fish such as redband trout in the subbasin.
- Inform community members about the characteristics of healthy fish habitat and raise awareness about specific habitat enhancement opportunities on private lands.
- Promote improved water quantity and quality for fish and other aquatic species.

13.0 CHANNEL MODIFICATION ASSESSMENT

13.1 Critical Questions

1. Where are channel modifications located?
2. Where are historic channel disturbances, such as stream cleaning, splash damming, hydraulic mining, and log drives, located?
3. How have fish in the Upper Deschutes Subbasin been impacted by channel modifications?
4. Has water quality been impacted by channel modifications?

13.2 Approach

The channel modification section was written under the assumption that channel modifications and in-channel activities may have altered the quality and quantity of aquatic resources in the subbasin. In the absence of documentation on pre-European settlement watershed conditions, the impact to aquatic resources from channel modifications can be inferred from the type of modification or historic disturbance and the channel habitat type affected.

In the Upper Deschutes Subbasin as elsewhere, channel disturbances such as extensive bank erosion or channel widening, with no apparent adjacent cause, are response indicators of changes in upstream channel input factors that may or may not be related to human activities. Therefore, the channel modification section will examine historic and current alterations to stream channels in the Upper Deschutes Subbasin, as well as potential upstream and downstream impacts from these modifications. Due to the fact that impacts to the stream channel impact water quantity, water quality, fish and fish habitat, much of the information and data in this section mirrors information from other sections of the assessment.

13.2.1 Types of Channel Modifications

The majority of the channel modifications found within the Upper Deschutes Subbasin are linked to storing or diverting water for irrigation purposes. Some hydropower facilities do exist within the subbasin, including the Pelton Round Butte Development at the northern edge of the subbasin, and Central Oregon Irrigation District and Pacific Power's hydropower facilities on the Upper Deschutes, but the majority of channel modifications in the subbasin are the dams and diversions that are utilized for managing irrigation water.

13.2.1.1 Dams and Diversions

Figure 5 in the surface water quantity section depicts the relative locations of the storage facilities, irrigation canals, and water diversions present throughout the Upper Deschutes Subbasin and Central Oregon.

Table 34 gives a brief outline of the locations and descriptions for hydroprojects, dams, impoundments, or diversions on rivers or creeks within the Upper Deschutes Subbasin. Both the Deschutes River and Tumalo Creek are heavily managed for irrigation purposes and, therefore, have multiple diversions withdrawing water from instream use.

Table 34: Hydroprojects, Dams, Impoundments, and Diversions

Name	Location	Description and Comments
Crane Prairie Reservoir	Approximately 30 miles downstream from the headwaters of the Deschutes River, near river mile 225.	Owned by the United States Bureau of Reclamation and operated in partnership with the Oregon Water Resources Department and several irrigation districts. Crane Prairie The original dam was built in 1922 but was replaced by a new structure due to leakage and safety concerns in 1940. The current dam is an earth-filled structure that is 36 feet high and 285 feet long. Crane Prairie stores approximately 50,000 acre-feet of water for irrigation purposes.
Wickiup Reservoir	Located at river mile 222.5, approximately 30 miles downstream from the headwaters of the Deschutes River.	Owned by the United States Bureau of Reclamation and operated in partnership with the Oregon Water Resources Department and several irrigation districts. Wickiup Reservoir was completed in 1949. The dam is an earthfill structure that is used to store as much as 200,000 acre-feet of water for irrigation purposes.
Central Oregon Canal	On the east side of the Deschutes River, across from Sunrise Village.	This is an irrigation diversion on the Deschutes River. It serves east Bend, Alfalfa and Powell Butte. The diversion has a fish screen that was painted black to blend with the environment. The water is carried via a flume that was originally wooden and installed in 1901. Trees were planted in front of the flume to screen it from the Sunrise Village subdivision across the river. The canal road runs north for about 1.5 miles to a hydroelectric plant. The road is not open to the public, but many use it for hiking and biking.
Central Oregon Irrigation District Hydroelectric Plant	On the east side of the Deschutes River across from the Mt. Bachelor Village trail.	Completed in 1989, this hydrofacility supplies 6 megawatts of electricity to the main power grid (equal to about 2,200 homes.) During high flow years the excess water from the Central Oregon Canal is diverted to the hydroplant to generate electricity. After running through the plant, the water is returned to the river. The plant is visible from the south end of the Mt. Bachelor Village trail.
Colorado Street Dam	On Colorado Street	This dam was built by the lumber mill operators to create log storage and to provide water for fire protection. The last mill closed in 1993 and these functions are no longer used. However, over the years, a 5-acre wetland with importance to wildlife has been created due to backup from the dam.
Bend Hydroelectric Project & Mirror Pond	The dam is on the Deschutes River, just north of Newport Bridge in the City of Bend.	Mirror Pond has been described by many as the heart and soul of Bend. Surrounded by lovely old homes and well-kept public parks, this 40-acre impoundment is created by the Bend Hydroelectric Project. The powerhouse was built in 1910, bringing hydroelectric power to Central Oregon. Operated by Pacific Power, the project produces 1,100 kilowatts of electricity or enough for 400 homes. The dam was issued a Federal Energy Relicensing Commission (FERC) license in 1970 that expired in 1993. A relicensing study was undertaken in 1990 in anticipation of renewal. However, FERC decided a license was not necessary because the river is not designated a navigable waterway. Mirror Pond acts as a settling pond for nutrient-enriched sediment from upstream sources, primarily bank erosion due to fluctuating water flows. In the late 1970's, silt filled in the pond resulting in shallow water depths. A Mirror Pond Citizens Committee was formed in 1975 to study the siltation problem. A report recommending dredging as a solution was published in 1981.

		As a result, the pond was dredged in 1982 at a cost of approximately $275,000. The dredged material was pumped upstream and used as a fill in a low area on the west bank of the river in the Old Mill District. According to the report completed prior to the dredging, the silt is expected to build up again 20 years from the dredging date.
Steidl Dam & Tumalo Irrigation District Bend Feeder Canal	On the Deschutes River in front of the Riverside Motel near Pioneer Park in the City of Bend.	This dam was built in 1922 to raise the height of the water in order to divert it into the Bend Feed Canal. The Deschutes River trail begins on the west side of the river at 1st Street Rapids on top of the buried Bend Feed Canal. The canal was buried in the 1970's. Historians disagree with the name Steidl dam because that was that original name of the North Canal Dam, but Steidl is the name in common use today.
North Canal Reservoir & North Canal, Swalley Irrigation Canal and North Unit Main Canal	Just north of Riverview Park on the Deschutes River in the City of Bend.	This impressive 33 foot tall dam was built to raise the height of the water for three diversions – North Canal (Pilot Butte Canal), Swalley Canal, and North Unit Main Canal. The dam is adjacent to Division Street, but not visible to passers by. The area surrounding the dam on the westside was recently rezoned to commercial. There is a Park District easement for a fisherman trail on the west side of the river from Mt. Washington Boulevard to the dam. Today, otter play on and around the dam. An osprey fishes in the pond where the trumpeter swans were released in 1998. The North Canal, also known at the Pilot Butte Canal, is managed by COID and goes to Redmond and Terrebonne. The Swalley Irrigation Canal goes to the north part of Bend. The North Unit Main Canal, managed by the North Unit Irrigation District, goes to Madras with no water deliveries until north of the Crooked River. It is currently being lined with concrete to reduce water loss.
The City of Bend surface water intake	Located on Bridge Creek, about 500 feet upstream of the confluence with Tumalo Creek.	Bridge Creek is a small stream south of Tumalo Creek, located about 11 miles west of Bend. Bridge Creek dam stores a large portion of the municipal water for the City of Bend. Bridge Creek dam prevents fish from migrating upstream.
Tumalo Feed Canal	Located on Tumalo Creek, 2 ½ miles upstream from the confluence with the Deschutes River.	Managed by the Tumalo Irrigation District, the Tumalo Feed Canal provides irrigation water to the unincorporated community of Tumalo.
Pelton-Round Butte dam complex	Located at the northernmost edge of the Upper Deschutes Subbasin	Managed by Portland General Electric and the Confederated Tribes of Warm Springs, the Pelton-Round Butte dam complex is a set of three hydroelectric dams that generate 427 megawatts of power. These dams are the impoundments that create Lake Billy Chinook. There were some fish passage facilities installed in the dam, but they were not effective for moving smolts downstream. In the late 1960's, fish passage efforts were abandoned as a failure.

Source: McNamara 1999; ODFW 1996;USGS 2002

Crane Prairie Reservoir was previously a natural meadow in which the Deschutes River, Cultus River, Rock Creek, Cold Creek, Quinn River, Deer Creek, and Cultus Creek once converged. Rock and Cold Creeks, which can be seen on old survey maps, are currently completely inundated by impounded water. When the reservoir was first filled, the waters that flooded the meadow at Crane Prairie and a portion of the adjacent forest killed numerous trees. The reservoir was drained for many subsequent years to allow harvest of marketable timber. Currently, the reservoir still reveals the results of flooding the meadow with lodgepole and ponderosa snags and stumps as observable features. The original dam was built in 1922 but was replaced by a new structure due to leakage and safety concerns in 1940 (ODFW 1996). The current dam is an earth-filled structure that is 36 feet high and 285 feet long.

Wickiup Reservoir was constructed by the Bureau of Reclamation and was completed in 1949. The dam is an earthfill structure that is used to store water during the winter for irrigation uses in the summer. The holding capacity for Wickiup is 200,000 acre-feet. The water releases from Wickiup are currently managed by the Oregon Water Resources Department (OWRD). The reservoir water is not part of the municipal water supply and the dam serves no hydropower functions. The reservoir's purpose is to store water for irrigation use in the summer. The current annual flow regime released out of Wickiup Reservoir is defined by the quantity of water rights held by irrigation districts in the area. In order to fulfill the requirements of irrigation districts' water rights, Wickiup Reservoir must be filled to a certain level every winter. Consequently, winter flows in the Deschutes are suppressed until sufficient water is stored for the upcoming irrigation season. As a result of winter water storage, the current levels of water flow below Wickiup have been substantially altered from the natural stable annual hydrograph of the river. While the natural flows of the Upper Deschutes River were historically stable year round, the current regulated hydrograph can swing between 20 cubic feet per second (cfs) to over 2,100 cfs (USDA 1996). The modifications and extreme fluctuations of flow have contributed to conditions that have destabilized the stream banks, increased stream bank erosion, and reduced water clarity, thereby decreasing water quality for fisheries and humans (USDA 1996). In response to the modified flows, the channel is shifting and potentially trying to find a new equilibrium (Wasniewski 2002).

North Canal Dam is the dam below Bend that creates the diversion for three canals operated by Swalley Irrigation District, Central Oregon Irrigation District, and North Unit Irrigation District (ODFW 1996).

13.2.1.2 Channel Restoration

Soda Creek is located near the western margin of the Upper Deschutes Subbasin. Originating as glacial waters on Broken Top, Soda Creek eventually drains into Sparks Lake. In 1997-1998 the United States Forest Service restored seven new bends to the previously channelized stream. A glacial moraine had collapsed from Broken Top in 1966 and sent tons of rock and sediment into the stream channel. At that time, the channel was bulldozed and straightened. In order to return Soda Creek to a healthy system for fish and wildlife, the Forest Service and project manager Marc Wilcox used aerial photos, contour maps, and historical maps to attempt to mimic and design a more natural channel. The creek was restored to 1.5 feet deep instead of its post-1966 six inches, willows were planted along the riparian zone to anchor the soils of the new channel, and the creek was extended from 1,000 to 1,800 feet long with seven new meanders (USDA 2000).

13.2.1.3 Dredged channels

Mirror Pond is a 40-acre impoundment that is created by the Bend Hydroelectric Project. The powerhouse was built in 1910, bringing hydroelectric power to Central Oregon. Operated by Pacific Power, the dam that creates Mirror Pond acts as a settling pond for nutrient-enriched sediment from upstream sources. These sources primarily include bank erosion due to fluctuating water flows. In the late 1970's, silt filled in the pond resulting in shallow water depths. A Mirror Pond Citizens Committee was formed in 1975 to study the siltation problem. A report recommending dredging as a solution was published in 1981. As a result, the pond was dredged in 1982 at a cost of approximately $275,000. The dredged material was pumped upstream and used as a fill in a low area on the west bank of the river in the Old Mill District. According to the 1981 report completed prior to the dredging, the silt was expected to build up again 20 years from the dredging date.

13.3 Impacts of Modification

13.3.1 Tumalo Creek

Following the Bridge Creek fire, the Tumalo Creek channel has been unstable. The removal of large quantities of instream and riparian wood after the fire caused this system to become very unstable. Tumalo Creek is mainly a C type channel with small inclusions of steeper B type channels. The parts of the creek that are C type channels are more sensitive to disturbances and changes in the watershed such as wildfires. The average width of the channel is 45 feet; however, widths were as wide as 95 feet in areas of braided zones of deposition. In some sections, the channel is entrenched which causes greater than bankfull flows to stay in the channel. The higher flows create high bank shear stress and excessive bank erosion. It is estimated from stable reaches that the bankfull width should be around 32 feet.

Tumalo Creek abandoned its old channel and created a new channel during the 2002 high flows as indicated by aerial photos taken in 2001 and 2002. The old channel was approximately 735 feet where the new channel is now only 615 feet. The shorter stream length increases stream gradient thereby increasing stream power, which increases bank erosion through higher shear stresses. As the new channel was formed, within a one-year period it eroded 1,367 yards, or approximately137 truckloads of material (Wasniewski 2002).

Substantial sections of the creek have lost stream bank and riparian habitat. The total estimated loss is 15,708 yards of material. This is the rough equivalent to 1,570 truckloads of bank material into the channel. As the channel moves laterally across the valley this land loss increases. According to Deschutes National Forest hydrologists, the sediment from the stream banks is converted from bank material to instream substrate. In the stream, it overwhelms the sediment transport balance. The stream becomes wider and braided, which reduces the amount of available stream power to move the sediment through the system. It becomes very difficult and requires long periods of time for a braided system to naturally recover on its own. Additionally, the alders that had been present along Tumalo Creek have been dying off. The loss of rooting strength from the alder in addition to the removal of large quantities of instream and riparian wood after the Bridge Creek fire caused this system to become very unstable (Wasniewski 2002). Without rooting vegetation the banks erode very easily. The banks mainly consist of rounded cobble intermixed with sands and gravels.

As the old channel becomes totally cut off by future bedload deposits, more stresses will be put on the new channel causing it to erode banks and widen. The new channel comes very close to the South Fork of Tumalo Creek as it parallels the main channel. This creates a concern that the main Tumalo may move into the South Fork, thereby moving the new confluence about .5 miles upstream. If the main channel moves into the South Fork, there would be substantial bank loss over approximately one-half mile of lost riparian habitat. The stream bank volume would be transported downstream creating additional channel and bank erosion. There is also a risk of draining beaver ponds and spring water directly into the main channel where they currently parallel the riparian area (Wasniewski 2002).

13.3.2 Upper Deschutes River

As discussed in previous sections, Wickiup Reservoir's construction and operation in 1949, water storage and release schedules have significantly modified the flows in the Deschutes River, subsequently affecting the channel morphology including erosion and sedimentation. While the natural flows historically remained very stable year-round, the regulated flows below Wickiup rise and plunge dramatically through the course of a given year. During the winter storage season the minimum regulated river flow below Wickiup Reservoir is 20 cfs, which represents and 95% reduction the natural unregulated flows (minimum natural unregulated flows were approximately 419 cfs prior to the construction of the reservoir) and during the summer irrigation season, the maximum daily river flows have been recorded at 2,280 cfs, which is approximately 162% of the natural unregulated flows (maximum natural unregulated flows in the summer were approximately 1400 prior to the construction of the reservoir) (USDA 1996) (see Appendix I for more information).

The Upper Deschutes River channel between Wickiup Dam and Fall River contains sediments deposited from volcanic activity and the washing down of glacial debris that are relatively fine and provide little natural resistance to the erosive forces present. This natural lack of resistance is exacerbated by releases and flows from Wickiup Dam that exceed those that occurred prior to regulation (USDA 1996).

The management of flows has created the equivalent of a 25-year flood event sustained for the six-month irrigation season since the construction of Wickiup in 1949 (USDA 1996). Artificial flood stages from irrigation releases have accelerated lateral erosion on the outside banks of bends in the river and increased deposition on the inside of river bends. Evidence of these stream bank changes was gathered by comparing contemporary and historic photographs. The results from the comparison include a 20% increase in the width of the channel between 1943 and 1991 and an increase in the number of meander cutoffs from 2 to 12 from 1943 to 1991 (USDA 1996). The type of bank material present plays a key role in the greater or lesser impact that the hydraulic force of the water exerts on a stream bank. While in some sections of the river such as the Benham Falls area, geologic processes have constructed hard bedrock channels that resist erosion, the Deschutes River channel between Wickiup Reservoir and Fall River is composed primarily of highly erodable fine sediments deposited from successive volcanic activity. The high springtime flows released from Wickiup erode the fine sediments that are not held in place by either the roots of riparian vegetation or large woody material (USDA 1996).

13.4 Data Gaps

- Research and/or modeling of the potential success for fish populations between Wickiup Reservoir and the City of Bend with stable annual water levels is needed.
- A better understanding of the impacts the modified flow releases out of Wickiup Reservoir have on the bank stability issues over a longer period of time is needed.
- Further monitoring of sediment loss from stream banks downstream from Wickiup Reservoir will help resource managers understand the impacts of the reservoir on the stream channel.
- A complete understanding of the dimension and profile of the Tumalo Creek channel that existed prior to the Bridge Creek fire and subsequent fire management activities is needed.

13.5 Key Findings

- The construction and management of Wickiup Reservoir has seriously degraded watershed resources such as water quality, fish habitat conditions, and riparian zone conditions.
- As revealed through channel cross-sections completed by the Deschutes National Forest and the Upper Deschutes Watershed Council's Upper Deschutes River Bank Characterization, the stream banks between Wickiup Reservoir and the City of Bend are eroding and the channel shape is changing.
- Tumalo Creek's current channel is unstable following the Bridge Creek fire and the post-fire removal of almost all instream and stream bank large woody material. The wood that had previously acted as stabilizing features for the channel was removed. Channel instability has resulted in substantial loss of fish habitat in Tumalo Creek.

13.6 Recommendations

- Complete cross sectional profiles of the remaining key reaches on the Upper Deschutes below Wickiup Reservoir. Use data to locate and quantify levels of sediment transport.
- Continue to monitor stream bank erosion of the stream banks between Wickiup and the City of Bend with community programs such as Streamwalk.

- Survey reference reaches on Tumalo Creek and Bridge Creek. Survey areas for the presence of large woody material to help guide effective channel restoration projects.
- Participate in stream bank restoration projects on Tumalo Creek.
- Use the restoration of Tumalo Creek as an opportunity to raise awareness among community members about the impacts that channel modifications and land management activities can have on water quality, fish and fish habitat, and riparian zone conditions.

14.0 SEDIMENT SOURCES ASSESSMENT

14.1 Critical Questions

1. What are primary sediment sources in the watershed?
2. Which reaches of the river have high-suspended sediment or sediment bedload levels?
3. What impact do high sediment levels have on fish or aquatic habitat conditions?
4. Does upstream erosion contribute significantly to downstream sediment levels?
5. What primary areas are experiencing high rates of sediment deposition?
6. What areas qualify as high priorities for remedying sediment conditions in the watershed?

14.2 Approach

The sediment section was researched and written under the assumption that sediment is a normal and critical component of stream habitat for fish and other aquatic organisms. However, the more that sediment levels deviate from natural patterns of a watershed, the more likely that aquatic habitat conditions will be impacted and altered. Human-caused increases in sediment commonly occur at a limited number of locations within the watershed and can be identified by examining a combination of site characteristics and land use practices. Sediment movement is often episodic, with most erosion and downstream soil movement occurring during infrequent and intense erosive events.

The majority of the information and data for this section comes from the 1996 USDA *Upper Deschutes Wild and Scenic River Record of Decision and Final Environmental Impact Statement,* the Deschutes National Forest *Upper Deschutes River Instream Flow Assessment* (1994), the 2002 Oregon Department of Environmental Quality's 303(d) List, and the Upper Deschutes Watershed Council's 2002 *Upper Deschutes River Bank Stability Characterization* (see Appendix I).

14.3 Sediment Sources

14.3.1 Location and Type

14.3.1.1 Upper Deschutes River between Wickiup and the City of Bend

Many previous studies including: the 1991 USDA Instream Flow Study for the Deschutes River Above Bend, the 1994 USFS *Upper Deschutes River Instream Flow Assessment*, the *Upper Deschutes Wild and Scenic River Record of Decision and Final Environmental Impact Statement*, and the Oregon Department of Environmental Quality's *Upper and Little Deschutes 2001TMDL Water Quality Monitoring Study (Draft)* have identified elevated levels of sediment and turbidity occurring immediately following spring water releases from Wickiup Reservoir.

In areas between Wickiup Reservoir and the City of Bend, the Deschutes River is on the Department of Environmental Quality (DEQ) 2002 303(d) list for both turbidity and sediment. DEQ's 2001 (Draft) *Upper and Little Deschutes TMDL Water Quality Monitoring Study* identified stream bank erosion as the primary cause for increased sedimentation along this reach. The stream banks are a primary sediment source in between Wickiup and Bend.

Stream bank erosion contributes to increased levels of sediment and turbidity. Elevated erosion rates can lead to unfavorable water quality conditions involving accelerated sediment yields, changes in stream instability, and related stream type changes. Water quality monitoring by the Oregon Department of Environmental Quality and the Deschutes National Forest Service have identified two water quality parameters, turbidity and sediment, that do not meet DEQ standards on the Upper Deschutes River.

Turbidity, one parameter used to measure water quality, can increase with increased erosion and sediment release (Harden-Davis 1991). Increases in levels of turbidity and sediment in the Upper Deschutes have been linked to the regulation and release of flows from upstream reservoirs (USDA 1996). From spring until midsummer in the upper reaches of the Deschutes, water quality is very good as it first leaves Wickiup Reservoir. However, the quality of the water rapidly deteriorates in the first few miles below the dam. In the spring, a large slug of suspended sediment reaches General Patch Bridge at river mile 199 that is at least 10 times the background levels measured at Wickiup dam (USDA 1994). Turbidity levels peak when flows are ramped up to 800 cfs (USDA 1996).

The elevated turbidity levels that follow the initial spring irrigation release are largely a result of the dramatic fluctuations in flow levels on the Upper Deschutes. During the winter storage season as little as 20 cfs (USDA 1996) is released from upstream reservoirs, leaving much of the channel exposed. At such low flows, weathering and frost action loosens the exposed channel and its bank material which is later eroded by the increased flows of as much as 2280 cfs in the spring. After the initial spring water releases, turbidity levels decrease gradually through the summer. As a result, neither the turbidity nor the sediment levels of 54 miles of the Upper Deschutes meet the state water quality standard, which defines a water quality violation for turbidity as an increase in excess of 10 % over background (USDA 1996).

Specifically, many of the channel banks of the Deschutes River between Wickiup dam and Benham Falls are bare and badly eroding (Yake 2002). In this area, bank erosion averages .2 to .4 feet per year and apparently started subsequent to the operation of Wickiup dam. Most of the eroded material is fine grained (less than 2 millimeters) (Cameron and Major 1986). A comparison of 1943 and 1991 forest service photographs reveals that the Deschutes River between Wickiup dam and Benham Falls widened an average of 20% during this 48-year period (USDA 1994).

According to the 1994 USFS *Instream Flow Assessment*, the previously discussed erosion conditions are linked to the following characteristics of the Upper Deschutes that combine to create stream banks that are a primary source of sediment in the area. On the Upper Deschutes below Wickiup Reservoir:

- The ash and streamborne sediments of the river channel are the fine-grained materials that have low bulk density, lack cohesion, and are highly erodable.
- The gradient of the river between Wickiup and Benham Falls is low--a drop of 132 feet in 44 river miles.
- In the early years of this century much of the large woody material between Wickiup's current location and Bend was removed from the channel to facilitate the transportation of logs down the river from Wickiup to ½ mile above Benham Falls.
- There is a large amount of private and a lesser amount of public development adjacent to the river.

The *Instream Flow Assessment* also documented the following features and erosion conditions that are the product of regulated flow regimes in the Upper Deschutes:

- Nearly 15% of the channel banks are bare and badly eroding.
- A comparison of 1943 and 1991 photographs reveals that the Deschutes River between Wickiup Reservoir and Benham Falls widened an average of 20% during this 48-year period.
- In 1943, two cutoff meanders existed. In 1991, twelve existed.
- From Wickiup Reservoir to Fall River there is a "drawdown" area in the river channel that lacks vegetation. This area is between the levels of about 30 and 1000 cfs flows.
- Turbidity increases downstream from Wickiup to peak levels that exceed 10 ntu's when irrigation water is initially released then reduces to near 2.5 ntu's even though flows continue to increase.

14.3.1.2 Mirror Pond

A century of evolving water management practices has resulted in significant changes in the character of the Upper Deschutes River as it flows through the City of Bend. Perhaps most notably, Mirror Pond is filling with sediment and the shape and character of the river is changing in response. Sediment from the upper portions of the subbasin is carried into Mirror Pond by flows in the Deschutes River. When these flows reach the wide, shallow Mirror Pond area, sediment settles to the river bottom (Houston 2003).

Mirror Pond is downstream from three dams on the Deschutes River-- Crane Prairie, Wickiup Reservoir, and the Colorado Street dam. The pond sits behind the Bend Hydroelectric Project and dam which are just north of Newport Bridge. The reservoir basin behind a dam commonly contains quantities of sediments that would not be there if the dam had not been built. This is because dams form effective sediment traps until eventually their pool areas become completely filled with sediment. The amount of trapped material depends on the size of the reservoir, rate of sediment supply from the upstream watershed, and length of time the dam has been in place. Many small dams throughout the west have pool areas that are completely filled with sediment (Heinz 2002).

In Mirror Pond, sedimentation has been occurring since the creation of the pond in 1910. In an effort to deepen the pond and mitigate the effects of sedimentation, the City of Bend dredged the pond in the early 1980s. Since the dredging, sediment has continued to fill the pond and there are currently sections of the pond that are less than 12 inches deep. The sedimentation in Mirror Pond impacts recreation, water quality, aesthetics, fish and wildlife habitat, and the overall health of the downstream watershed. In some portions of the pond, there are unpleasant odors and excessive algal growth which affect recreational use and impact private and public property.

The Upper Deschutes Watershed Council has developed a partnership with the City of Bend to define and understand the specific causes and sources of the sedimentation. Together, they plan to evaluate the impacts and develop a range of potential solutions to the sedimentation of Mirror Pond (Houston 2003).

14.3.1.3 Potential Sediment Sources

In an undisturbed forest, levels of soil erosion are extremely low. However, disturbances including road building, harvesting activities, fires, and fire management activities can lead to erosion. Potential sediment sources can include road instability; rural road runoff; urban runoff; surface erosion from crop land, range land, or burned land.

Management activities that can accentuate overland flow include those that contribute to the loss of vegetation or litter, increase compaction, increase amounts of bare soil, or increase the frequency of hot burns or catastrophic fires. Surface flow or runoff carries eroded soils across upslope areas. Runoff exhibits short travel times during periods of general moisture excess. Moisture storage and the infiltration capacity of soil may be exceeded by high snowmelt rates, high rainfall amounts, or rain-on-snow conditions. During these conditions, overland flow can occur with relatively rapid movement of water downslope towards depressions and channels.

While natural factors sometimes contribute to the existence of overland flow, land use activities can sometimes increase or exacerbate its occurrence. The human activity that can most often accelerate surface erosion is an alteration such as road building or other disturbance to the soils of upland slopes. Surface erosion typically removes those portions of a soil profile that are the highest in nutrients and organic matter and where surface erosion is severe, the long-term productivity of a site may decrease. Accelerated levels of sediment eroding down from hillslopes can also have a profound effect on water quality, composition of streambed sediments, channel stability, and fish habitat (Beschta 1998).

Due to the fact that burn sites are especially sensitive, logging after a fire can lead to accelerated erosion, sedimentation, and soil compaction. Post-burn soil conditions can certainly vary depending on fire severity, steepness of slopes, and inherent erodability, but regardless, soils are exceptionally vulnerable in a burned landscape (Beschta et. al

1995). Many riparian areas along the Upper Deschutes River are already highly susceptible to erosion due to loose volcanic soils, and logging post-burn areas at or near riparian zones has been shown to increase erosion and subsequent sedimentation in the river. Sedimentation is already a concern on the Upper Deschutes River between Wickiup and the City of Bend; this section of the river is on DEQ's 303 (d) list for sedimentation and turbidity and management activities that increase erosion into the river negatively impact fish and other aquatic species.

Sediment transfer and reduced soil productivity are two major concerns in a burned landscape (McIver 1998). Soil disturbance and erosion vary based on the type of logging activity and whether or not roads were built. According to ecologist James McIver, road building causes the greatest impact and plays the biggest role in contributing to post-fire erosion. An estimated 90% of sedimentation from logging activities comes from road building.

Sedimentation, erosion, and run-off all increase in areas that are logged when compared to unlogged areas. Post fire ground- based logging and the associated road-building can compact soil and lead to more run-off (McIver 1998). According to the collaborative 1995 report:

> *Roads are associated with a variety of negative effects on aquatic resources, including disruption of basin hydrology and increased chronic and acute sedimentation. Under no circumstances should new roads be introduced into sensitive areas, including roadless or riparian areas* (Beschta et. al 1995).

Any activity that disturbs litter layers, the soil surface, or removes stabilizing features such as downed trees can accelerate soil erosion and sediment delivery to aquatic systems (Beschta et al.1995). Specifically, a portion of the wet and dry meadows including Tetherow Meadows on the Upper Deschutes River have been damaged by off road vehicles, which compact soils and substantially increase erosion problems.

14.3.2 Impact on Fish Habitat

The Upper Deschutes River has certain characteristics that make sedimentation especially critical. The gradient of the river is only a few feet per mile (Bennet 1970) and, due to this low gradient, the river is unable to flush sediment out of the streambed. Additionally, this abnormal inability to flush sediment is caused by the natural lack of seasonal water level fluctuation.

Sedimentation has caused the filling in of trout spawning beds. Ongoing sedimentation has led gravels in the Upper Deschutes River to become compacted to nearly concrete consistency in spawning beds. This level of compaction has made it physically impossible for trout to use gravels for egg deposition (Garvin 1977). When sediment enters spawning beds, it impacts the oxygen concentration of the intragravel water, the removal of metabolic waste from redds, the flow of water through the bed, and the ease of emergence of trout fry from the bed. The unnatural addition of excessive sediment into the streambed decreases the volume of spaces within the bed and the volume of water is reduced proportionally. The flow or exchange of intragravel water is decreased from sediment filling and blocking the available spaces. Although the volume of water is reduced, the metabolic rate of organisms in the spawning bed remains constant, thereby decreasing the dissolved oxygen concentration of the intragravel water (Garvin 1977).

The flow of water in spawning beds is critically important as it removes metabolic wastes. When water flow through beds is decreased, the concentration of metabolic wastes increases. This increase in metabolic wastes decreases the dissolved oxygen concentrations in the nest; and toxins from the waste can poison eggs or fry. Sediment can also physically block the emergence of fry from the streambed. Because of the effect of sediment on the flow of water and the emergence of fry, fry size at hatching is reduced (Garvin 1977).

14.4 Opportunities

Some sedimentation in the upper Deschutes River has been reduced due to cooperative work with the watermaster and the irrigation districts responding to the water releases out of Wickiup Reservoir. Including: slowing down the rates of change in water release, better timing of the releases, and in some cases, reducing the total amount of water released, these efforts attempt to reduce the effects of dramatic fluctuations in river flows. The Upper Deschutes Wild and Scenic River and State Scenic Waterway Comprehensive Management Plan has set a target of 0.1 ft/ 4 hr (rising) and .2 ft/ hr (falling) ramping rates. In current practice, the watermaster attempts to limit water release changes to .5 ft/ day (USDA 1996). Even with these cooperative endeavors however, the sedimentation problem still exists. The long-term minimum flow target set by the Wild and Scenic management plan is 300 cfs for 90% of the time. Currently, minimum flows are as low as 20 cfs. There is no limitation for current maximum flows out of Wickiup, but the Wild and Scenic management plan has set targets for 1400 cfs.

14.5 Data Gaps

- Although there has been significant interest and research focused on the upper Deschutes River, a comprehensive analysis of the relationship between flows, erosion, and sedimentation has not been completed.
- Widespread public understanding of the stream bank stability issues between Wickiup and the City of Bend is needed.
- Additional monitoring of sediment loss in the Upper Deschutes River between Wickiup and the City of Bend needs to be completed.
- An analysis of past stream bank restoration successes and failures on the Upper Deschutes needs to be completed in order to understand what stream bank stabilization techniques will effectively reduce sediment loss within the modified flow regimes.

14.6 Key Findings

- Between Wickiup Reservoir and the City of Bend, the Deschutes River is on the Department of Environmental Quality's (DEQ) 2002 303(d) list for both turbidity and sediment. DEQ's 2001 Draft Upper and Little Deschutes TMDL Water Quality Monitoring Study identifies stream bank erosion as the primary cause for increased sedimentation along this reach. Turbidity, one parameter used to measure water quality, has increased with increased erosion and sediment release and the turbidity levels now exceed Oregon water quality standards.
- The Deschutes River channel below Wickiup Reservoir contains loose sediments deposited from the combination of volcanic activity and alluvial processes. These sediments are relatively fine and provide little natural resistance to the erosive forces present.
- The stream banks between Wickiup Reservoir and the City of Bend are eroding heavily. The volcanic soils of the banks are dewatered in the winter and are consequently exposed to freeze/thaw conditions that make them exceptionally vulnerable to erosion. When high river flows are released for irrigation in the spring, a large rush of sediment is washed downstream. The stream banks in this area are a significant source of sediment to the river system.
- The sediment that is eroded from upstream stream banks is later deposited in downstream areas of lower velocity.

14.7 Recommendations

- The existing information and field work should be directed toward using the bank stability characterization data (see Appendix I) to complete further calculations and analyses of sediment source locations and quantity of sediment eroding from each bank section in the Upper Deschutes between Wickiup and Bend.
- The Upper Deschutes River Bank Stability data and characterization map can be used by resource and land managers as an informative tool for choosing and prioritizing stream bank restoration project sites.
- Resource managers coordinating stream bank restoration projects along the Upper Deschutes River must collaborate and coordinate with other interested groups and agencies doing restoration work in the watershed.
- Stream bank restoration projects should be prioritized based on the impact and benefit to the stream system as a whole.
- Stream bank stabilization and restoration projects should be consistently monitored to determine project effectiveness and downstream impact.
- Additional examination and research can be directed toward stream bank stabilization and riparian restoration methods appropriate and effective within the unique modified flow regime of the Upper Deschutes.
- A pilot project applying methodology specific to the Upper Deschutes flow regime will be researched, implemented, and monitored for effectiveness and success. As there are currently very few, if any, models for stabilization and restoration projects in systems with channel types, bank materials, and flow regimes such as in the Upper Deschutes, it should be a priority for resource

managers in the area to pioneer a pilot project that accurately represents the unique characteristics at work. The pilot project can stand as a model for future stabilization and restoration projects on the Upper Deschutes.

15.0 KEY FINDINGS AND RECOMMENDATIONS

In order to enhance or protect watershed resources, watershed managers must have an understanding of both the historic and current conditions within the area of concern. The complete story of a watershed's health rests in the land use trends just as much as it rests in the water quality data or fish habitat information collected for the area. The data gaps, key findings, and recommendations provide a condensed version of the information from all of the previous sections. Together, they represent an effort to paint an interconnected picture of the historic and current conditions within the Upper Deschutes Subbasin. Only by understanding how watershed conditions have changed over time, and how those conditions are related to and affected by human impacts and choices, will resource managers understand how best to steward future watershed health.

15.1 Historical Conditions

15.1.1 Data Gaps

- There is little data on the historical conditions of some private lands in the subbasin.

15.1.2 Key Findings

- Historically, the Upper Deschutes Subbasin provided suitable and plentiful habitat for widespread bull trout populations.
- The Deschutes River contained abundant fish and wildlife that provided sustenance and resources to Native Americans in the area.
- Timber was the leading resource for settlers in the early 1900s. At that time, the Deschutes River was home to two of the biggest pine sawmills in the world.
- The forested portions of the Upper Deschutes Subbasin that have not been designated as wilderness have a high forest road density.
- The Deschutes River was historically used to transport logs to downstream lumber mills. The stream banks were scoured of large woody material in order to prevent log-jams. The lack of large woody material along the river during the early part of the 20^{th} century contributed to erosion along the stream banks
- The development and irrigation of most of the arid lands within the subbasin occurred following the passage of the Carey Act in 1894. Irrigation development created the possibility for more settlers to move to and thrive in the drier parts of the subbasin.

15.1.3 Recommendations

- Collaborate with natural resource agencies and organizations in the area to collect and consolidate historical watershed information that can be used to guide restoration efforts.
- Help secure funding for projects that synthesize and publish accurate historical watershed information.

15.2 Land Use

15.2.1 Data Gaps

- The impacts from private land management and private land use and are not well documented.
- The potential impacts that a rapid shift from a resource-based economy to a tourism/recreation-based economy will have on the watershed resources of the Upper Deschutes Subbasin are not well understood.

15.2.2 Key Findings

- Deschutes has been the fastest growing county in Oregon since 1989. Almost 90% of the county population growth between 1990 and 2000 was due to new individuals and families moving into the area. The new residents moving to the area are frequently unfamiliar with the specific watershed issues, history, and concerns of the Upper Deschutes Subbasin.
- One of the most distinctive characteristics drawing growth to the subbasin is the Deschutes River system and its aquatic life. The health of the river will continue to be threatened by the growth that is drawn to it unless proactive steps to protect watershed resources are taken by community members, resource agencies, landowners, and regulators.
- Rapid population growth is the most challenging issue facing the Upper Deschutes Subbasin. All resource and land managers must take the brisk rate of growth into consideration when choosing and prioritizing projects in the area.
- The rapid growth in urban centers will impact watershed resources in cities as well as in downstream rural areas.
- Outdoor recreation and natural resource-based tourism are rapidly growing to be some of the primary industries providing jobs and attracting both visitors and new residents to the area.
- As the combined social and economic base in the area shifts from a focus on resource-based industries such as timber and agriculture to an emphasis on outdoor recreation and urban services, there are increasing conflicts in water and resource allocation.
- The Upper Deschutes Wild and Scenic River Management Plan and the Upper Deschutes Subbasin Fish Management Plan are data rich and comprehensive management plans that provide accurate water quality, fish, and fish habitat

information for resource managers to use when choosing, prioritizing, and coordinating watershed enhancement projects.

15.2.3 Recommendations

- Promote awareness about the impact of past, present, and future land use decisions on watershed resources.
- Respond to the rapid influx of new residents to the area by implementing outreach programs that raise awareness among community members about watershed health and current watershed concerns such as water quantity and water quality for fish, wildlife, and human use. Use outreach programs to apply citizen involvement toward monitoring watershed and stream health conditions.
- Present watershed resource information at public gatherings. As a way to raise community awareness about watershed issues, support existing outreach activities and programs such as Riverfest, the Kokannee Karnival, and Salmon Watch.
- Collaborate with recreation-based organizations and companies to foster the informed use of watershed resources; thereby reducing negative impacts on the watershed during recreation activities.
- Work with policy makers to promote a watershed-based understanding of urban issues.
- Initiate and support projects that promote the objectives for preserving fish, wildlife, and watershed resources as articulated within the Upper Deschutes Wild and Scenic River Management Plan and the Upper Deschutes Subbasin Fish Management Plan.

15.3 Upland Vegetation

15.3.1 Data Gaps

- There is currently no systematic method for mapping the distribution and abundance of noxious weeds on all lands in the assessment area.
- There have been no comprehensive maps created that present current or historic noxious weed populations across management boundaries. The noxious weed maps that have been assembled are not comprehensive; generally these maps include only sites that are easily accessible by roads or trails.

15.3.2 Key Findings

- Combined with density and structural changes, species composition of vegetation throughout the higher elevation portions of the subbasin has shifted from being dominated by fire climax species of large ponderosa pines to predominantly shade tolerant true fir species. Primarily the result of fire suppression and selection harvesting, this shift has caused an increase in overall canopy cover above that which occurred historically.

- The shift in vegetation structure, density, and species composition throughout the Upper Deschutes Subbasin has lead to a general increase in overall susceptibility to disease agents such as armillaria root disease.
- Specifically, increased forest densities are leading to a higher vulnerability to insect attack. Pines are highly vulnerable to attack by the western pine beetle in the high density conditions present throughout some parts of the subbasin.
- The remaining old growth ponderosa pine stands in the Upper Deschutes Subbasin provide valuable food and shelter for wildlife such as: the northern spotted owl, marten, woodducks, white-headed woodpecker, and ash-throated flycatchers.
- As throughout most of the Western states, noxious weeds are invading the Upper Deschutes Subbasin due to past introductions, soil disturbances, land use practices, and increased access to introduce exotic weed species to new areas. Weeds continue to crowd out native plants and exacerbate erosion problems.
- Many effective groups have formed in response to the increasing noxious weed problem in the Upper Deschutes Subbasin. Including the Deschutes County Weed Board, BLM and Deschutes National Forest weed programs, the Deschutes County Soil and Water Conservation District, From the Ground Up, and the Upper Deschutes Watershed Council, many organizations have coordinated weed pulls and have provided some limited weed mapping,

15.3.3 Recommendations

- Support programs that raise awareness about the impacts of the shift in vegetative species composition throughout the subbasin.
- Support efforts to combine weed data from natural resource agencies and organizations to create a comprehensive noxious weed map of the Upper Deschutes Subbasin.
- Raise awareness among local community members and landowners about the causes of weed invasions and the impacts of noxious weeds on watershed resources.
- Support and collaborate with the existing weed programs of the Deschutes National Forest, BLM, and Deschutes and Jefferson Counties to manage volunteer groups in large-scale weed pulls.
- Continue to support organized events such as Riverfest as a way to increase widespread awareness of noxious weed problems in the Upper Deschutes Subbasin.

15.4 Wildlife

15.4.1 Data Gaps

- The condition of wildlife habitat and the extent and degree of habitat loss due to land management, development, and urban growth is generally understood by resource agencies and organizations, but is poorly documented or conveyed to the public.

- Many species of wildlife are migratory and they therefore winter in areas outside of the subbasin. Since land use and land management practices in critical habitat areas and in migration corridors influence these species viability, it is difficult for land managers in the Upper Deschutes Subbasin to document or quantify the effects of human impact on wildlife populations.
- The habitat relationships for nongame species such as reptiles, amphibians, bats, rodents, and passerine birds are not well understood.

15.4.2 Key Findings

- There are two key elk habitats adjacent to the Upper Deschutes River. The Fall River elk area is between Fall River and Pringle Falls, and the Ryan Ranch Elk Habitat extends from Sunriver to the Inn at the Seventh Mountain resort.
- The Upper Deschutes river corridor provides a reliable water supply, important food sources, and secure calving areas for elk.
- The low winter water flows in the Upper Deschutes River between Wickiup and the City of Bend and the low summer water flows in the Middle Deschutes area just downstream from Bend reduces the water quality and the quality of fish habitat in those areas. As the flows have an impact on the fishery, they also play a role in limiting the food source for wildlife such as river otters, mink, bald eagles, osprey, and kingfishers that feed on fish.
- Songbirds and big game find important shelter and thermal cover in dense lodgepole thickets along the Upper Deschutes River.
- Towhee, kingbirds, robins, and chipping sparrows seek forage in thinned stands of young ponderosa and lodgepole pines.

15.4.3 Recommendations

- Raise awareness and provide landowners with information about the impacts on elk habitat conditions between Fall River and the Inn at the Seventh Mountain.
- Research connections between flows in the Upper and Middle Deschutes River and the fish populations as a food source for osprey, eagles, and other wildlife in those sections.
- Raise awareness among community members and recreation user groups about the connections between water quantity and quality, fisheries, and wildlife.

15.5 Fire

15.5.1 Data Gaps

- There are no current fire risk assessments on private lands in the subbasin.
- Developing and coordinating effective fire treatments for the Upper Deschutes Subbasin depends in part on collecting more information on down woody material loading.

- Although a large body of information exists on the erosion and sedimentation impacts of forest roads and new road construction in post-burn areas, little data has been compiled or published regarding the impacts of roads specifically in the Upper Deschutes Subbasin.
- More data is needed on the effects of fire on post-burn noxious weed colonization.
- More information on juniper crown fire potential is needed.
- More information is needed on Threatened and Endangered species locations and the effects of fire and forest harvesting on neotropical bird habitat in the Upper Deschutes Subbasin.

15.5.2 Key Findings

- Fire plays an important role in the natural disturbance and recovery patterns of native species and ecosystems. Specifically, western ecosystems have evolved with and in response to wildfire.
- Fire suppression has altered the historic frequency and intensity of fires in the Upper Deschutes Subbasin.
- Fire suppression activities can lead to modified forest structures including: increased stand densities, increased crown closure, altered vegetative composition, smaller stand diameter, decreased percentage of undergrowth, increased forest litter, higher quantities of woody debris, and higher fuel loads.
- The results of fire suppression can lead to the degradation of forest ecosystem integrity and the increased likelihood of large, high-severity wildfires.
- Roading and recreation have increased the number of ignition sources by approximately 50% since the 1950's. Areas of particular concern in the subbasin include the undeveloped camping areas along the Deschutes River, Cultus Lake, and Crane Prairie Reservoir.
- Heavy fuels and a growing population have led fuels treatments to be a priority around the City of Bend.

15.5.3 Recommendations

- Support fire management activities that seek to protect soil integrity, avoid new road construction in sensitive areas, and reduce the sedimentation effects from existing roads.
- Research the effects of salvage logging in sensitive areas of the Upper Deschutes Subbasin. Make existing information widely available to the public.
- Promote natural regeneration of post-fire plant species.
- Support and initiate monitoring projects that track unintended consequences from fire management and incorporate implementation and effectiveness monitoring.
- Raise community awareness in both rural and urban areas about the roles that fire, fire suppression, and forest harvesting play in the Upper Deschutes Subbasin.
- The large body of existing information documenting the erosion impacts of forest roads, particularly new road construction, on the sedimentation of spawning

habitat must be applied to future fire suppression, fire prevention treatments, and thinning or logging in the Upper Deschutes Subbasin.

- An evaluation of the impact of the existing forest road systems on aquatic resources in the Upper Deschutes Subbasin is needed.
- A predictive model for forest activities, erosion, and sedimentation has been developed by the research arm of the U.S. Forest Service. This model, the Water Erosion Prediction Project (WEPP), has not been used on the Deschutes National Forest, but it is applicable to predict impacts from forest and fire management activities.
- Support programs that continue to research the effects of fire management activities on watershed resources.

15.6 Riparian Zones

15.6.1 Data Gaps

- There have been no published analyses comparing the current riparian zone conditions in the Upper Deschutes to the conditions that existed prior to the establishment and operation of Wickiup dam. Similarly, there have been no published analyses comparing current riparian zone conditions with potential future conditions.
- ODEQ is currently modeling the effects of riparian loss on the TMDL parameter temperature, but that information has not yet been completed.
- There is no comprehensive inventory of the riparian zone conditions on the Upper Deschutes River. There is some information on the conditions that lie either on the Deschutes National Forest or within the boundaries of the Upper Deschutes Wild and Scenic River designation, but the information is fragmented. Much of the land between the City of Bend and Lake Billy Chinook is privately owned and, therefore, has very little data on the current, historic, or potential riparian zone conditions in that area.
- There is no comprehensive inventory or map of the noxious weed infestations in riparian areas in the Upper Deschutes Subbasin.

15.6.2 Key Findings

- Upper Deschutes River banks are particularly sensitive to erosion due to the minimal natural resistance of the volcanic soils.
- The artificially high summer river flows and the low winter river flows that result from the release schedule from Wickiup Reservoir accelerate lateral erosion of the river banks on the Upper Deschutes River between Wickiup Reservoir and the City of Bend.
- Where established, riparian vegetation anchors stream bank soils with fibrous and woody root systems that resist the erosive forces of high river flows. Riparian root systems can increase bank stability, and streamside vegetation reduces the impact

of the peak velocities of high flows, thereby decreasing energies that could otherwise erode banks, elevate sediment loads, and widen channels. By stabilizing soils, the root systems of healthy streamside vegetation also helps reduce or mitigate potential erosive damage from upland management activities such as logging and livestock grazing.

- Riparian vegetation is very difficult to restore on the Upper Deschutes between Wickiup Reservoir and the City of Bend due to the current managed flow levels that have significantly altered the natural hydrograph. Riparian vegetation that is planted to reach the water source in the summer is dewatered in the winter, and riparian vegetation that is planted to reach the water source in the winter is drowned in the summer.
- There have been a number of revegetation projects that have attempted to mitigate the effects of flow on eroding banks, but the disparity between the winter and summer flow regimes have made bank restoration projects very challenging, expensive, and often unsuccessful.
- The primary issue of concern in the Upper Deschutes Subbasin is the rapid rate at which the Upper Deschutes River banks are eroding. Stream bank erosion causes channel instability, land loss, diminished water quality, and riparian/aquatic habitat loss.
- Although there is no comprehensive noxious weed map, anecdotal evidence shows that current noxious weed infestations within riparian zones between Wickiup and the City of Bend appear to be concentrated only in high use areas.

15.6.3 Recommendations

- Initiate a multi-partner program to evaluate the impacts of the Wickiup Reservoir release schedule and seek timing and quantity of releases that ensure acceptable riparian conditions between Wickiup and Bend.
- Gather aerial photos of riparian plants between Wickiup Reservoir and Lake Billy Chinook. Create a photo repository of riparian conditions in the Upper Deschutes Subbasin to provide a point of comparison for future riparian zone conditions.
- Through Streamwalk and other programs, raise awareness among community members about the impacts of flow modification on riparian zones in order to promote a better understanding of the ways in which water conservation can improve river conditions.
- Form partnerships with landowners on the Upper Deschutes. Collaboratively research opportunities to revegetate bare and eroding banks between Wickiup and the City of Bend.
- Explore alternative riparian restoration and enhancement treatments that effectively reduce exacerbated erosion rates given the modified flow regime.
- Assist landowners with projects that replace nonnative vegetation with native riparian plants.
- Similar to the 2002 Stream bank Stability Characterization (see Appendix I), complete a characterization of the current on-the-ground conditions of the riparian zones between the City of Bend and Lake Billy Chinook.

- Address hikers, bikers, and walkers using Deschutes River trails in order to raise awareness about types and impacts of noxious weeds.
- Collaborate with Deschutes River user groups to coordinate and implement annual weed pulls.

15.7 Wetlands

15.7.1 Data Gaps

- There is no comprehensive inventory of wetlands in the Upper Deschutes Subbasin. Without an inventory of past and current wetland conditions, there can be no analysis of wetlands status and trends.
- The National Wetlands Inventory (NWI) for wetlands across the United States is outdated and inaccurate.

15.7.2 Key Findings

- Wetlands are very important in maintaining and improving water quality.
- Although there is no comprehensive wetlands inventory for the Upper Deschutes Subbasin, The 1999 Riverway study did assess and characterize the two wetlands known to be present within the City of Bend.
- The 5.38 acre wetland located along the Deschutes River just upstream of the Colorado Street Bridge in the City of Bend is a valuable wetland habitat. With 20 different vegetation zones, this area has a number of open water areas that provide nesting, foraging, and cover for birds.
- There is a wetland forming in the area downstream from 1st Street Rapids in the northern part of the City of Bend on the Deschutes River. This wetland is developing in areas of slow moving water on both sides of the river.

15.7.3 Recommendations

- Initiate collaboration among resource managers to collect, synthesize, and share wetlands data.
- Consolidate existing data and map the locations of wetlands in the Upper Deschutes Subbasin.
- Complete an inventory of the current conditions of wetlands in the Upper Deschutes subbasin.
- Analyze the status and trends of current wetlands' conditions in the Upper Deschutes Subbasin.
- Strengthen local and State wetland protection and restoration programs.
- Support programs that raise awareness among community members about the valuable roles that wetlands play within the watershed system.

15.8 Groundwater

15.8.1 Data Gaps

- The Upper Deschutes Subbasin is one of the many subbasins located upstream from the Lake Billy Chinook region. Although both groundwater discharge and recharge for the entire region are known, values specific to the Upper Deschutes Subbasin have not been identified from the most recent USGS study. Similarly, groundwater flow between the subbasins within the region has not been characterized.
- Exactly how much, where, and when canal leakage returns to the river is not known.
- There are no close analyses of the spatial and temporal resolution of the channel gains and losses from the canals.

15.8.2 Key Findings

- Groundwater recharge occurs directly and indirectly from precipitation falling predominantly in the upper elevations of the subbasin. Subsequently, groundwater generally flows from the Cascades and Newberry Volcano areas of high elevation, precipitation, and permeable soils towards lower elevation and low precipitation areas.
- Groundwater discharge occurs where canyons intersect the water table, or where the groundwater encounters low permeability formations. This occurs near the basin outlet near Lake Billy Chinook and at the western boundary of the La Pine structural basin.
- Groundwater and surface water are directly linked as all groundwater eventually discharges to surface water either within the subbasin or into adjacent subbasins.
- Groundwater withdrawals will affect surface flows both within the subbasin and in neighboring subbasins. However, these effects are difficult to detect due to inherent complexity and measurement error and the large amount of natural variability in groundwater discharge compared to current groundwater withdrawal.
- Some groundwater discharged to surface water re-enters the groundwater system via infiltration of applied irrigation water and from channel leakage in stream and canals.
- Due to the porous geology of the subbasin, unpiped or unlined canals may leak approximately 50% of their water. Therefore, canals are a conveyance mechanism in which surface water is converted back to groundwater. This groundwater is then discharged in its entirety in the Lake Billy Chinook area.
- A large proportion of the water lost from leaking irrigation canals north of Bend is discharging to the lower Crooked River upstream of the Opal Springs gage. Therefore, waters that would otherwise contribute to the instream flows of the Upper Deschutes River are actually contributing to the Crooked River flows.

- The City of Bend's current Urban Growth Boundary and the corresponding 20-year water supply plan will require additional water resources to meet growing urban needs. Increased groundwater use availability through surface water conservation and exchange, and stream restoration and mitigation projects are key to increasing the municipal water supply.

15.8.3 Recommendations

- Complete synoptic measurements at a finer spatial resolution to identify losses in canals. Combine this with other existing information on flow and loss data for streams and canals.
- Use the existing USGS groundwater model to identify the specific recharge and discharge values in the Upper Deschutes Subbasin.
- Conduct analysis and ongoing monitoring of the effects of groundwater pumping on the flows of nearby stream reaches.
- Raise awareness among community members about the interconnections between groundwater and surface water in order to promote the conservation of both.

15.9 Surface Water Quantity

15.9.1 Data Gaps

- More research is needed regarding the shallow hydrogeologic interaction between the river and canals near the canal diversion points.
- A close analysis of how much canal leakage enters the groundwater system to later return to the river is needed.
- There are no close analyses of the spatial and temporal resolution of the channel gains and losses both from the river and the canals.

15.9.2 Key Findings

- Low wintertime stream flow levels play a major role in impacting the resource conditions of the Upper Deschutes River between Wickiup Reservoir and the City of Bend by degrading riparian conditions, reducing high quality fish habitat, and diminishing water quality.
- Low summertime flow levels play a major role in impacting the water quality and aquatic resource conditions of the Deschutes River between the City of Bend and Lake Billy Chinook by dewatering fish habitat and increasing stream temperatures.
- High water springtime releases from Wickiup Reservoir can scour sediment from loose stream banks to increase the turbidity levels in the river.

15.9.3 Recommendations

- Initiate a program that will work to improve and increase minimum wintertime flow levels as identified by the Oregon Department of Fish and Wildlife in the Upper Deschutes River between Wickiup Reservoir and the City of Bend.
- Initiate river mitigation programs to assist the cities of Deschutes County in obtaining future municipal groundwater supplies and maintain minimum summertime flow levels in the Middle Deschutes river below the City of Bend that are consistent with the levels identified by the Oregon Department of Fish and Wildlife as necessary to protect fish and wildlife habitat.
- Support current and future methods to improve the efficiency of water delivery systems. Support canal piping projects that comply with Oregon's conserved water statute.
- Continue to increase public understanding of the connections between water quantity and water quality conditions.
- Research connections between water conservation measures and water storage in Wickiup Reservoir.

15.10 Surface Water Quality

15.10.1 Data Gaps

- The Upper Deschutes Watershed Council has been implementing a water quality monitoring program. In its initial stages, the program has focused on collecting and synthesizing the water quality data from all of the participating agencies in the area. The past water quality data for the Upper Deschutes Subbasin has been inconsistent. There needs to be more consistent and long term monitoring and data gathering for water quality parameters in the Upper Deschutes Subbasin.
- ODEQ is setting TMDLs for temperature and evaluating what is needed to reestablish temperature regimes, but this information is not yet available.

15.10.2 Key Findings

- Water quality conditions in the Upper Deschutes Subbasin are inextricably linked to water quantity and flow levels. The water quality parameters monitored by the Oregon Department of Environmental Quality including temperature, dissolved oxygen (DO), and pH are affected by low flow conditions in the subbasin.
- As a result of channel erosion, the flow release schedule from Wickiup Reservoir, and summer primary algae productivity in Wickiup Reservoir, turbidity levels in the upper Deschutes River do not meet the Oregon water quality standard.
- Multiple sections of the upper Deschutes both above and below the City of Bend do not meet Oregon water quality standards.

15.10.3 Recommendations

- Decrease sedimentation and turbidity levels in sections of the Upper Deschutes River between Wickiup Reservoir and the City of Bend by maintaining the target winter minimum flow level of 300 cfs set by the Upper Deschutes Wild and Scenic River Management Plan.
- Reduce erosion and subsequent turbidity and sedimentation by maintaining springtime ramping rates (0.1 ft/ 4hrs rising) that are consistent with the Upper Deschutes Wild and Scenic River Management Plan.
- Improve water quality and reduce algal blooms and nutrient loading between the City of Bend and Lower Bridge by maintaining higher summer flows.
- Monitor water quality parameters including: temperature, DO, pH, turbidity, bacteria, and chlorophyll a, as a way to improve understanding of changes and impacts on water quality.
- Support and initiate interagency water quality monitoring activities such as the Upper Deschutes Watershed Council's effort to implement the regional coordinated water quality monitoring plan.
- Research and model the location of erosion and sedimentation in the upper Deschutes River between Wickiup and Bend. Quantify the amount of sediment loss and the sediment bedload levels.

15.11 Fisheries and Aquatic Habitat

15.11.1 Data Gaps

- Although the Deschutes National Forest recently compiled the data for the fish distributions throughout the Upper Deschutes Subbasin, the current distribution of sculpin species through the subbasin is unknown.
- A specific analysis of the impacts that the low winter flows have on fish and fish habitat between Wickiup and the City of Bend is needed.
- A close analysis of the impacts that low summer flows have on fish and fish habitat below the water diversions downstream from the City of Bend is needed.

15.11.2 Key Findings

- On June 10, 1998 the Columbia River population of bull trout was listed by the USFWS as a Threatened species.
- The goal for the United States Fish and Wildlife Service Recovery Plan for bull trout in the Deschutes Recovery Unit is to ensure the long-term persistence of self-sustaining complex interacting groups of bull trout distributed throughout the species native range so that the species can be delisted.
- The United States Fish and Wildlife Service has proposed to designate sections of the Deschutes River and Odell Lake as critical habitat for bull trout. The final

decision will be made in October 2003 following a public comment period and a series of informational hearings.

- Bull trout are indigenous to the Upper Deschutes Subbasin but their numbers rapidly declined in the 1950's following the construction and operation of Wickiup and Crane Prairie Reservoirs. While they were previously abundant throughout the subbasin, currently, bull trout are found only in Trapper Creek, Odell Lake, and Lake Billy Chinook.
- The remnant population of bull trout in Odell Lake is the only resident non-reservoir adfluvial population remaining in Oregon.
- Redband trout are indigenous to the Upper Deschutes River and its tributaries. Redbands have been listed as a state and federal sensitive species. They were historically found throughout almost all of the streams and lakes within the subbasin, but their current range includes only the mainstem of the Deschutes, Odell Lake, Davis Lake, Wickiup Reservoir, and Crane Prairie Reservoir.
- Introductions of non-native fish species have competed with native fish populations for resources in the subbasin.
- Fish habitat conditions and successful fish spawning between Bend and Lake Billy Chinook have been severely reduced since the construction and operation of Wickiup Reservoir.
- The Oregon Department of Fish and Wildlife has stated that fish screens, minimum flow releases, and modifications to flow release timing at Wickiup and Crane Prairie Reservoirs are necessary to improve downstream conditions for fish and other aquatic species.

15.11.3 Recommendations

- Support ongoing monitoring of fish habitat restoration and enhancement projects such as the Trapper Creek bull trout habitat restoration project.
- Collaborate with the Odell Lake Bull Trout Working Group and use outreach activities to develop a bull trout recovery plan for Odell Lake.
- Initiate and participate in monitoring activities as a way to understand the limiting factors affecting native fish populations in the subbasin.
- Initiate and support efforts such as fine sediment sampling projects to monitor and address the changing habitat conditions on the mainstem of the Deschutes.
- Support fish species that are wild and native to the Upper Deschutes Subbasin by minimizing the impacts of hatchery trout.
- Initiate collaborative and interagency enhancement and restoration projects that seek to improve both water quality and fish habitat conditions for native fish such as redband trout in the subbasin.
- Inform community members about the characteristics of healthy fish habitat and raise awareness about specific habitat enhancement opportunities on private lands.
- Promote improved water quantity and quality for fish and other aquatic species.

15.12 Channel Modifications

15.12.1 Data Gaps

- Research and/or modeling of the potential success for fish populations between Wickiup Reservoir and the City of Bend with stable annual water levels is needed.
- A better understanding of the impacts the modified flow releases out of Wickiup Reservoir have on the bank stability issues over a longer period of time is needed.
- Further monitoring of sediment loss from stream banks downstream from Wickiup Reservoir will help resource managers understand the impacts of the reservoir on the stream channel.
- A complete understanding of the dimension and profile of the Tumalo Creek channel that existed prior to the Bridge Creek fire and subsequent fire management activities is needed.

15.12.2 Key Findings

- The construction and management of Wickiup Reservoir has seriously degraded watershed resources such as water quality, fish habitat conditions, and riparian zone conditions.
- As revealed through channel cross-sections completed by the Deschutes National Forest and the Upper Deschutes Watershed Council's Upper Deschutes River Bank Characterization, the stream banks between Wickiup Reservoir and the City of Bend are eroding and the channel shape is changing.
- Tumalo Creek's current channel is unstable following the Bridge Creek fire and the post-fire removal of almost all instream and stream bank large woody material. The wood that had previously acted as stabilizing features for the channel was removed. Channel instability has resulted in substantial loss of fish habitat in Tumalo Creek.

15.12.3 Recommendations

- Complete cross sectional profiles of the remaining key reaches on the Upper Deschutes below Wickiup Reservoir. Use data to locate and quantify levels of sediment transport.
- Continue to monitor stream bank erosion of the stream banks between Wickiup and the City of Bend with community programs such as Streamwalk.
- Survey reference reaches on Tumalo Creek and Bridge Creek. Survey areas for the presence of large woody material to help guide effective channel restoration projects.
- Participate in stream bank restoration projects on Tumalo Creek.
- Use the restoration of Tumalo Creek as an opportunity to raise awareness among community members about the impacts that channel modifications and land management activities can have on water quality, fish and fish habitat, and riparian zone conditions.

- Research and/or modeling of the potential success for fish populations between Wickiup Reservoir and the City of Bend with stable annual water levels is needed.
- A better understanding of the impacts the modified flow releases out of Wickiup Reservoir have on the bank stability issues over a longer period of time is needed.
- Further monitoring of sediment loss from stream banks downstream from Wickiup Reservoir will help resource managers understand the impacts of the reservoir on the stream channel.
- A complete understanding of the dimension and profile of the Tumalo Creek channel that existed prior to the Bridge Creek fire and subsequent fire management activities is needed.

15.13 Sediment Sources

15.13.1 Data Gaps

- Although there has been significant interest and research focused on the upper Deschutes River, a comprehensive analysis of the relationship between flows, erosion, and sedimentation has not been completed.
- Widespread public understanding of the stream bank stability issues between Wickiup and the City of Bend is needed.
- Additional monitoring of sediment loss in the Upper Deschutes River between Wickiup and the City of Bend needs to be completed.
- An analysis of past stream bank restoration successes and failures on the Upper Deschutes needs to be completed in order to understand what stream bank stabilization techniques will effectively reduce sediment loss within the modified flow regimes.

15.13.2 Key Findings

- Between Wickiup Reservoir and the City of Bend, the Deschutes River is on the Department of Environmental Quality's (DEQ) 2002 303(d) list for both turbidity and sediment. DEQ's 2001 Draft Upper and Little Deschutes TMDL Water Quality Monitoring Study identifies stream bank erosion as the primary cause for increased sedimentation along this reach. Turbidity, one parameter used to measure water quality, has increased with increased erosion and sediment release and the turbidity levels now exceed Oregon water quality standards.
- The Deschutes River channel below Wickiup Reservoir contains loose sediments deposited from the combination of volcanic activity and alluvial processes. These sediments are relatively fine and provide little natural resistance to the erosive forces present.
- The stream banks between Wickiup Reservoir and the City of Bend are eroding heavily. The volcanic soils of the banks are dewatered in the winter and are consequently exposed to freeze/thaw conditions that make them exceptionally vulnerable to erosion. When high river flows are released for irrigation in the

spring, a large rush of sediment is washed downstream. The stream banks in this area are a significant source of sediment to the river system.
- The sediment that is eroded from upstream stream banks is later deposited in downstream areas of lower velocity.

15.13.3 Recommendations

- The existing information and field work should be directed toward using the bank stability characterization data (see Appendix I) to complete further calculations and analyses of sediment source locations and quantity of sediment eroding from each bank section in the Upper Deschutes between Wickiup and Bend.
- The Upper Deschutes River Bank Stability data and characterization map can be used by resource and land managers as an informative tool for choosing and prioritizing stream bank restoration project sites.
- Resource managers coordinating stream bank restoration projects along the Upper Deschutes River must collaborate and coordinate with other interested groups and agencies doing restoration work in the watershed.
- Stream bank restoration projects should be prioritized based on the impact and benefit to the stream system as a whole.
- Stream bank stabilization and restoration projects should be consistently monitored to determine project effectiveness and downstream impact.
- Additional examination and research can be directed toward stream bank stabilization and riparian restoration methods appropriate and effective within the unique modified flow regime of the Upper Deschutes.
- A pilot project applying methodology specific to the Upper Deschutes flow regime will be researched, implemented, and monitored for effectiveness and success. As there are currently very few, if any, models for stabilization and restoration projects in systems with channel types, bank materials, and flow regimes such as in the Upper Deschutes, it should be a priority for resource managers in the area to pioneer a pilot project that accurately represents the unique characteristics at work. The pilot project can stand as a model for future stabilization and restoration projects on the Upper Deschutes.

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Appendix I:
Upper Deschutes River Bank Stability Characterization

Upper Deschutes River Bank Stability Characterization

August 2002

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Abstract

The Upper Deschutes River Bank Stability Characterization is designed to assess stream bank erosion on the Upper Deschutes River along approximately 60 miles between Wickiup Reservoir and the City of Bend, Oregon. Many previous studies conducted by local, state and federal resource agencies have previously identified elevated levels of erosion and in-stream sedimentation and turbidity as a primary factor in water quality, riparian health and fish habitat concerns in the region. This characterization provides previously unavailable information about the extent of stream bank erosion to help prioritize future efforts in stream bank restoration, water quality restoration and fish habitat enhancement. Using the Bank Erosion Hazard Index (BEHI) methodology, bank height, bank angle, vegetation cover, root density, root depth, and bank materials was evaluated for a total of 130 reaches throughout the study area. Results indicated that 47 of the stream bank reaches are classified as having high, very high, or extreme erodability; 45 are classified as moderate, 37 are classified as low and 6 are classified as very low. Maps showing the extent and distribution of the sites are included and strategies to address the erosion problems are discussed.

Introduction

The stream banks of the Upper Deschutes River downstream from Wickiup Reservoir are heavily eroded. While the geologic processes that define river channels in some areas might result in bedrock banks or channels lined with large boulders that are resistant to erosion, the Deschutes River channel between Wickiup Reservoir and Fall River contains loose sediments deposited from the combination of volcanic activity and alluvial processes. These sediments are relatively fine and provide little natural resistance to the erosive forces present. The erosion of bank materials has been linked to the combination of lower than natural winter flows and higher than natural summer flows. Bank erosion and subsequent turbidity is exacerbated by the combination of regulated winter flows below Wickiup Reservoir that drop substantially lower than the levels of natural flows that occurred prior to the management of water out of Wickiup Reservoir and summer flows that are significantly higher than natural flows (see complete discussion under 'Flow Regime').

The Upper Deschutes Watershed Council (UDWC) is collaborating with a broad range of local partners to complete a watershed assessment of the entire Upper Deschutes subbasin. Local agencies and partners including the Deschutes Resources Conservancy (DRC), Oregon Department of Fish and Wildlife (ODFW), Oregon Water Resources Department (OWRD), Oregon Department of Environmental Quality (DEQ), and the United States Forest Service (USFS) have long recognized and identified the need for a comprehensive assessment focused on the stream bank conditions above Bend. In addition to the larger community need for a comprehensive characterization of the current and potential rates of erosion on the Upper Deschutes, UDWC's subbasin assessment identified a need to rank eroding stream banks and prioritize potential restoration project areas. There have been no previous primary data collection projects prioritizing restoration opportunities along this reach of the Deschutes River.

The objectives of the stream bank stability characterization are to:

1) Inventory bank conditions between Wickiup Reservoir and the City of Bend.
2) Identify sediment source locations.
3) Rank relative bank erosion hazard and erodability among stream banks.
4) Assess priorities for bank restoration projects.
5) Create a characterization map depicting the erosion conditions between Wickiup and the City of Bend.
6) Supply local resource managers with comprehensive stream bank erosion data for restoration project prioritization and implementation.

Study Area

The study area includes approximately 60 miles of the Deschutes River corridor downstream from Wickiup Reservoir (near river mile 226) to the upstream edge of the City of Bend (near river mile 171). This portion of the Deschutes River is within the area of interest for the Upper Deschutes Watershed Council and it includes a majority of the upstream sections of the Upper Deschutes Subbasin Assessment. Due to the mix of private, state, and federally owned lands, the river corridor along the Upper Deschutes is managed for a variety of interests and uses.

Wickiup Dam was constructed by the Bureau of Reclamation and was completed in 1949. The dam is an earthfill structure that is used to store water during the winter for irrigation uses in the summer. The water releases from Wickiup are currently managed by the Oregon Water Resources Department (OWRD). The reservoir water is not part of the municipal water supply and the dam serves no hydropower functions. The reservoir's sole purpose is to store water for irrigation use in the summer. The current annual flow regime released out of Wickiup Reservoir is defined by the quantity of water rights held by irrigation districts in the area. In order to fulfill the requirements of irrigation districts' water rights, Wickiup Reservoir must be filled to a certain level every winter. Consequently, winter flows in the Deschutes are suppressed until sufficient water is stored for the upcoming irrigation season. As a result of winter water storage, the current levels of water flow below Wickiup have been substantially altered from the natural stable annual hydrograph of the river. While the natural flows of the Upper Deschutes River were historically stable year round, the current regulated hydrograph can swing between 20 cubic feet per second (cfs) to over 2,100 cfs (USDA 1996). The modifications and extreme fluctuations of flow have contributed to conditions that have destabilized the stream banks, increased stream bank erosion, and reduced water clarity, thereby decreasing water quality for fisheries and humans (USDA 1996).

The riparian zones between Wickiup Reservoir and the City of Bend consist of an overstory of stands of lodgepole pine and ponderosa pine, a shrub understory of spirea, snowberry, alder, or willow, and a herbaceous layer of forbs and sedges. There are several large willow/sedge meadows scattered along the area. In addition to meadow, the lodgepole (wet) plant association group is also included in the riparian classification. Lodgepole (wet) plant association is typically associated with high water tables or partially or frequently inundated soils. Approximately 1,850 acres of meadow and 5,070 acres of lodgepole (wet) habitat occur along the Deschutes River above Bend. In general, the root systems of riparian vegetation plays a critical role in stabilizing the erosive potential of stream banks. Flow regulation of the water from Wickiup Reservoir has resulted in the reduction of riparian vegetation at the outside bends of the river and an increase in the width of the point bars and associated vegetation on the inside of the bends (USDA 1996).

Flow Regime

Since Wickiup Reservoir's construction in the 1949, water storage and release schedules have significantly modified the flows in the Deschutes River, subsequently affecting the channel morphology including erosion and sedimentation. While the natural flows historically remained very stable year-round, the regulated flows below Wickiup rise and plunge dramatically through the course of a given year (Figure 1). During the winter storage season the minimum regulated river flow below Wickiup Reservoir is 20 cfs, which represents and 95% reduction the natural unregulated flows (minimum natural unregulated flows were approximately 419 cfs prior to the construction of the reservoir) and during the summer irrigation season, the maximum daily river flows have been recorded at 2,280 cfs, which is approximately 162% of the natural unregulated flows (maximum natural unregulated flows in the summer were approximately 1400 prior to the construction of the reservoir) (Table 1) (USDA 1996).

Tributaries and springs augment the flow of the main stem Deschutes between Fall River and the north boundary of Sunriver (USDA 1996). The perennial streams that feed the Upper Deschutes are Fall River, the Little Deschutes River, and the Spring River complex, which includes significant accretion from springs and seeps in addition to Spring River itself. These tributaries slightly moderate the downstream effects of the highs and lows of regulated flows Table 2 presents the location and mean flows of Upper Deschutes tributaries.

Figure 1: Median Natural and Regulated Flows Below Wickiup Reservoir (OWRD 2002)

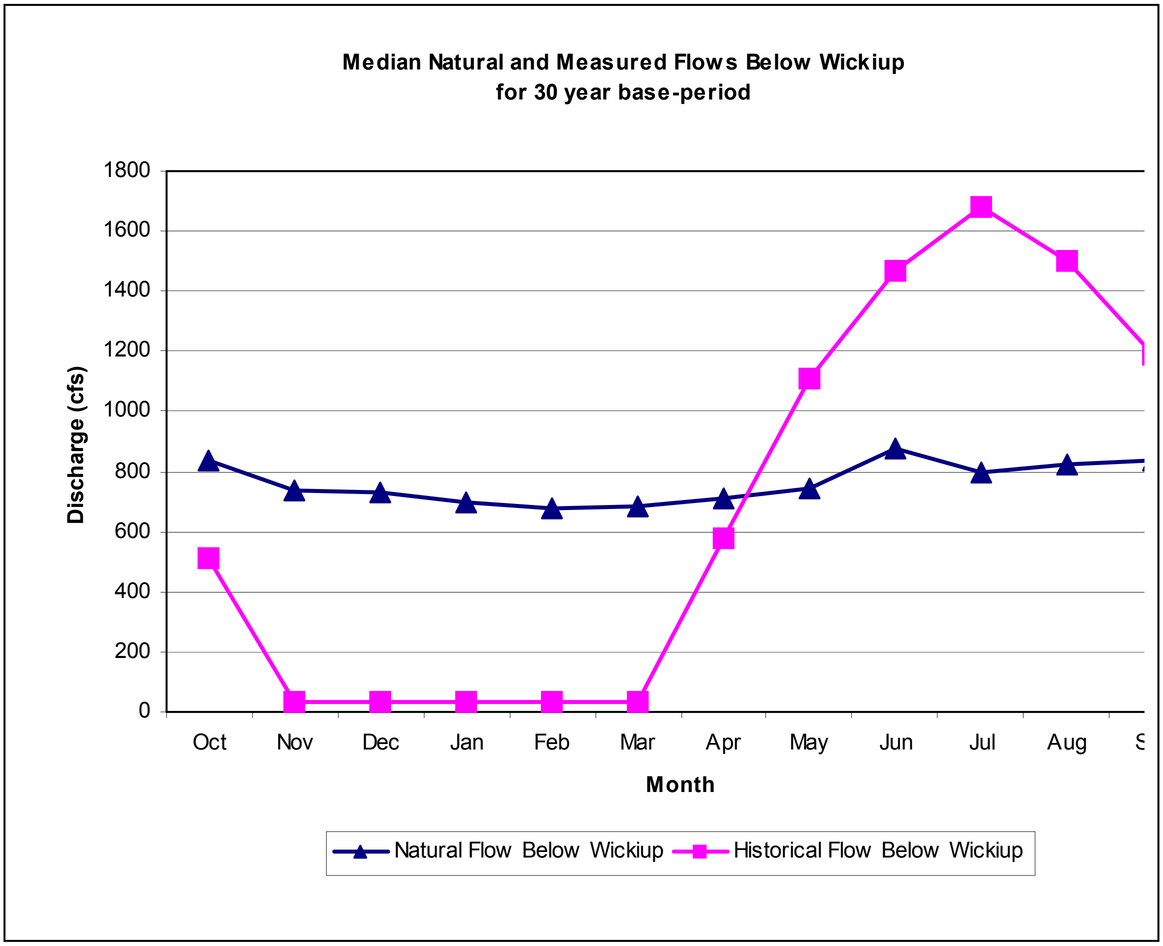


Table 1: Maximum and Minimum Mean Daily Flows Below Wickiup Reservoir (USDA 1996)		
	Minimum Daily Flow (winter)	Maximum Daily Flow (summer)
Regulated Flow (1943-1987)	20 cfs	2280 cfs
Natural (unregulated) flow (1925-1941)	419 cfs	1400 cfs
Comparison between	95% decrease in flow under regulated	162% increase in flow under regulated

regulated and unregulated flows	conditions	conditions

Table 2: Perennial Tributaries to the Upper Deschutes		(USFS 1994)	
		Mean Annual Flow	Mean Annual Flow
Tributary	River Mile	Low	High
Fall River	205	140	160
Little Deschutes River	193	160	350
Spring River complex	190	220	220

The management of flows has created the equivalent of a 25-year flood event sustained for the six-month irrigation season since the construction of Wickiup in 1949 (USDA 1996). Artificial flood stages from irrigation releases have accelerated lateral erosion on the outside banks of bends in the river and increased deposition on the inside of river bends. Evidence of these stream bank changes was gathered by comparing contemporary and historic photographs. The results from the comparison include a 20% increase in the width of the channel between 1943 and 1991 and an increase in the number of meander cutoffs from 2 to 12 from 1943 to 1991 (USDA 1996). The type of bank material present plays a key role in the greater or lesser impact that the hydraulic force of the water exerts on a stream bank. While in some sections of the river such as the Benham Falls area, geologic processes have constructed hard bedrock channels that resist erosion, the Deschutes River channel between Wickiup Reservoir and Fall River is composed primarily of highly erodable fine sediments deposited from successive volcanic activity. The high springtime flows released from Wickiup erode the fine sediments that are not held in place by either the roots of riparian vegetation or large woody material (USDA 1996).

Turbidity and Sediment

In areas between Wickiup Reservoir and the City of Bend (RM 168.2 to 222.2), the Deschutes River is on the Department of Environmental Quality (DEQ) Draft 2002 303(d) list for both turbidity and sediment. DEQ’s 2001 Draft Upper and Little Deschutes TMDL Water Quality Monitoring Study identified stream bank erosion as the primary cause for increased sedimentation along this reach. Turbidity, one parameter used to measure water quality, can increase with increased erosion and sediment release (Harden-Davis 1991). Increases in levels of turbidity and sediment in the Upper Deschutes have been linked to the regulation and release of flows from upstream reservoirs (USDA 1996). From spring until midsummer in the upper reaches of the Deschutes, water quality is very good as it first leaves Wickiup Reservoir. However, the quality of the water rapidly deteriorates in the first few miles below the dam. The turbidity of the river below the dam increases as much as 30 times the levels found in Wickiup Reservoir when irrigation water is first released from storage in early spring (USDA 1996). Turbidity levels peak once flows reach 800 cfs and at that point can range between two to five times background levels until the end of July (USDA 1996). In this case, the background levels are the quantities of sediment and turbidity present in the water stored in Wickiup Reservoir.

The elevated turbidity levels that follow the initial spring irrigation release are largely a result of the dramatic fluctuations in flow levels on the Upper Deschutes. During the winter storage season little water is released from upstream reservoirs, leaving much of the channel exposed. Weathering and frost action loosens the exposed channel and its bank material which is later eroded by the increased flows in the spring. After the initial spring water releases, turbidity levels eventually decrease gradually through the summer. As a result, neither the turbidity nor the sediment levels of 54 miles of the Upper Deschutes meet the state water quality standard, which defines a water quality violation for turbidity as an increase in excess of 10 % over background (USDA 1996).

The 1994 Upper Deschutes River Instream Flow Assessment completed by the Deschutes National Forest documented the following features and erosion conditions that are the product of regulated flow regimes in the Upper Deschutes:

- Nearly 15% of the channel banks are bare and badly eroding.
- A comparison of 1943 and 1991 photographs reveals that the Deschutes River between Wickiup Reservoir and Benham Falls widened an average of 20% during this 48-year period.
- In 1943, two cutoff meanders existed. In 1991, twelve existed.
- From Wickiup Reservoir to Fall River there is a "drawdown" area in the river channel that lacks vegetation. This area is between the levels of about 30 and 1000 cfs flows.
- Turbidity increases downstream from Wickiup to peak levels that exceed 10 ntu's when irrigation water is initially released then reduces to near 2.5 ntu's even though flows continue to increase and level off at much higher levels than initial releases.

According to the Instream Flow Assessment, the previously listed erosion conditions are linked to the following characteristics of the Upper Deschutes:

- The ash and streamborne sediments of the river channel are the fine-grained materials that have low bulk density, lack cohesion, and are highly erodable.
- The gradient of the river between Wickiup and Benham Falls is low--a drop of 132 feet in 44 river miles.
- In the early years of this century much of the large woody material between Wickiup and Bend was removed from the channel to facilitate the transportation of logs down the river from Wickiup to ½ mile above Benham Falls.

- There is a large amount of private and a lesser amount of public development adjacent to the river.

Methods

UDWC project manager, Kolleen Yake, collaborated with representatives from Deschutes National Forest, Bureau of Land Management, Oregon Department of Fish and Wildlife, and the Oregon Department of Environmental Quality to determine the scope, location, and methodology for the project. The project manager then assembled an assessment team including OSU-Cascades Riparian Studies Professor, Bob Ehrhart, and two interns, Alasia Heinritz and Matt Maloney. The assessment team surveyed and characterized approximately 60 river miles between Wickiup Reservoir and the City of Bend.

In order to identify and rank relative rates of erosion, the assessment utilized the Bank Erosion Hazard Index (BEHI) methodology created by David Rosgen (Wildland Hydrology) for assessing relative rates of erosion. BEHI is a quantitative prediction of stream bank erosion rate uses an estimation, process-integration approach. The prediction model applies a stream bank erodability index that combines a variety of stream bank characteristics and integrates their cumulative impact. Stream bank characteristics involving bank heights, bank angles, bank materials, presence of layers, rooting depth, rooting density, and percent of bank protection are used to develop the stream bank erodability index (Rosgen 2001).

The BEHI stream bank erosion model attempts to predict the erodability of a bank by combining and integrating all of the different factors affecting the stream bank erosion processes. Rosgen (2001) defines the BEHI methodology as "an expert system was used to transfer field observations of potential erodability to relative rankings. Field experience from direct observations of stream bank instability was used to document stream bank conditions associated with active erosion and various modes of failure. The field measured variables assembled as predictors of erodability (BEHI) were converted to a risk rating of 1-10 (10 being the highest level of risk)." The risk ratings from 1 to 10 indicate corresponding adjective values of risk of very low, low, moderate, high, very high, and extreme potential erodability. The total points are obtained by converting the measured bank variables of the stream bank characteristics to risk rating values. The BEHI characteristics, values, and indices are shown in Table 3.

The field team conducted the primary data collection portion of the characterization between August 12 and August 23, 2002 and on February 28, 2003. In order to assess all 60 miles of stream banks in the area, 80% of the assessment was completed from a raft and 20% of the stream banks were assessed from hiking trails paralleling the river. 130 total sites were assessed.

Table 3. Stream bank characteristics used in the Bank Erosion Hazard Index (BEHI) (Rosgen 2001)

Adjective Hazard	Root Depth/	% Root	Bank Angle	% Surface	Totals
Or risk rating categories	Bank Height	Density	(degrees)	Protection	

VERY LOW	Value	1.0-.9	100-80	0-20	100-80	
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	4-7.6
LOW	Value	.89-.5	79-55	21-60	79-55	
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	8-15.6
MODERATE	Value	.49-.3	54-30	61-80	54-30	
	Index	4.0-5.9	4.0-4.9	4.0-4.9	4.0-4.9	16-19.6
HIGH	Value	.29-.15	29-15	81-90	29-15	
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	24-31.6
VERY HIGH	Value	.14-.05	14-5.0	91-119	14-10	
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	32-36
EXTREME	Value	<.05	<5	<119	<10	
	Index	10	10	10	10	37-40

GPS readings were taken at the beginning and end points of each stream reach. In order to capture current erosion conditions, two downstream photos and two upstream photos were taken at the beginning and end points of each reach. The bank materials, vegetation type, and percentage of vegetative cover were visually estimated by the UDWC assessment team. Professor Ehrhart analyzed the vegetation type to estimate root depth and root density. A range finder was used to calculate bank height and a clinometer was used to measure bank angle. Narrative notations documented visually apparent land use impacts, land ownership, roads, bridges, restoration project sites, instream structures, recreation areas, trails, tributaries, seeps, and noxious weeds.

Located at the end of the report, table 3 presents the BEHI index values and calculations for all of the stream bank reaches characterized on the Upper Deschutes. Each stream bank condition was quantified with a corresponding index value based on the BEHI's geomorphologic assumptions. The index values were summed and multiplied to compute a score for each stream reach. Adjustments based on bank materials were made to the score to then reach a total score that corresponded with a relative erosion/ erodability rating of extreme, very high, high, moderate, low, or very low. The stream bank reaches are ranked in descending order from extreme down to very low.

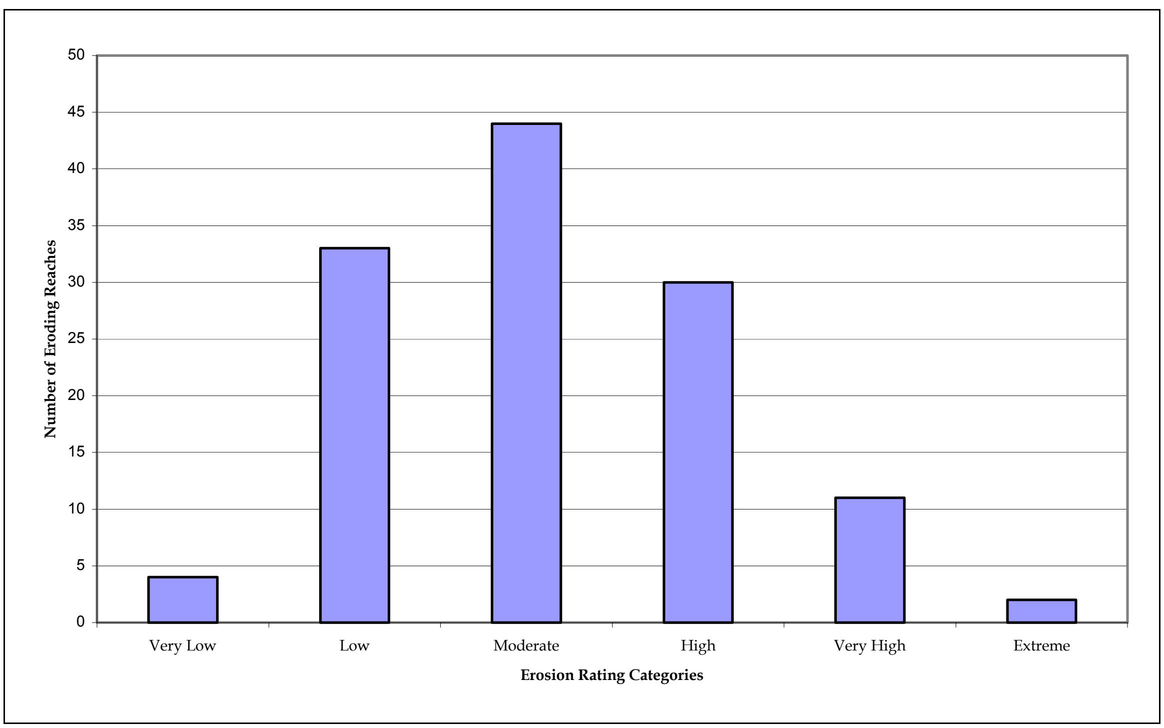
Several modifications of the BEHI method were used in order to adapt the protocol to the specific site conditions. The BEHI methodology also measures bankfull height and uses the ratio of bank height/ bankfull height as an erodability index value. Bankfull levels play a critical role in assessing the erosion potential of many rivers; however, the regulated flow regime of the Upper Deschutes creates predictable annual flows that never exceed certain levels. The Deschutes River does not flood the way that free-flowing rivers do. The bankfull level of the Upper Deschutes is annual and predictable as it is released and regulated out of Wickiup Reservoir. Therefore, the Upper Deschutes River Bank Stability Characterization project did not integrate bankfull measurements into the erosion and erodability assessment.

When faced with time and budget constraints, the UDWC chose not to characterize the entirety of the stream banks between Wickiup and Bend. Stream reaches where banks on both sides were exhibiting no apparent erosion were not characterized. Instead, the characterization includes all of the stream banks that appeared to have had previously eroded or were currently eroding. For every eroding stream bank that was assessed and characterized, so too were the opposite banks. The opposing banks often had no active erosion occurring, but they provide representation for the different types of systemic responses downstream from the dam.

Results

The data for the BEHI values of each stream reach assessed are presented at the end of this document in Table 4. Next to each stream bank condition value is the corresponding index value from the BEHI ranking system presented in Table 3. Of the 130 reaches assessed, 2 were rated as extreme, 13 were rated as very high, 32 were rated high, 45 received moderate ratings, 37 were rated low, and 6 were rated very low. Figure 2 presents a graphical comparison of the eroded stream reaches. The digital photos taken of each stream reach are located on the compact disc included with this report. The physical locations for each stream reach are depicted in the Upper Deschutes River Bank Stability Characterization Map book.

Figure 2: Stream bank Erosion Ratings for the Upper Deschutes River



Discussion

The results indicate that 47 reaches on the Upper Deschutes are currently eroding at high, very high, or extreme rates. Analysis of the methodology for assessing the bank heights of stream sections has revealed that there may in fact be a greater number of high, very high, and extreme banks than the study indicates due to the fact that bank height and surface protection were both measured to the very top of the bank instead of to the top of the eroding portion of the bank. Therefore, it might appear that there is a greater percentage of surface cover protecting the bank from eroding than currently exists.

As mentioned in the introduction, some sections of the Upper Deschutes are naturally resistant to erosion due to the geology of the area. Taken from the overlook at Benham Falls, photograph 1 displays the bedrock that is remnant from the Lava Butte Flow from the eruption of Newberry Volcano. The lava rock remains and lines the channel at Benham Falls. Although the gradient and velocity are high in this reach, the erosion potential is very low.

Photograph 1: Reach 104, Benham Falls

Distinctly different from the banks at Benham Falls, the stream reach in photograph 2 consists of primarily silt and clay fine sediments. This reach is located at river mile 209 near La Pine State Park. The bank received a BEHI rating of moderate due to the combination of loose bank materials, moderate vegetation, and a 45 degree bank angle. The sedges and other herbaceous material at the water's edge combined with some surface protection from the pine roots to prevent a higher erosion rating.

Photograph 2: Reach 51, La Pine State Park

Taken just below river mile 213, photograph 3 presents a stream bank that received a BEHI rating of extreme. On this bank there is vegetation at the top portions of the bank but it is serving no protective service to the erosion or erodability of the bank at the water's edge.

Photograph 3: Reach 30, Tetherow Log Jam

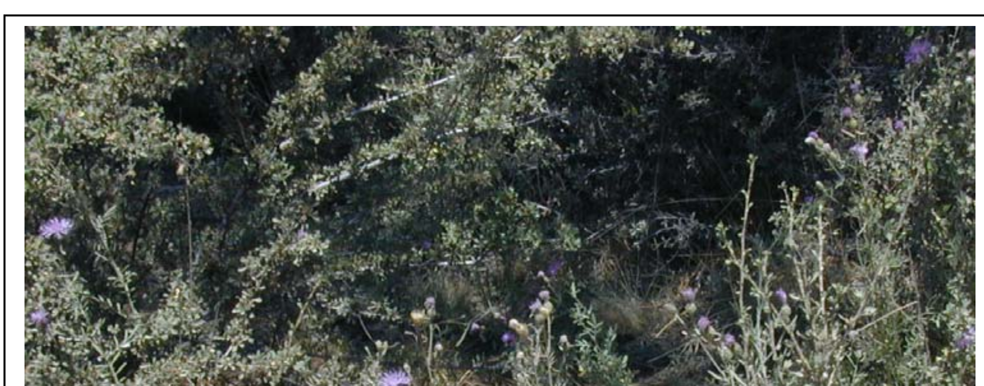
The land use notations documented by the assessment team included information regarding past stream bank restoration sites. The assessment team observed a variety of project sites that consisted of unsuccessful willow plantings and large woody material that appeared to be exacerbating erosion.

The assessment team documented the use of rip-rap or revetments as attempted methods to cease erosion in private riverfront property locations. Occasionally, the rip-rap appeared to exacerbate erosion downstream from the site; however, the bulk of the heavily eroded areas occurred on public forest service land and not on privately owned lands.

The relatively small number of banks receiving a very low BEHI rating is due to the fact that a large percentage of the banks that appeared to have no erosion problem were not included in the assessment. Reach 62 shown in photograph 4 is a bank that was assessed in order provide a representative sample of banks that, due to high levels of surface protection and low height, have very low or no erodability potential. Photograph 4 is representative of the majority of inside meander bends on the Upper Deschutes. As in the photo, the inside of meanders were typically deposition areas that had well established sedge meadow and willow vegetation.

Photograph 4: Reach 62, Fall River Area

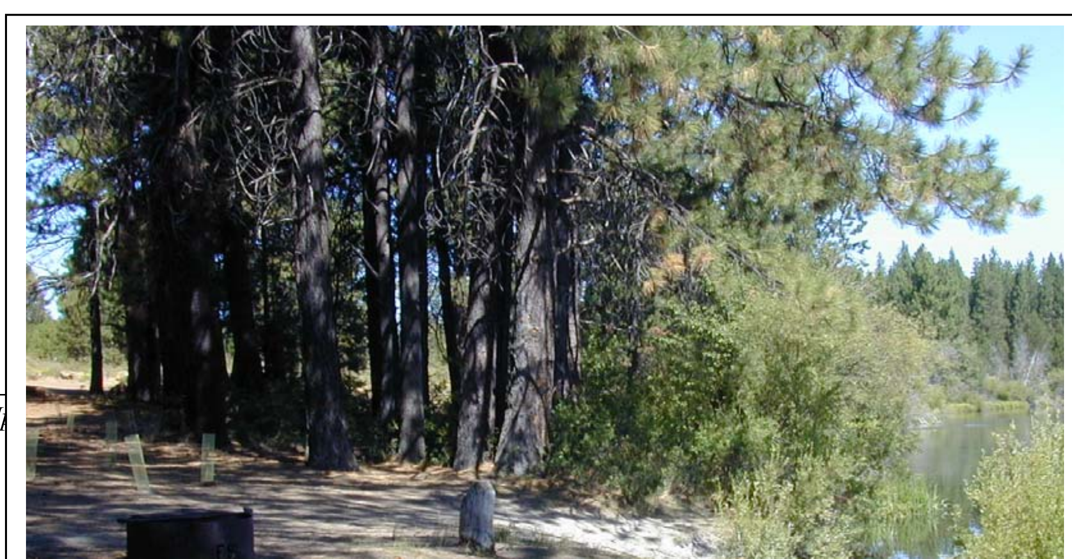
Photograph 5 shows a substantial patch of knapweed located right on the river trail. This patch of knapweed is between the trail and the water's edge. As knapweed sends down a single deep taproot, the weed can exacerbate erosion but edging out other native riparian vegetation that would more effectively hold soil in place.



Photograph 5: Reach 108, ¼ mile downstream from Slough campground

There were a relatively low number of visible noxious weed infestations along the river corridor. The notable exceptions included mullein and bull thistle on a large patch of private property just downstream from Foster Bridge, small periodic patches of bull thistle in the Sunriver area, and knapweed in a variety of small patches along the west river trail between Dillon Falls and Bend's urban growth boundary. The trail receives high use from hikers, runners, and cyclists and the parking lots located adjacent to the trail are a prime avenue for noxious weeds to be transported from infected outside areas. In the Upper Deschutes area infestations of knapweed and other noxious weeds are most often found along roads or other locations where humans import the seeds (Grenier, 2002).

Photograph 6 was taken at Slough campground near river mile 180. There is an overnight campground, a dirt road, and a boat launch located here and the river trail runs from Bend up through the campground. Although the campground receives high levels of use, the erosion is low. The low erosion is probably due to low bank heights and lower water velocity.



Photograph 6: Reach 107, Slough

There are many areas along the Upper Deschutes River that see high levels of human use. The recreation sites, boat launches, dispersed camping, campgrounds, and day use areas along the river all exhibit trampled and degraded riparian vegetation and eroding stream banks. However, the eroding banks are located in areas that are primarily receiving high-density, concentrated impact. The banks are primarily very low height and are, consequently, losing very little sediment. Generally, the areas of high erosion and erodability were not located on or adjacent to human use areas. Most likely, this is due to the fact that recreation areas are located at sites that are close to the river with very low stream banks. Areas such as these tend to be on inside meander bends where there are sedge meadows and low banks.

Recommendations

UDWC recommends that the following steps be taken in response to the current levels of erosion in the Upper Deschutes. UDWC recommends that:

1) Stream channel cross sections of each extreme, very high, and high reaches are completed and overlain upon the data from the Bank Stability Characterization. The Deschutes National Forest has already completed stream channel cross sections for a small number of sections on the Upper Deschutes; these comprehensive cross sections provide valuable information regarding the widening of the stream channel and the corresponding loss of sediment quantities. When combined with the stream bank characterization data, the cross sections would reveal which areas are simply shifting and which areas are in fact widening.

2) Additional field work and research be directed toward using the bank stability characterization data to complete further calculations and analyses of sediment sources and quantity of sediment eroding from each bank section.

3) The Upper Deschutes River Bank Stability data and characterization map be distributed and used among resource managers as an informative tool for choosing and prioritizing restoration project sites.

4) Resource managers considering stream bank restoration projects communicate and collaborate with other interested groups and agencies doing restoration work in the watershed.

5) Restoration projects are prioritized based on the impact and benefit to the system as a whole.

6) Erosion levels and erodability rankings are taken into consideration when prioritizing projects.

7) Stream bank stabilization and restoration projects are consistently and accurately monitored to determine project effectiveness and downstream impact.

8) Additional examination and research be directed toward stream bank stabilization and restoration methods appropriate and effective within the unique modified flow regime of the Upper Deschutes.

9) A pilot project applying methodology specific to the Upper Deschutes flow regime will be researched, implemented, and monitored for effectiveness and success. As there are currently very few, if any, models for stabilization and restoration projects in systems with channel types, bank materials, and flow regimes such as in the Upper Deschutes, it should be a priority for resource managers in the area to pioneer a pilot project that accurately represents the unique characteristics at work. The pilot project can stand as a model for future stabilization and restoration projects on the Upper Deschutes.

Table 4: Stream Bank Stability Index Values for the Upper Deschutes River From Tenino to Columbia Street Bridge in Bend, Oregon. August 12-23, 2002 and February 28, 2003

Reach	Name	Bank Side	Angle (degrees)	Angle Index	Surface Protection (%)	Surface Protection Index	Height (BH) (ft)	Root Depth (RD) (ft)	RD/BH Ratio	RD/BH Index	Root Density (%)	Root Density Index	Sum of Indices	Adjust .	Total Score	Rating
65	Fall River Area	Right	50	3.0	10	9.0	25	2	0.08	7.0	2	10.0	29.0	10	9.75	extreme
30	Log Jam	Left	90	8.0	0	10.0	26	0	0.00	10.0	0	10.0	38.0	0	9.50	extreme
38	Tetherow	Right	60	4.0	5	10.0	33.6	0	0.00	10.0	1	10.0	34.0	2	9.00	very high
12C	Wyeth	left	80	6.0	0	10.0	25	0	0.00	10.0	0	10.0	36.0	0	9.00	very high
31	Tetherow	Right	80	6.0	5	10.0	4	5	1.25	10.0	5	9.0	35.0	0	8.75	very high
57	La Pine State Park	Right	90	8.0	5	10.0	5	5	1.00	1.0	10	8.5	27.5	7	8.63	very high
11	Bull Bend	left	90	9.0	5	10.0	45	10	0.22	7.0	10	8.0	34.0	0	8.50	very high
68	Fall River Area	Right	45	3.0	30	6.0	29	3	0.10	7.0	15	8.0	24.0	10	8.50	very high
69	Fall River Area	Right	45	3.0	15	8.0	12	3	0.25	7.0	15	8.0	26.0	8	8.50	very high
101	Sun River	Left	90	8.0	15	8.0	4	1	0.25	7.0	10	8.5	31.5	2	8.38	very high
24	Tetherow Burn	Right	85	7.0	15	8.0	13	2	0.15	8.0	10	8.5	31.5	1	8.13	very high
23	Tetherow Burn	Left	50	3.0	10	9.0	14.22	1	0.07	10.0	15	8.0	30.0	2	8.00	very high
27	Tetherow Burn	Left	80	6.0	10	9.0	48	3	0.06	8.5	10	8.5	32.0	0	8.00	very high
39	Tetherow	Left	55	3.0	5	10.0	35	3	0.09	7.0	5	10.0	30.0	2	8.00	very high
63	Fall River Area	Left	45	3.0	20	7.0	6	3	0.50	4.0	15	8.0	22.0	10	8.00	very high
43	La Pine	Left	50	3.0	10	9.0	21	3	0.14	8.5	5	9.0	29.5	2	7.88	High
12B	Wyeth	left	80	6.0	10	9.0	45	10	0.22	7.0	10	9.0	31.0	0	7.75	high
44	La Pine	Right	55	3.0	10	9.0	24	3	0.13	8.5	10	8.5	29.0	2	7.75	High
111	Big Eddy	Left	90	8.0	90	3.0	15	3	0.20	7.0	45	3.0	21.0	10	7.75	High
1	Tenino	Left	50	3.0	5	10.0	40.75	8	0.20	7.0	2	10.0	30.0	0	7.50	High
60	Foster Bridge	right	45	3.0	10	9.0	8	2	0.25	7.0	5	9.0	28.0	2	7.50	High
62	Fall River Area	Left	90	8.0	50	3.0	7	5	0.71	3.0	15	8.0	22.0	8	7.50	High
42	La Pine	right	45	3.0	10	9.0	26	5	0.19	7.0	10	8.5	27.5	2	7.38	High
59	Foster Bridge	Left	45	3.0	10	9.0	15	3	0.20	7.0	10	8.5	27.5	2	7.38	High
70	Fall River Area	right	45	3.0	15	8.0	5	2	0.40	5.0	10	8.5	24.5	5	7.38	High
34	Tetherow	Left	50	3.0	10	9.0	92	10	0.11	8.5	10	8.5	29.0	0	7.25	High
64	Fall River Area	right	50	3.0	80	2.0	22	10	0.45	7.0	20	7.0	19.0	10	7.25	High
67	Fall River Area	right	50	3.0	40	5.0	20	8	0.40	5.0	30	6.0	19.0	10	7.25	High
76	Big River	Left	90	8.0	20	7.0	12	10	0.83	3.0	10	8.5	26.5	2	7.13	High
3	Tenino	Left	60	4.0	30	7.0	38	5	0.13	8.5	15	8.5	28.0	0	7.00	High
20	Tetherow Burn	right	70	5.0	20	7.0	61	10	0.16	7.0	20	7.0	26.0	2	7.00	High
61	Foster Bridge	Left	90	8.0	80	2.0	3	1	0.33	6.0	20	7.0	23.0	5	7.00	High
36	Tetherow	right	50	3.0	5	10.0	35	10	0.29	7.0	20	7.0	27.0	0	6.75	High
77	Big River	right	60	4.0	40	5.0	12	3	0.25	7.0	5	9.0	25.0	2	6.75	High
97	Sun River Marina	right	90	8.0	20	7.0	3	2	0.67	3.0	20	7.0	25.0	2	6.75	High
99	Sun River Bridge	Left	90	8.0	30	6.0	4	2	0.50	4.0	20	7.0	25.0	2	6.75	High
106	Benham Falls	Left	90	8.0	20	7.0	32	10	0.31	6.0	30	6.0	27.0	0	6.75	High
71	Fall River	Left	45	3.0	30	6.0	8	5	0.63	3.0	20	7.0	19.0	7	6.50	high
4	Tenino	right	60	5.0	50	5.0	45	5	0.11	8.5	25	7.0	25.5	0	6.38	high
7	Dillman	Left	50	3.0	30	6.0	35	5	0.14	8.5	15	8.0	25.5	0	6.38	high

18	Tetherow Burn	right	45	3.0	40	5.0	21	3	0.14	8.5	20	7.0	23.5	2	6.38	high
74	Big River	Left	50	3.0	15	8.0	10	5	0.50	4.0	10	8.5	23.5	2	6.38	high
19	Tetherow Burn	Left	47	3.0	30	6.0	9	3	0.33	5.0	10	8.5	22.5	2	6.13	high
12	Bull Bend	left	60	5.0	5	10.0	10	10	1.00	1.0	10	8.0	24.0	0	6.00	high
16	Pringle Falls	right	52	3.0	50	5.0	62	10	0.16	7.0	20	7.0	22.0	2	6.00	high
102	Sun River	right	30	3.0	25	7.0	10	2	0.20	7.0	20	7.0	24.0	0	6.00	high
121	Columbia Bridge	Left	45	3.0	50	5.0	3	1	0.33	6.0	50	5.0	19.0	5	6.00	high
29	Tetherow Log Jam	Left	50	3.0	20	7.0	6	3	0.50	4.0	10	8.5	22.5	1	5.88	moderate
92	Sun River	right	75	5.0	40	5.0	4	3	0.75	3.0	10	8.5	21.5	2	5.88	moderate
10	Dillman	left	55	5.0	20	7.0	30	10	0.33	6.0	40	5.0	23.0	0	5.75	moderate
6	Tenino	right	50	3.0	50	5.0	20	3	0.15	8.0	25	7.0	23.0	0	5.75	moderate
33	Tetherow	right	50	3.0	60	3.0	25	10	0.40	7.0	50	5.0	18.0	5	5.75	moderate
55	La Pine State Park	right	60	4.0	40	5.0	47	10	0.21	7.0	20	7.0	23.0	0	5.75	moderate
54	La Pine State Park	Left	50	3.0	15	8.0	8	5	0.63	3.0	10	8.5	22.5	0	5.63	moderate
87	Water Wonderland	right	40	3.0	20	7.0	4	5	1.25	1.0	10	8.5	19.5	3	5.63	moderate
104	Benham Falls	right	90	8.0	100	1.0	80	5	0.06	8.5	50	5.0	22.5	0	5.63	moderate
104	Benham Falls	Left	90	8.0	100	1.0	60	5	0.08	8.5	50	5.0	22.5	0	5.63	moderate
17	Pringle Falls	Left	75	5.0	60	3.0	10	2	0.20	7.0	35	5.0	20.0	2	5.50	moderate
22	Tetherow Burn	right	80	6.0	60	3.0	8.7	3	0.34	5.0	30	6.0	20.0	2	5.50	moderate
41	Tetherow	right	90	8.0	80	2.0	4	2	0.50	4.0	70	3.0	17.0	5	5.50	moderate
85	Big River	right	60	4.0	70	3.0	30	5	0.17	7.0	30	6.0	20.0	2	5.50	moderate
91	Harper Bridge	Left	45	3.0	30	6.0	15	3	0.20	5.0	20	6.0	20.0	2	5.50	moderate
35	Tetherow	Left	50	3.0	20	7.0	20	10	0.50	4.0	20	7.0	21.0	0	5.25	moderate
52	La Pine State Park	Left	75	5.0	40	5.0	44	10	0.23	5.0	30	6.0	21.0	0	5.25	moderate
53	La Pine State Park	right	40	3.0	15	8.0	7	10	1.43	1.0	10	8.5	20.5	0	5.13	moderate
2	Tenino	right	50	3.0	50	5.0	21.56	5	0.23	5.0	25	7.0	20.0	0	5.00	moderate
50	La Pine Bridge	right	65	5.0	80	2.0	62	10	0.16	7.0	30	6.0	20.0	0	5.00	moderate
66	Fall River Area	right	45	3.0	40	5.0	15	5	0.33	6.0	30	6.0	20.0	0	5.00	moderate
78	Big River	Left	40	3.0	40	5.0	8	5	0.63	3.0	20	7.0	18.0	2	5.00	moderate
5	Tenino	Left	58	5.0	25	7.0	16.6	7	0.42	5.0	80	2.0	19.0	0	4.75	moderate
13	Pringle Falls	Left	50	3.0	80	2.0	35	7	0.20	7.0	40	5.0	17.0	2	4.75	moderate
37	Tetherow	Left	40	3.0	20	7.0	18	10	0.56	3.0	15	6.0	19.0	0	4.75	moderate
58	Foster Bridge	Left	90	8.0	80	2.0	3	3	1.00	1.0	30	6.0	17.0	2	4.75	moderate
79	Big River	right	60	4.0	60	3.0	6	3	0.50	4.0	30	6.0	17.0	2	4.75	moderate
82	Big River	right	45	3.0	50	5.0	5	3	0.60	3.0	30	6.0	17.0	2	4.75	moderate
94	Sun River	right	35	2.5	40	5.0	4	3	0.75	3.0	30	6.0	16.5	2	4.63	moderate
14	Pringle Falls	Left	40	3.0	70	3.0	40	8	0.20	7.0	50	3.0	16.0	2	4.50	moderate
15	Pringle Falls	Left	30	3.0	60	3.0	17	10	0.59	3.0	20	7.0	16.0	2	4.50	moderate
40	Tetherow	right	75	5.0	70	3.0	32	10	0.31	5.0	60	3.0	16.0	2	4.50	moderate
40	Tetherow	Left	45	3.0	20	7.0	10	10	1.00	1.0	20	7.0	18.0	0	4.50	moderate
25	Tetherow Burn	right	45	3.0	90	3.0	57	10	0.18	7.0	60	3.0	16.0	1	4.25	moderate
81	Big River	Left	50	3.0	30	6.0	8	5	0.63	3.0	70	3.0	15.0	2	4.25	moderate
84	Big River	right	45	3.0	50	5.0	4	10	2.50	1.0	30	6.0	15.0	2	4.25	moderate
86	Water Wonderland	right	35	3.0	60	3.0	30	10	0.33	6.0	60	3.0	15.0	2	4.25	moderate
88	Water Wonderland	right	60	4.0	60	3.0	15	10	0.67	3.0	40	5.0	15.0	2	4.25	moderate
32	Tetherow	Left	50	3.0	80	2.0	44	5	0.11	8.5	70	3.0	16.5	0	4.13	moderate
45	La Pine	Left	45	3.0	60	3.0	14	10	0.71	3.0	50	5.0	14.0	2	4.00	moderate
49	La Pine Bridge	Left	80	6.0	80	2.0	17	10	0.59	3.0	50	5.0	16.0	0	4.00	moderate
51	La Pine State Park	right	45	3.0	60	3.0	17	10	0.59	5.0	50	5.0	16.0	0	4.00	moderate
103	Benham Falls	Left	30	3.0	60	3.0	27	10	0.37	5.0	40	5.0	16.0	0	4.00	moderate

110	Aspen Camp	Left	45	3.0	60	3.0	2	2	1.00	1.0	30	6.0	13.0	3	4.00	moderate
118	Meadow Camp	Left	45	3.0	100	1.0	12	3	0.25	7.0	50	5.0	16.0	0	4.00	moderate
56	La Pine State Park	Left	45	3.0	50	5.0	11	10	0.91	1.5	30	6.0	15.5	0	3.88	low
113	Lava Falls	Left	90	8.0	95	1.5	1	1	1.00	1.0	80	2.0	12.5	3	3.88	low
9	Dillman	left	50	4.0	80	2.0	30	10	0.33	6.0	60	3.0	15.0	0	3.75	low
41	Tetherow	Left	40	3.0	90	3.0	21	10	0.48	5.0	80	2.0	13.0	2	3.75	low
46	La Pine	Left	20	2.0	80	2.0	16	10	0.63	3.0	60	3.0	10.0	5	3.75	low
48	La Pine	right	50	3.0	70	3.0	11	10	0.91	2.0	50	5.0	13.0	2	3.75	low
72	Big River	right	60	4.0	50	3.0	5	5	1.00	1.0	40	5.0	13.0	2	3.75	low
83	Big River	Left	30	3.0	30	6.0	10	10	1.00	1.0	70	3.0	13.0	2	3.75	low
90	Harper Bridge	Left	40	3.0	80	2.0	15	10	0.67	3.0	50	5.0	13.0	2	3.75	low
93	Sun River	right	45	3.0	70	3.0	4	5	1.25	1.0	30	6.0	13.0	2	3.75	low
95	Sun River	right	45	3.0	70	3.0	3	5	1.67	1.0	30	6.0	13.0	2	3.75	low
15	Pringle Falls	right	50	3.0	95	1.5	23	10	0.43	5.0	60	3.0	12.5	2	3.63	low
96	Sun River	Left	90	8.0	90	1.5	2	2	1.00	1.0	80	2.0	12.5	2	3.63	low
21	Tetherow Burn	Left	45	3.0	80	2.0	11	3	0.27	5.0	80	2.0	12.0	2	3.50	low
30	Log Jam	right	45	3.0	60	3.0	30	10	0.33	5.0	60	3.0	14.0	0	3.50	low
45	La Pine	right	45	3.0	60	3.0	13	10	0.77	3.0	60	3.0	12.0	2	3.50	low
46	La Pine	right	45	3.0	70	3.0	15	10	0.67	3.0	60	3.0	12.0	2	3.50	low
89	Water Wonderland	right	60	4.0	80	2.0	5	10	2.00	1.0	40	5.0	12.0	2	3.50	low
98	Sun River Marina	right	55	3.0	80	2.0	4	10	2.50	1.0	40	5.0	11.0	3	3.50	low
115	Meadow Camp	Left	90	8.0	100	1.0	1	2	2.00	1.0	80	2.0	12.0	2	3.50	low
120	Mt Bachelor Trail	Left	35	3.0	90	1.5	2	3	1.50	1.0	70	3.0	8.5	5	3.38	low
12A	Bull Bend	right	40	3.0	60	3.0	20	10	0.50	4.0	60	3.0	13.0	0	3.25	low
80	Big River	right	30	3.0	80	2.0	4	10	2.50	1.0	50	5.0	11.0	2	3.25	low
114	Lava Falls	right/left	45	3.0	100	1.0	30	5	0.17	7.0	80	2.0	13.0	0	3.25	low
116	Meadow Camp	Left	20	2.0	60	3.0	1	3	3.00	1.0	80	2.0	8.0	5	3.25	low
26	Tetherow Burn	right	45	3.0	60	3.0	10.6	10	0.94	1.5	40	5.0	12.5	0	3.13	low
28	Tetherow Log Jam	right	45	3.0	70	3.0	12	10	0.83	3.0	60	3.0	12.0	0	3.00	low
75	Big River	right	65	5.0	70	3.0	5	5	1.00	1.0	60	3.0	12.0	0	3.00	low
47	La Pine	Left	40	3.0	80	2.0	16	10	0.63	3.0	60	3.0	11.0	0	2.75	low
48	La Pine	Left	30	3.0	80	2.0	6	10	1.67	1.0	60	3.0	9.0	2	2.75	low
47	La Pine	right	40	3.0	85	1.5	15	10	0.67	3.0	60	3.0	10.5	0	2.63	low
100	Sun River	right	45	3.0	90	1.5	2	2	1.00	1.0	70	3.0	8.5	2	2.63	low
105	Benham Falls	Left	45	3.0	95	1.5	3	2	0.67	3.0	70	3.0	10.5	0	2.63	low
32	Tetherow	right	40	3.0	90	3.0	10	10	1.00	1.0	70	3.0	10.0	0	2.50	low
107	Slough	Left	40	3.0	75	3.0	2	2	1.00	1.0	80	2.0	9.0	0	2.25	low
108	Dillon	Left	40	3.0	90	3.0	1	1	1.00	1.0	80	2.0	9.0	0	2.25	low
119	Meadow Camp	Left	30	3.0	100	1.0	2	2	1.00	1.0	75	3.0	8.0	0	2.00	low
73	Big River	Right	45	3.0	95	1.5	5	15	3.00	1.0	70	1.5	7.0	0	1.75	very low
8	Dillman	Right	30	3.0	90	1.0	2	2	1.00	1.0	90	1.0	6.0	0	1.50	very low
8	Dillman	Left	30	3.0	90	1.0	2	2	1.00	1.0	90	1.0	6.0	0	1.50	very low
109	Dillon	left/right	variable	1.0	100	1.0	1	1	1.00	1.0	80	2.0	5.0	0	1.25	very low
112	Big Eddy	left/right	variable	1.0	100	1.0	1	1	1.00	1.0	80	2.0	5.0	0	1.25	very low
117	Meadow Camp	right/left	variable	1.0	100	1.0	1	1	1.00	1.0	80	2.0	5.0	0	1.25	very low

Appendix I: References

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Appendix II:
Deschutes National Forest Riparian Plant Associations

Deschutes National Forest Riparian Plant Associations

RIPARIAN ZONE ASSOCIATION	SITE SUMMARY	SOILS	WILDLIFE/FISHERIES	FIRE	RESTORATION PATHWAYS
Lodgepole pine/Kentucky bluegrass (*Pinus contorta/Poa pratensis*)	Common in Pumice Plateau Forest, abundant on Cold Wet Pumice Plateau Basins Ecoregion. Various ecological potentials where potential has been altered by grazing or where water table has been lowered.	Soil texture and parent material variable. Parent material includes pumice, rhyolite, basalt, andesite, and tuff. High water holding capacity.	Pocket gophers, mice, and Columbian ground squirrels can have significant periodic impact by increasing the prevalence of perennial and annual forbs. It can take several years to reestablish Kentucky bluegrass after ground squirrel activity. Deer and elk use for cover and shade. Important habitat for raptors.	Cool burns should have little impact on rhizomatous Kentucky bluegrass or perennial forbs. Fire could reduce excessive little buildup on rested pastures with care given to fire sensitive lodgepole pine.	Renovation with native graminoids seems impractical given depleted water tables and morphological flexibility of Kentucky bluegrass. Unless water table is restored these sites will remain with a ground cover dominated by Kentucky bluegrass. 2-3 yrs of rest will restore the vigor of Kentucky bluegrass on fair or better condition pastures. Introduction of domestic species is not recommended.
Lodgepole pine/bearberry (*Pinus contorta/Arctostaphylos uva-urs*i)	One of the driest LPP types. Common on DNF. Occurs on imperfectly drained, low gradient landforms on the edges of meadows, forested drainages & basins.	Surface soils are air laid or flow pumice over buried soils from alluvium, lava, or tuff.	Provides hiding and thermal cover for deer and elk, which feed in adjacent meadows. Raptor perch & nest sites when adjacent to meadows.	LPP is killed by fire while bearberry is moderately resistant to fire. Cool light prescribed fire will provide maximum survival of LPP and regeneration of bearberry.	Revegetation is not normally needed as LLP and bearberry readily regenerate following logging or wildlife. Soils are too dry and course in late summer for Kentucky bluegrass.
Lodgepole pine/Douglas spiraea/forb (*Pinus contorta/Spiraea douglasii/forb*)	Common between 4,100-5,300 ft on DNF especially low gradient, shallowly incised pumice-filled drainages & basins, narrow, deeply incised, moderate gradient drainages with narrow floodplain within the Cold Wet Pumice Plateau Basins Ecoregion.	Deep pumice alluvium or air-laid pumice.	Important raptor habitat where it occurs next to meadows and water. Thermal and hiding cover for deer in adjacent meadow and wetlands. Important trout stream pass though landforms supporting this association.	Wildfire was probably common. Soils are dry in mid summer so fire can encroach from adjacent uplands. Douglas spiraea will resprout from the base. LPP is not fire resistant.	Rehabilitation is not usually necessary with LPP or Douglas spiraea since either regenerate following logging or fire. Soils are likely too dry for Kentucky bluegrass.
Lodge pole pine/Douglas spiraea/widefruit sedge (*Pinus contorta/ Spiraea douglasii/Carex eurycarpa*)	Common between 4,100-5,100 ft on DNF. Strongly associated with deep pumice mantle on Cold Wet Pumice Plateau Basins and Pumice Plateau Forest Ecoregions. Microtopography is flat, slightly undulating, to slightly concave.	Deep pumice alluvium.	Deer use common. Sites provide forage, browse, cover, and water. Raptors use where adjacent to meadows & water. Often occurs along important trout streams such as Crescent Creek and Little Deschutes River.	Wildlife was probably fairly common. Soils usually are surface dry in August allowing fire encroaching from uplands. LPP is sensitive to fires. Shrubs and forbs are well adapted for regeneration following fire. Willow cover may increase following a reduction in LPP.	The association has not been observed in deteriorated condition.
Lodge pole pine/Bog Blueberry/Forb (*Pinus contorta/Vaccinium occidentalis/forb*)	Occurs over a wide range of elevations (4,500-5,900 ft) and most common on Cold Wet Pumice Plateau Basins and Pumice Plateau Forest Ecoregions.	Air-laid pumice, pumice alluvium, or pumice lacustrine deposits.	Important habitat for raptors where next to meadows & water. Provides fawning habitat, shade, and cover for deer and elk.	Ground surface is dry by August so fire can easily move from adjacent uplands. LLP is sensitive to fire but regenerates rapidly on burned sites. Understory species	All sampled stands were at or near climax so little is know about methods for rehabilitating disturbed stands.

RIPARIAN ZONE ASSOCIATION	SITE SUMMARY	SOILS	WILDLIFE/FISHERIES	FIRE	RESTORATION PATHWAYS
				regenerate after fire.	
Lodgepole pine/bog blueberry/widefruit sedge (*Pinus contorta/Vaccinium occidentalis/Carex eurycarpa*)	Not very common because bog blueberry does not extend far below the elevation range of Englemann spruce except on exceptionally cold sites. Fond on flat wet, cold floodplain and basin land forms. All within the Cold Wet Pumice Plateau Basins and Pumice Plateau Forest Ecoregions.	Deep pumice mantles and deep pumice alluvium.	Provides considerable browse, forage, and cover for deer & elk. Important raptor habitat where it occurs next to meadows & water. Streams such as Crescent Creek support good trout habitat.	Fire is suppressed until late summer. LLP is sensitive to fire. Willows, Douglas spiraea, & bog blueberry will resprout. Fire will not change forb layer.	All sampled stands were at or near climax so little is know about methods for rehabilitating disturbed stands.
Lodgepole pine/widefruit sedge (*Pinus contorta/Carex eurycarpa*)	Strongly associated with Cold Wet Pumice Plateau Basins and Pumice Plateau Forest Ecoregions. Occurs below 4,000-5,400 ft. Forested floodplains along streams such as Little Deschutes River, Crescent Ck.	Deep pumice alluvium.	Important raptor habitat where it occurs next to water and meadow. Deer and elk appear to spend considerable time here and in adjacent meadows in spring, summer, & fall. Provides important calving& fawning habitat for elk & deer.	Wildfire was probably infrequent. Widefruit sedge will regenerate from rhizomes.	Site in mid seral or better ecological condition status will increase rapidly in status with rest and late season grazing. Site converted to LLP Kentucky bluegrass may need stream rehab to raise the water table to regain the sedge.
Quaking aspen/blue wildrye (*Populus tremuloides/Elymus glaucus*)	Occurs infrequently on Cold Wet Pumice Plateau Basins, Pumice Plateau Forest. Microtopography is flat to concave.	Variably of alluvium and/or colluvium.	Aspen stands provide a critical source of diversity and habitat for wildlife, particularly birds. Common flickers, chickadees, hairy woodpeckers, yellow-bellied sapsuckers and many other birds nest in aspen. Deer and elk feed, bed, and raise young in aspen stands. Stands near perennial water provide important habitat for beaver. Beaver activity in conjunction with browsing by cattle, deer and elk can severely damage the stand.	Fire suppression has contributed to the conversion of aspen stands to LLP or herbaceous meadow. Fire can be an important tool in stimulating aspen suckers and rejuvenating deteriorated aspens stands.	Clearcutting and prescribed fire will help rejuvenate over mature aspen when done in conjunction with protection from browsing. Aspen resprouts poorly from stem cuttings but can be transplanted successfully from nursery stock.

RIPARIAN ZONE ASSOCIATION	SITE SUMMARY	SOILS	WILDLIFE/FISHERIES	FIRE	RESTORATION PATHWAYS
Mountain alder (*Alnus incana*)	Found throughout central OR in all physiographic regions with elevations 2,400-5,600 ft. Sites are young seral, active channel shelves that lie between active and flood stage stream bank.	Shallow, skeletal alluvium over water worked cobbles and gravels.	Most streams passing through landforms containing alder association are degraded although capable of producing valuable fisheries. Banks anchored by alder are stable and can withstand relatively severe spring runoff. Moderately narrow, moderately deep stream profiles can provide cover, food, and shade for salmonids. Birds find habitat, and deer and elk browse on alder.	Fire is infrequent. Alder will only survive the coolest ground fires. Most fires will destroy the alder, leaving the active fluvial surfaces protected from erosion only by weak rooted graminoids and forbs.	Critical factors for channel shelf formation are season long moisture and rest from grazing. The dish profile stream is often bank full at peak runoff but is dry or nearly so by summer. This condition will not support the development of riparian vegetation and with continued overuse by livestock there can't be any positive change in the condition of the site. In 2-5 yrs with rest a relatively permanent channel with banks and channel shelves stay moist season long and begin to support the growth of riparian vegetation. Once the vegetation is tall enough to trap sediments it will take at least 5 yrs for the alder to grow stems heights and diameters resistant to grazing. 40% utilization of the herbaceous vegetation or less insures that livestock use will not cause degradation.
Mountain alder-Common Snowberry (*Alnus incana-Symphoricarpos alba)*	Abundant between 2,200-5,500 ft in Pumice Plateau Forest, Cold Wet Pumice Plateau Basin Ecoregions.	Sediment deposit has built soil depth to change site potential from Mt alder to Mt alder-common snowberry association.	Alder provides good bank stability and protection from floods. Diversity provided by the alder provides browse for deer and elk and habitat for birds.	Fire is infrequent. Alder will only survive the coolest ground fires. Most fires will destroy the alder, leaving the active fluvial surfaces protected from erosion only by weak rooted graminoids and forbs.	Mt alder is a prolific seeder and will usually reestablish after fire. It will not root from cutting.
Mountain alder-Douglas spiraea (*Alnus incana-Spiraea douglasii*)	Common in mountainous Ecoregions on the Deschutes and narrow, deeply incised, moderate gradient drainages in the Cold Wet Pumice Plateau Basins Ecoregion.	Accumulation of sediment has increased soil depth so that the vegetation composition reflects a drier moisture regime than the mt alder association. Well-aerated alluvium.	The diversity canopy provides habitat for birds, and browse for deer and elk.	Fire is infrequent. Alder will only survive the coolest ground fires. Most fires will destroy the alder, leaving the active fluvial surfaces protected from erosion largely by weak rooted graminoids and forbs. Mt alder is a prolific seeder and will usually reestablish after fire. It will not root from cutting. Weakly rooted spiraea, grasses and forbs provide protection from erosion. Widefruit sedge will provide good bank stability if abundant.	Mt alder will reestablish after fire, but requires protection from overuse by livestock and perhaps deer and elk. Alder seedlings can be planted in well-aerated soils that are moist throughout the summer. When livestock are removed at 40% forage use a return to late seral ecological status can be attained in 10-20 yrs. The rehab process can be accelerated if the pastures are rested for at least 5 yrs.

RIPARIAN ZONE ASSOCIATION	SITE SUMMARY	SOILS	WILDLIFE/FISHERIES	FIRE	RESTORATION PATHWAYS
Willow/Kentucky bluegrass (*Salix/Poa pratensis*)	Occurs on sites that have been highly altered by grazing, lowering water table or both. It is uncommon on the DNF and may occur in the watershed.	Deep fine textured alluvium over subsurface soils of various textures.	Rodents such as pocket gophers, mice and Columbian ground squirrel can be a significant impact. Willows provide browse for deer and elk and diversity for birds.	Cool burns should have little impact on rhizomatous species such as Kentucky bluegrass and willows will resprout following fire.	2-3 yrs of rest will restore the vigor of Kentucky bluegrass. 5-6 yrs can provide 5-8 ft willows. Unless water table can be restored, these sites will for all practical purposes remain with a ground cover dominate by bluegrass and should be managed as a naturalized community. Renovation of highly degraded site with native grasses and sedge is largely impractical given depleted water table and the flexibility of Kentucky bluegrass
Willow/widefruit sedge (*Salix/Carex eurycarpa*)	Widespread on DNF at 4,100-5,000 ft. on low gradient, low elevation floodplains along the Deschutes River and its tribs in the Pumice Plateau Forest Ecoregion and shallow, pumice filled drainages in the Pumice Plateau Forest and Cold Wet Pumice Plateau Basins Ecoregions.	Variable.	Willow and sedge provides habitat diversity for birds and mammals. Low gradient makes excellent habitat for beavers.	The association will be difficult to burn until late summer or fall. Dried vegetation will carry fire, reduce litter build up and increase productivity. Fire will reduce filtering and buffering capacity until following year. Sedge peat soils are flammable and when dry and can be severely damaged by fire.	Willows are sensitive to fire but will resprout at root crown. Rehab is usually not needed. Widefruit sedge will increase rapidly in cover with rest and late season grazing on sites in mid seral or better ecological status.
Willow/Sitka sedge (*Salix/Carex sitchensis*)	Abundant on the DNF from 3,100 - 5,200 ft. On low gradient streams floodplains in Pumice Plateau Forest Ecoregion such as Little Deschutes River, Crescent Ck. and headwaters of these in wet, poorly drained marshes and swamps such as Upper Big Marsh.	Floodplain soils are very deep alluvium. Headwaters areas have deep sedge peat accumulation.	Structural diversity provides habitat for birds, beaver, deer, elk, and other wildlife.	These sites are difficult to burn until late summer or fall. Dried vegetation will carry a fire, reducing buildup and increasing productivity for several years. Fire may reduce the buffer and filter capacity during next season's runoff. Willows are sensitive to fire however will sprout back from root crown. Peat sedge soils will burn when dry.	This association has been observed in late seral stage only. Sitka sedge will rapidly recolonize after rest and late season grazing.

RIPARIAN ZONE ASSOCIATION	SITE SUMMARY	SOILS	WILDLIFE/FISHERIES	FIRE	RESTORATION PATHWAYS
Cusick Bluegrass (*Poa cusickii*)	Flat micro relief of dry basins and drainages and inactive floodplains and terraces within the Cold Wet Pumice Plateau Basins Ecoregion.	Pumice alluvium.	Important habitat for raptors. Rodents such as mice, pocket gophers, and Columbian ground squirrel can have a large periodic impact. Feeding ground for deer and elk.	Little is known about the effects of fire. Cusick bluegrass is more sensitive to burning than the rhizomatous species such as Kentucky bluegrass or widefruit sedge. Fire frequency is probably less than 15 yr interval.	Excellent response of this meadow to rest is expected in areas where meadows have reached mid seral or better ecological status. Most sites are highly degraded with a low density of Cusick bluegrass that responds slowly to improved livestock management systems. Floodplains seeded with good results although it would be preferable to plant Cusick bluegrass. Drier sites are more common and may not be suitable for introduction of domestic grass seeds because of fluctuating water tables, soils and extreme summer drought.
Kentucky Bluegrass (*Poa pratensis)*	Uncommon on DNF. Found between 3,000-5,000 ft. Landforms are dry basins & floodplains with gentle slopes and smooth microtopography. This type now occupies sites of various potential including other graminoids and willow and ponderosa pine associations.	Variable.	Important habitat for raptors. Heavy infestations of mice, and other rodents can have a large periodic impact on the meadow resulting in increases in perennial and annual forbs.	Fire is an effective tool in reducing the effects built up litter layers. Cool burns should have little negative impact on this bluegrass.	Avoid early season use to prevent soil compaction. 2-3 yrs will restore lost vigor and vegetative composition on sites in mid seral or better ecological status. Restoring willows and natural sedge will reduce erosion.
Tufted hairgrass (*Deschampsia cespitosa*)	Broad elevational and geographic range results in this as on e of them most abundant and diverse in central OR. Meadow sites in flat to slightly concave drainages and basins and lakeshores.	Variable.	Deer, elk, rodents, and raptors area common.	Repeated burning of this meadow may favor rhizomatous species such as Kentucky bluegrass, beardless wheatgrass, and western needlegrass, but frequent fire is unlikely to provide a noticeable affect on tufted hairgrass.	An upward trend in ecological status requires timing the season of livestock use to both drying soil surface and to maturation of the tufted hairgrass seed heads. Livestock should be removed at 40% utilization of herbaceous forage. Meadows in mid seral or better ecological condition will respond rapidly to improved grazing strategies. Domestic species such as Kentucky bluegrass, Timothy, & meadow foxtail can be seeded but tufted hairgrass is preferred.
Nebraska sedge (*Carex nebraskensis*)	Found in most Ecoregions east of the Cascades at elevations between 4,000-5,000 ft.	Smooth organic loams derived from alluvium.	If willows are supported birds and some mammals will use the area.	It is difficult to burn this wet type except for late summer. Only the top growth would burn which would reduce the water holding capacity and reduce the sediment capture in spring runoff.	Nebraska sedge forms thick, dense, rhizome mats that provide stream bank erosion. It would be desirable to manage these areas to return to willow communities, however Nebraska sedge is very competitive. Grazing should be managed to remove livestock at 40% utilization standard. Excess grazing will result in pedestalling and breaking the sod.

RIPARIAN ZONE ASSOCIATION	SITE SUMMARY	SOILS	WILDLIFE/FISHERIES	FIRE	RESTORATION PATHWAYS
Widefruit sedge (*Carex eurycarpa*)	Widespread on DNF and most common in Pumice Plateau Forest and Cold Wet Pumice Plateau Basins Ecoregion. In active floodplains, and small shallow pumice-filled drainages.	Deep deposits of pumice alluvium.	Habitat provided for deer, elk, raptors and other wildlife.	It can be burned in late summer or early fall. Fire can reduce litter and increase productivity for several yrs. Hot fires may penetrate organic soils, destroying sedge rhizomes.	Widefruit sedge will rapidly recolonize sites in mid seral or better ecological status with rest and late season grazing. 40% removal utilization will insure maintenance of site in late seral or climax status. Stream bank stabilization can help raise the water table. Willow cutting may be successful where water tables are normal and willow regeneration is protected from browsing by deer, elk, livestock and beavers.
Short-beaked sedge (*Carex simulata*)	Scattered throughout central OR it is found in Upper Big Marsh on the DNF.	Organic loam and sedge peat.	Deer use this when hiding cover is in close proximity. Early spring forage may be provided.	Prescribed fire is not a useful tool. Soil surface becomes dry and the organic soils may become flammable destroying the sedge rhizomes.	Rehabilitation is not needed as the association is in late seral or climax ecological condition.
Slender sedge (*Carex lasiocarpa*)	Locally abundant between 4,600-5,700 ft in Cold Wet Pumice Plateau Basins and Pumice Plateau Forest Ecoregion including Big Marsh.	Marsh and lake sites support deep sedge and sedimentary peat soils, respectively.	If flooded long enough habitat is provided for nesting ducks, especially teal. Limited utility for songbirds and small mammals because of the lack of diversity and flooded soils. Mule deer feed on scattered forbs and seed heads of sedges.	By mid summer the site can burn but the rhizomatous nature of slender sedge would make it resistant to damage. Hot fire will penetrate the peat soils with increased damage.	Slender sedge will regain on disturbed sties. Livestock should be kept off wet soils with only late season grazing as an option. This site is unlikely to support willows.
Small-fruit bulrush Bigleaf sedge (*Scirpus microcarpus Carex amplifolia*)	Common on DNF. It has been observed in the Pumice Plateau Forest Ecoregion in areas 2,400-5,700 ft.	Water worked alluvium.	Overgrazing, trampling, and erosion disrupt the normal successional pattern and prevent development of other sedges and mountain alder, which would provide better wildlife habitat.	Both of these graminoids are resistant to fire. In late summer fire could be used to reduce litter. Fire should not be used on active fluvial surfaces because it would remove above ground plant parts critical to sediment entrapment slowing soil building.	Revegetation is not generally needed as small fruit bulrush and bigleaf sedge have dense, thick rhizomes that respond to rapidly to rest. Both are prolific seeders. Where bank erosion is severe, grasses such as reed canarygrass, Timothy, reedgrass, bentgrass, and meadow foxtail may be used to temporarily stabilize active fluvial surfaces. Areas with soil development may response to willow or mountain alder planting.
Sitka sedge (Carex sitchensis)	Abundant on the DNF mostly commonly on low gradient floodplain landforms along the Deschutes River and major tributaries in the Pumice Plateau Forest Ecoregion. Big Marsh is notable.	Deep alluvium high in organics.	Coarse tough Sitka sedge rhizomes are excellent anchors of riverbanks and floodplains and provide shade. Habitat structure and diversity from the complex mix of sedge, willow, and LLP provide habitat for elk, deer, and beaver.	Fire would only be likely in late summer or fall burning dried vegetation. Fire may reduce the buffering and filtering of the sedge the yr following the fire. Proximity of fire sensitive species such as willow and LLP in adjacent associations makes this type difficult to burn without damage.	Sites in mid seral or better ecological status will be rapidly recolonized by Sitka sedge with rest and late season grazing.

RIPARIAN ZONE ASSOCIATION	SITE SUMMARY	SOILS	WILDLIFE/FISHERIES	FIRE	RESTORATION PATHWAYS
				Sedge peat soils are flammable and could destroy sedge rhizomes.	
Inflated Sedge (*Carex vesicaria*)	Wide geographic and elevational (4,000-6,000 ft) distribution in a variety of low gradient landforms supporting shallow flooding or semi permanently saturated soils	Deep sedge and sedimentary peats or organic loam except seral sites such as active channels shelves.	Inflated sedge provides excellent barrier to stream bank erosion, helping to form narrow, deep profiles. Ponded sites provide important nesting and feeding habitat for a wide variety of waterfowl. Inflated sedge provides important forage for elk in mid to late summer.	Fire is likely on in late summer or fall. Fire reduces litter and increases productivity for several years but will not change species composition. Peat soils are flammable destroying sedge rhizomes.	Dense rhizomes are very resistant to trampling. Disturbed sites in mid seral or better ecological status will rapidly recolonized by inflated sedge with rest and late season grazing. Revegetation can be accomplished using grasses such as reed canarygrass, tall mannagrass, Timothy, and reedgrass, however these are not as resistant to erosion as inflated sedge. The site is too wet for willow planting.
Beaked sedge (*Carex rostrata*)	One of the wettest riparian associations in wide geographic and elevational distribution (4,000-6,000 ft) in every association in central OR. Low gradient landforms from permanently flooded basins to floodplains and wet meadows. Occurs on wet fluvial surfaces such as stream bank, active channel shelves, overflow channels, marshes, and fens.	Deep sedge or sedimentary peats, organic loam, or muck except for recently deposited alluvium.	Semi-permanently flooded sites provide habitat for many species of waterfowl.	Burns will be possible in dry summers when water table is below soil surfaces. Fire will reduce litter accumulation and increase productivity for several yrs but will not change species composition. Peat soils are flammable.	Dense sod is very resistant to trampling and beaked sedge will rapidly recolonize disturbed sites with rest. Banks can be temporarily revegetated with grasses such as reed canarygrass, tall mannagrass, Timothy, and reedgrass, however these are not as resistant to erosion as beaked sedge. The site is too wet for willow planting.
Creeping spikerush (*Eleocharis palustris*)	Found throughout central OR in a range of physiographic regions with elevations 3,000-6,800 ft., riparian landforms, and Ecoregions. Low valley gradient and standing bodies of water in natural or manmade settings, such as stockponds and reservoirs. It frequently forms community in ponded sites between stream rehab structures such as loose rock check dams.	Margins or lakes and older reservoirs are organic loam and sedimentary peat.	Broad zones of creeping spikerush along major lakes, larger stock ponds, and reservoirs offer valuable habitat for waterfowl. Seeds of rushes and sedges provide fair to good forage for duck and geese. Pondweeds, smartweeds, and water lentils are excellent forage for ducks and geese.	Prescribed fire is not a useful tool. Soil surface becomes dry and the organic soils may become flammable destroying the sedge rhizomes and will not change species composition unless fire penetrates organic soil.	Generally not needed. Stock ponds will revegetate rapidly if protected from trampling. The area should be fenced and water gravity fed to stock tanks protecting vegetation and water quality.

Source: Little Deschutes River Subbasin Assessment 2002 (UDWC)

Appendix III:
Potential Irrigation Efficiency

Potential Irrigation Efficiency: (Ultimate, Design, Seasonal & Typical)

Irrigation Method	Irrigation System	Ultimate 1/ Potential Efficiency	Irrigation System Design Efficiency	Overall 2/ Seasonal Irrigation Efficiency	Typical 3/ Irrigation Efficiency
Surface	*Borders				
	Level or Basin	90	50-80	50-90	80
	Graded	80	50-60	45-60	60
	*Furrow				
	Graded	75	50-60	50-60	60
	Corrugation	75	50-60	50-60	50
	*Flood – controlled	60	40-50	30-50	45
	*Flood – semi controlled	50	30-40	25-40	35
Sprinkler	*Periodic move				
	Side-roll Wheel line	70	65-70	60-65	65
	Hand Move	70	65-70	50-65	65
	Solid Set	75	65-75	50-65	65
	Big guns	60	60	50-60	60
	*Continuous Move				
	Big guns	60	60	50-60	60
	Center Pivot	85	85	75-85	80
Micro	*Continuous Tape	90	85-90	80-85	85
	*Point Source Emitters	90	85-90	80-85	85
	*Mini Spray	85	85	80-85	85

1/ Potential Efficiency is only obtainable where totally adaptable (based on totally ideal soil type & condition, crop type, suitable climate, field condition & topography, etc), with optimum operation and management, and a high degree of irrigation scheduling. Due to less than desirable soils, climate, typical field condition, economics, and the many hobby farmers in Central Oregon, these ultimate potential efficiencies cannot be reasonably obtained.

2/ This is a range of overall seasonal irrigation efficiency. This wide range is due to varying soil conditions, varying crops, local climate such as moderate to high temperatures and wind, low to high degree operation & management, and adequate equipment maintenance.

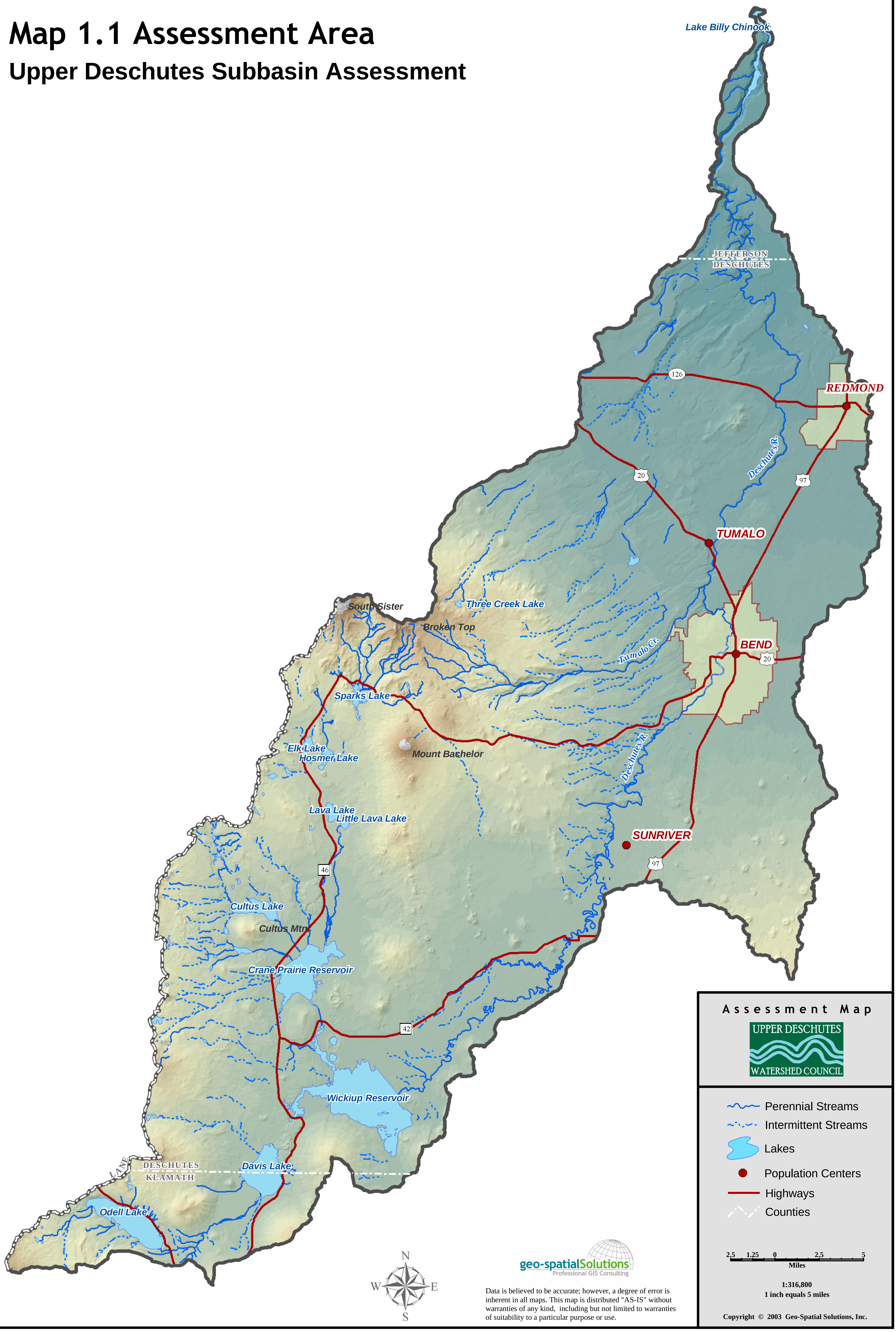
3/ Typical irrigation system efficiency for properly designed, somewhat adequately operated and managed, and maintained systems, and using some minimal method for scheduling irrigations.

Source: Ross, Elwin. 2003. On-Farm Irrigation Water Management/ Conservation Program. Deschutes SWCD.

Appendix IV:
Assessment Maps

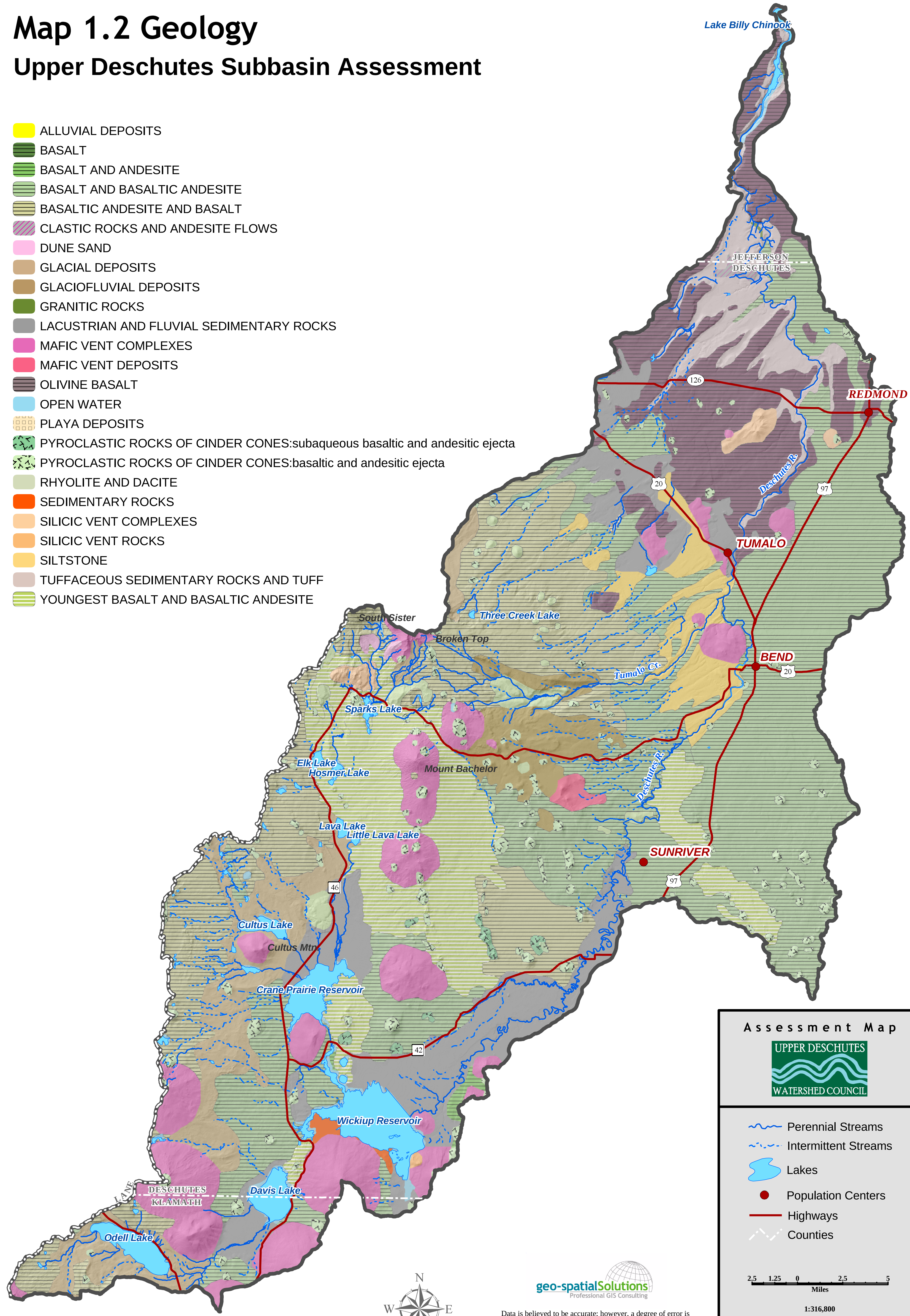
Map 1.1 Assessment Area

Upper Deschutes Subbasin Assessment



Map 1.2 Geology

Upper Deschutes Subbasin Assessment

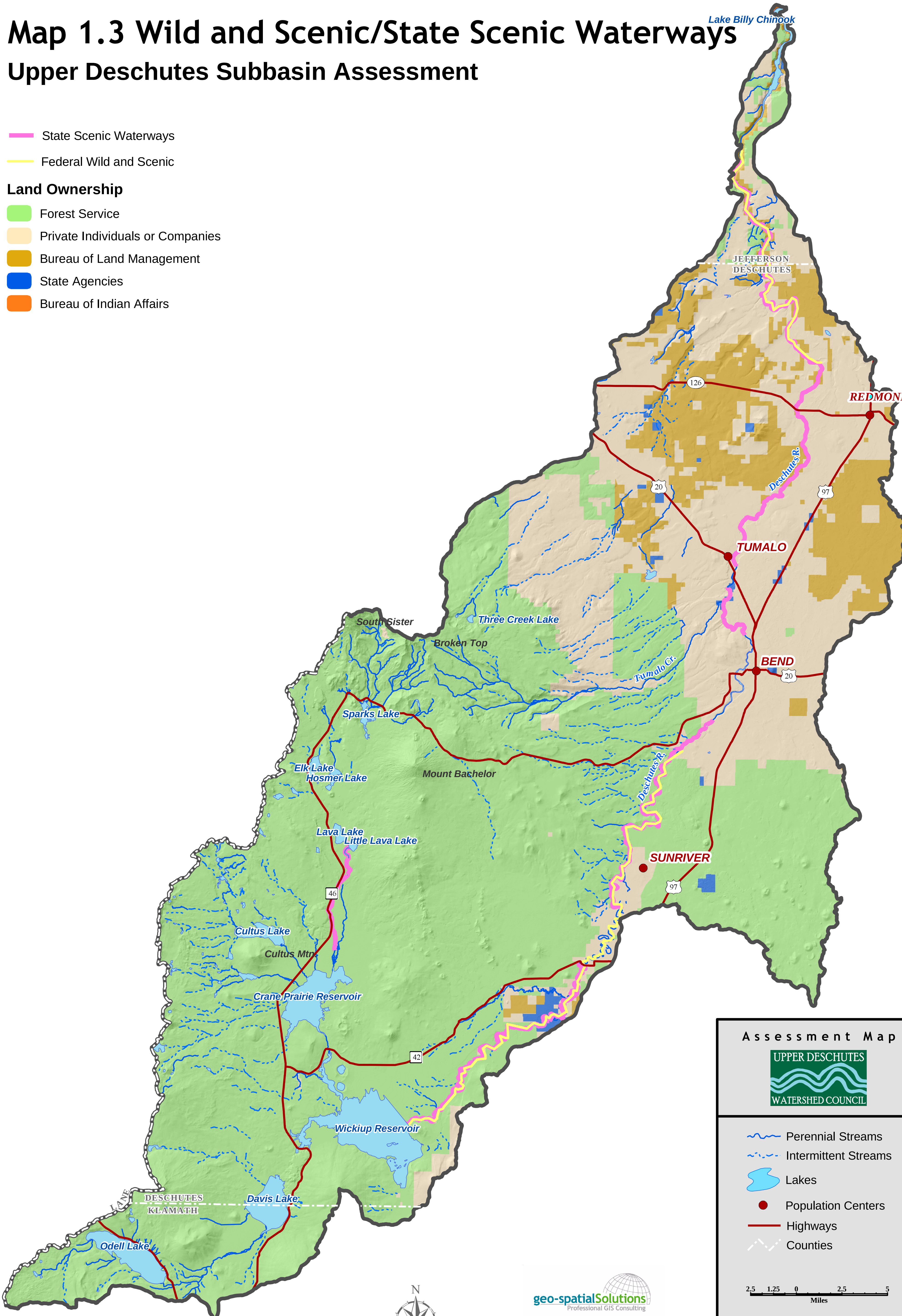


Data Source: Walker, G.W., and MacLeod, N.S., 1991, Geologic map Of Oregon: U. S. Geological Survey, scale 1:500,000

Data is believed to be accurate; however, a degree of error is inherent in all maps. This map is distributed "AS-IS" without warranties of any kind, including but not limited to warranties of suitability to a particular purpose or use.

Map 1.3 Wild and Scenic/State Scenic Waterways

Upper Deschutes Subbasin Assessment

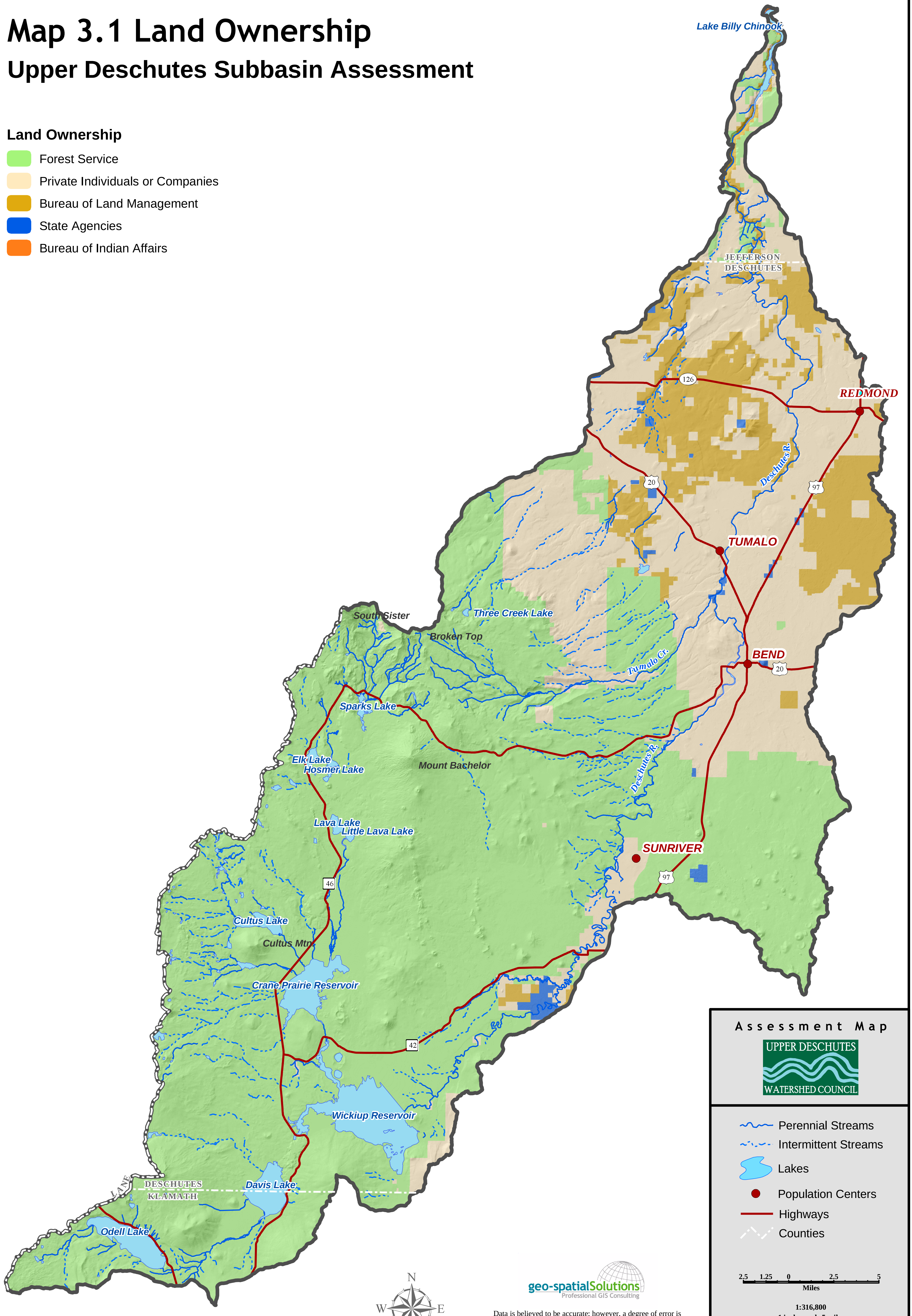


Data Source: US Fish and Wildlife Service 2000
Oregon Division of State Lands

Data is believed to be accurate; however, a degree of error is inherent in all maps. This map is distributed "AS-IS" without warranties of any kind, including but not limited to warranties of suitability to a particular purpose or use.

Map 3.1 Land Ownership

Upper Deschutes Subbasin Assessment

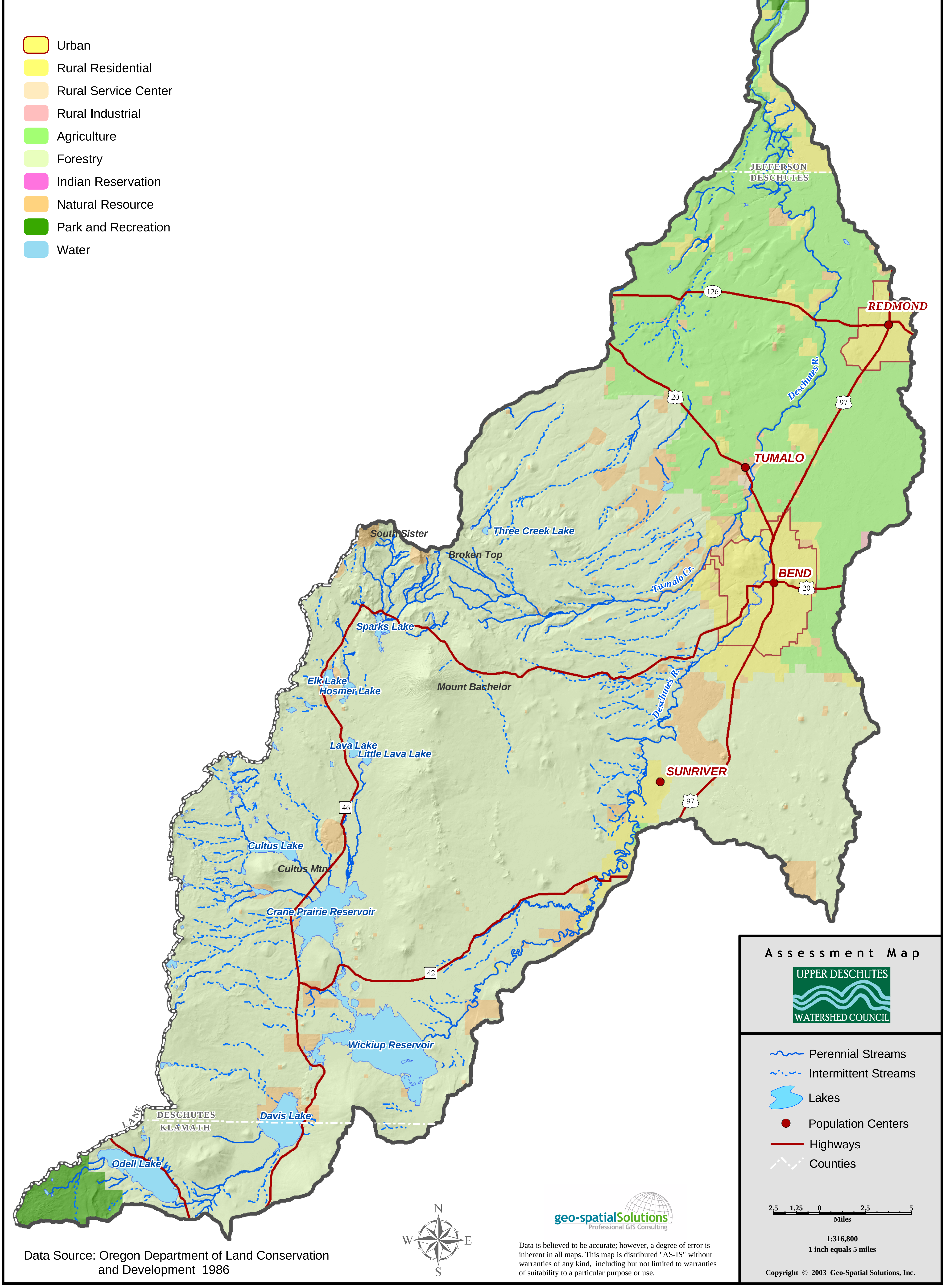


Data Source: Oregon Dept. of Forestry 2001

Data is believed to be accurate; however, a degree of error is inherent in all maps. This map is distributed "AS-IS" without warranties of any kind, including but not limited to warranties of suitability to a particular purpose or use.

Map 3.2 Land Use

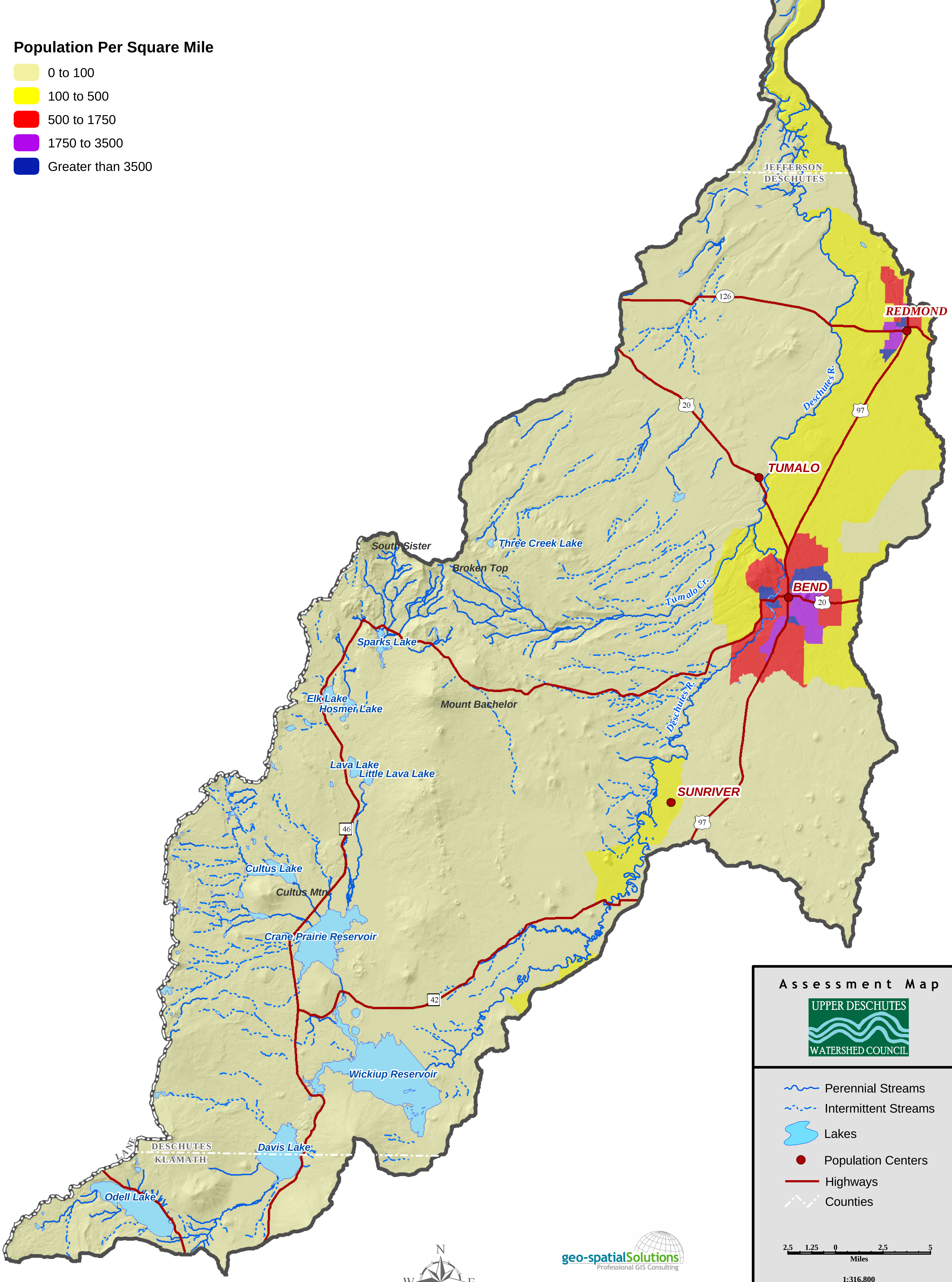
Upper Deschutes Subbasin Assessment



Data Source: Oregon Department of Land Conservation and Development 1986

Map 3.3 Population Density

Upper Deschutes Subbasin Assessment

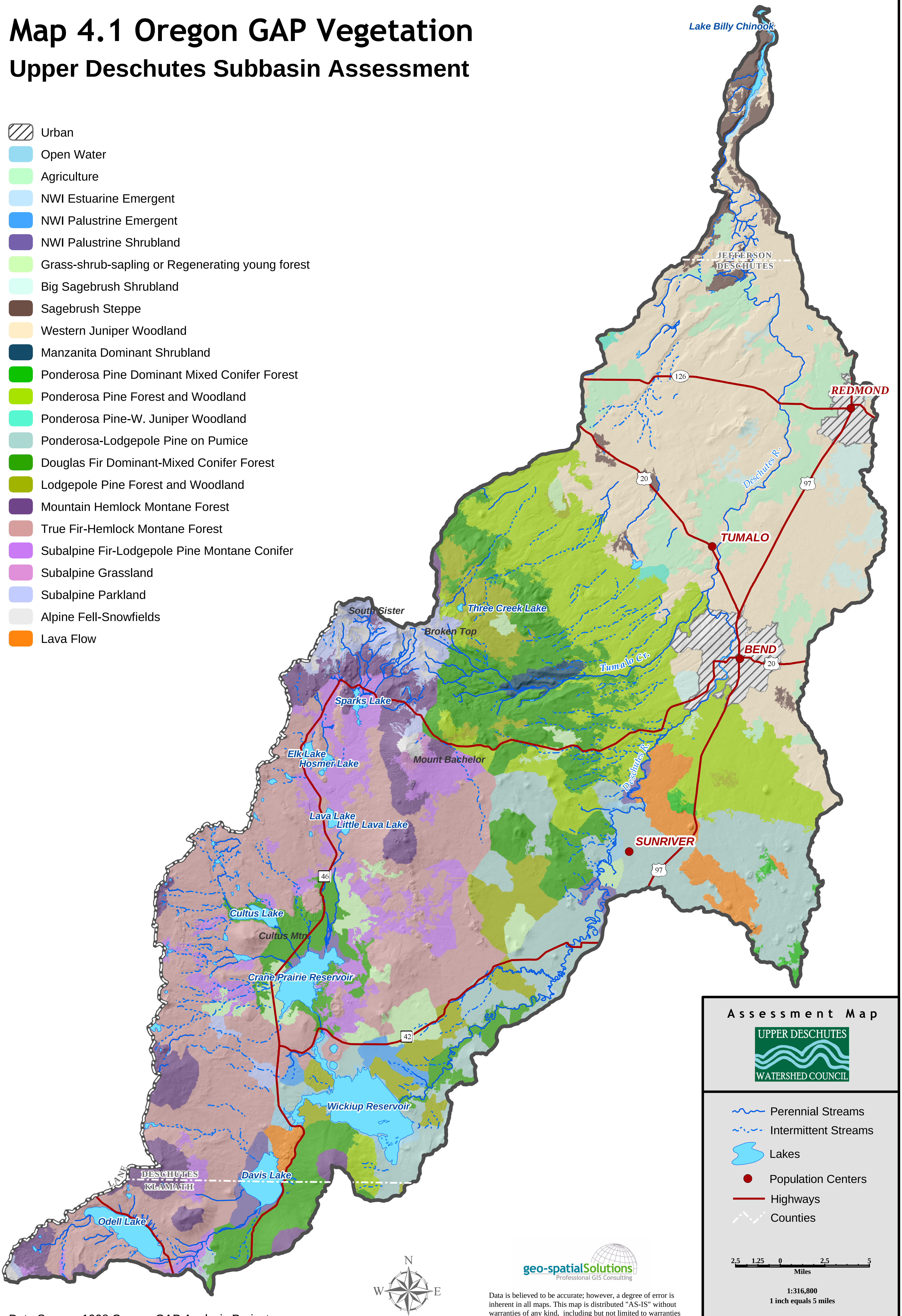


Data Source: ESRI 2000 US Census Data

Data is believed to be accurate; however, a degree of error is inherent in all maps. This map is distributed "AS-IS" without warranties of any kind, including but not limited to warranties of suitability to a particular purpose or use.

Map 4.1 Oregon GAP Vegetation

Upper Deschutes Subbasin Assessment

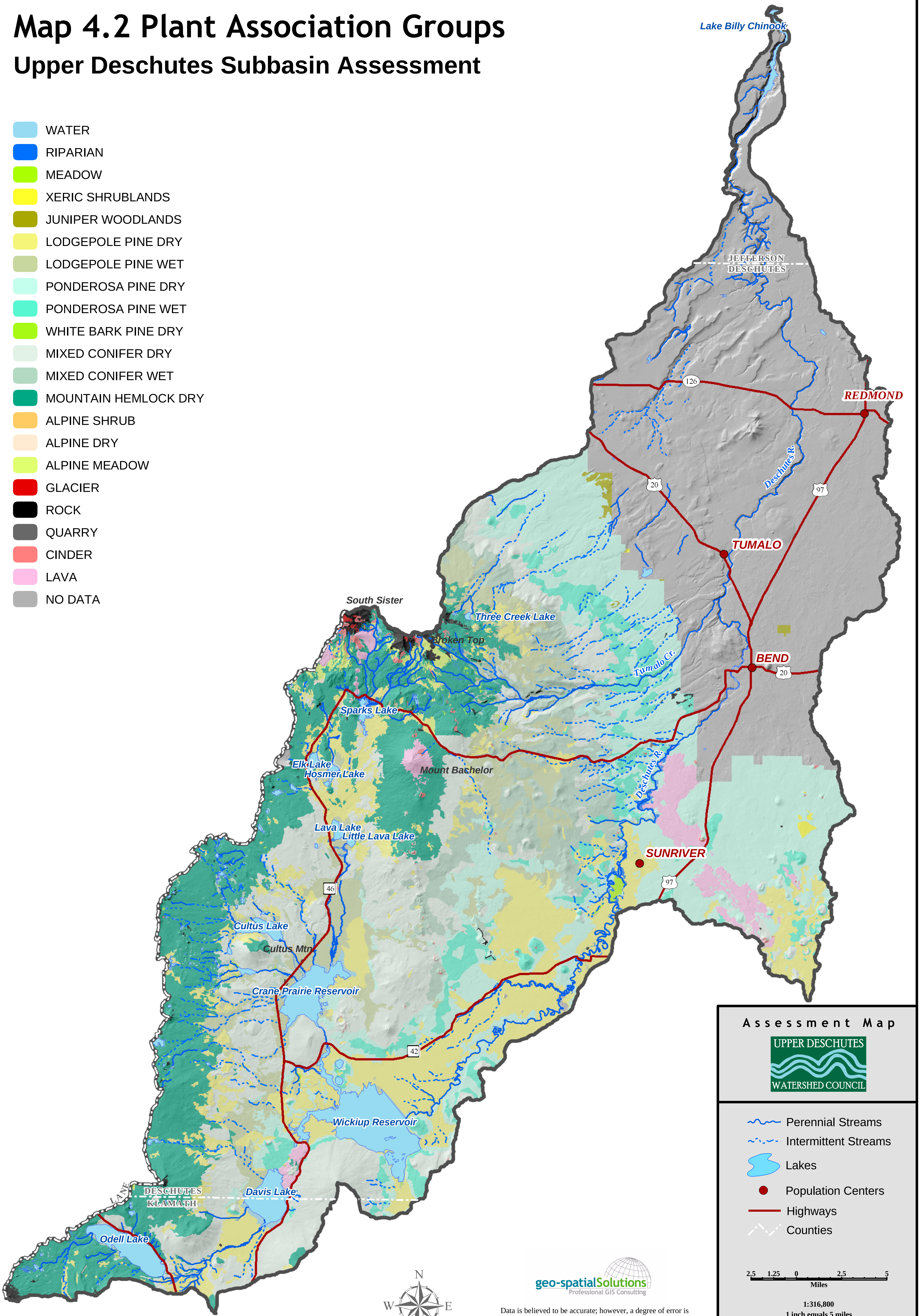


Data Source: 1998 Oregon GAP Analysis Project

Map 4.2 Plant Association Groups

Upper Deschutes Subbasin Assessment

- WATER
- RIPARIAN
- MEADOW
- XERIC SHRUBLANDS
- JUNIPER WOODLANDS
- LODGEPOLE PINE DRY
- LODGEPOLE PINE WET
- PONDEROSA PINE DRY
- PONDEROSA PINE WET
- WHITE BARK PINE DRY
- MIXED CONIFER DRY
- MIXED CONIFER WET
- MOUNTAIN HEMLOCK DRY
- ALPINE SHRUB
- ALPINE DRY
- ALPINE MEADOW
- GLACIER
- ROCK
- QUARRY
- CINDER
- LAVA
- NO DATA



Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

- Perennial Streams
- Intermittent Streams
- Lakes
- Population Centers
- Highways
- Counties

2.5 1.25 0 2.5 5

Miles

1:316,800

1 inch equals 5 miles

geo-spatialSolutions Professional GIS Consulting

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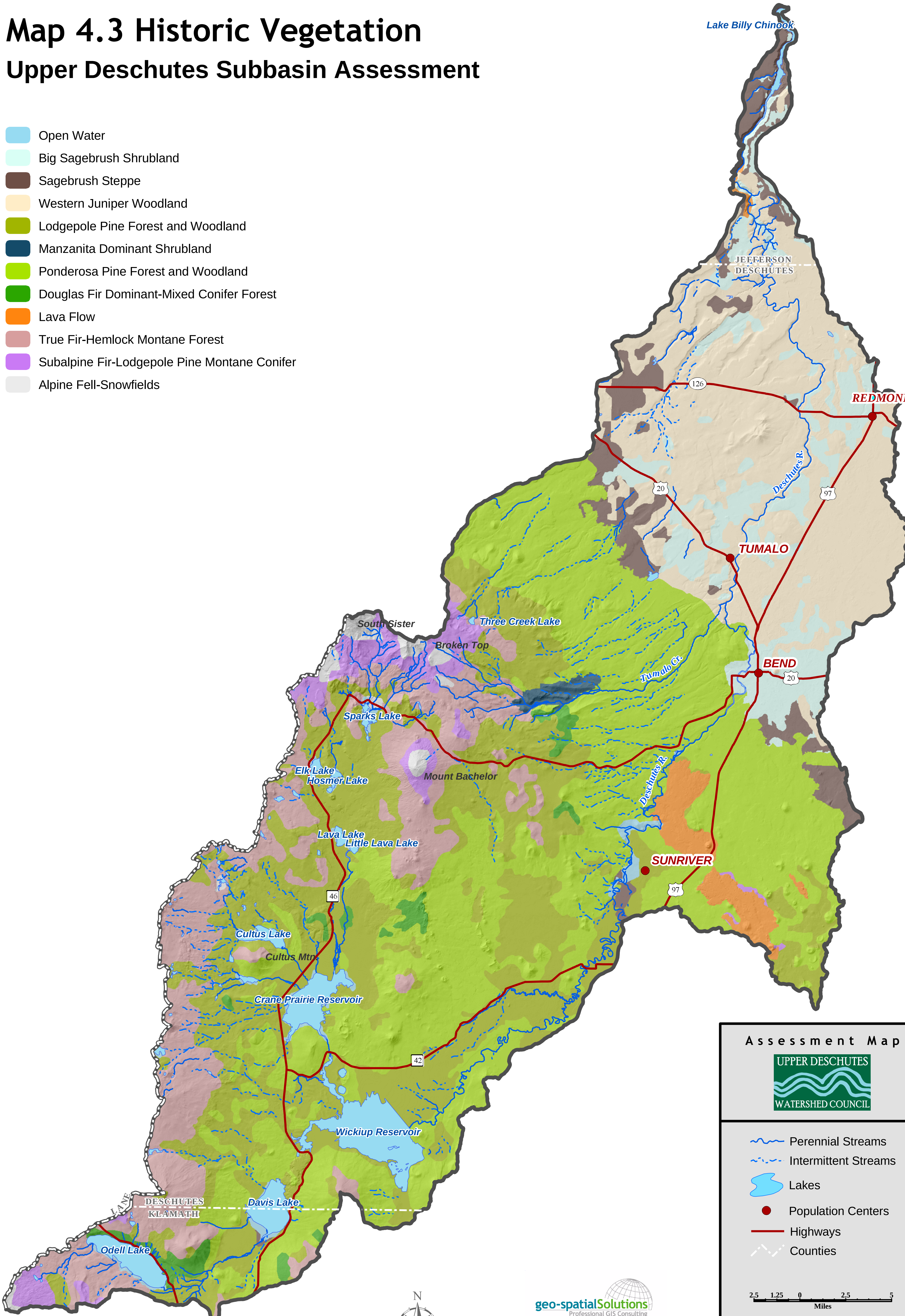
Data Source: Deschutes National Forest 1996

Map 4.3 Historic Vegetation

Upper Deschutes Subbasin Assessment

- Open Water
- Big Sagebrush Shrubland
- Sagebrush Steppe
- Western Juniper Woodland
- Lodgepole Pine Forest and Woodland
- Manzanita Dominant Shrubland
- Ponderosa Pine Forest and Woodland
- Douglas Fir Dominant-Mixed Conifer Forest
- Lava Flow
- True Fir-Hemlock Montane Forest
- Subalpine Fir-Lodgepole Pine Montane Conifer
- Alpine Fell-Snowfields



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Professional GIS Consulting

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Data Source: Oregon Natural Heritage Program 2002

Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

- Perennial Streams
- Intermittent Streams
- Lakes
- Population Centers
- Highways
- Counties

2.5 1.25 0 2.5 5
Miles

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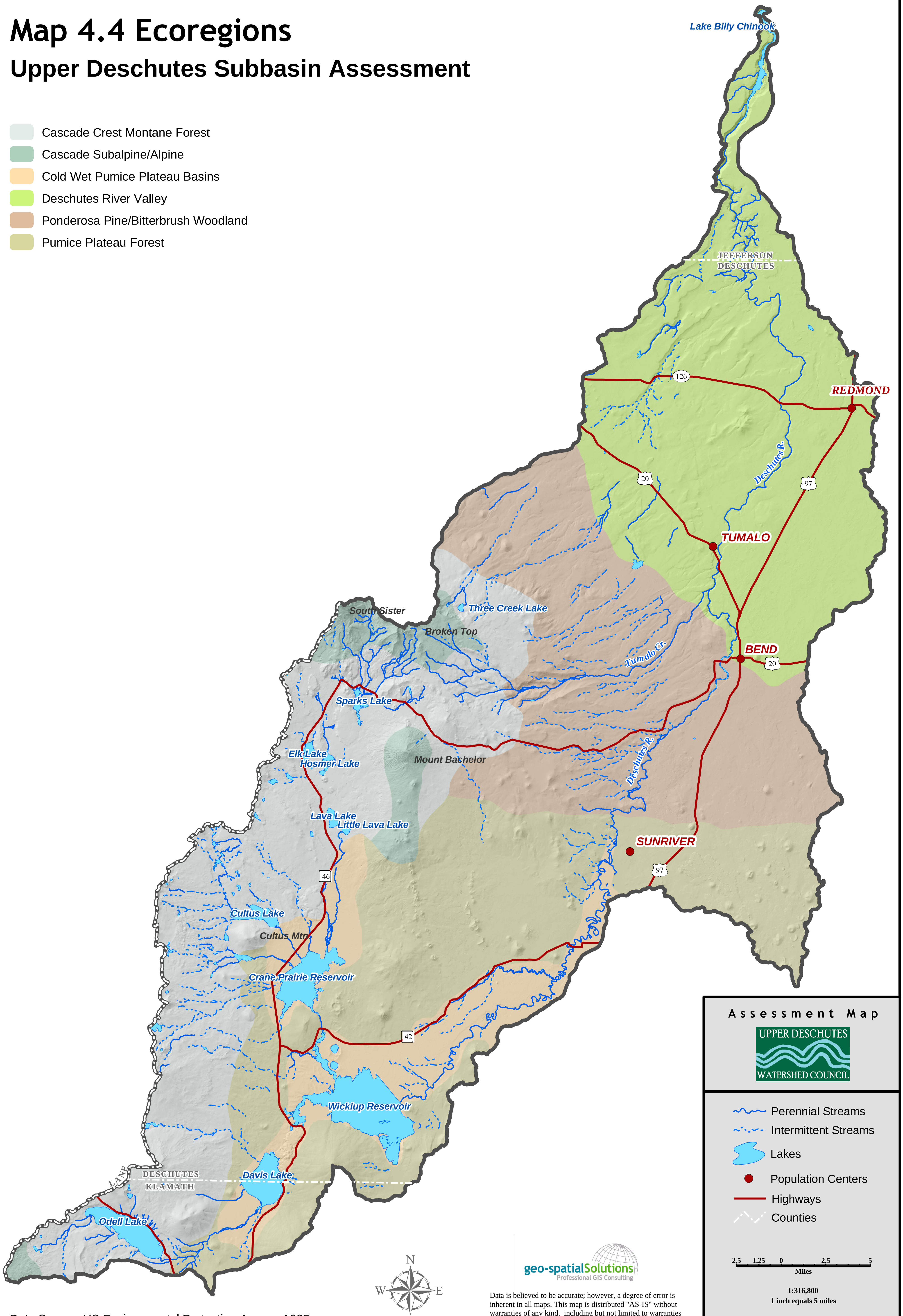
1 inch equals 5 miles

Map 4.4 Ecoregions

Upper Deschutes Subbasin Assessment

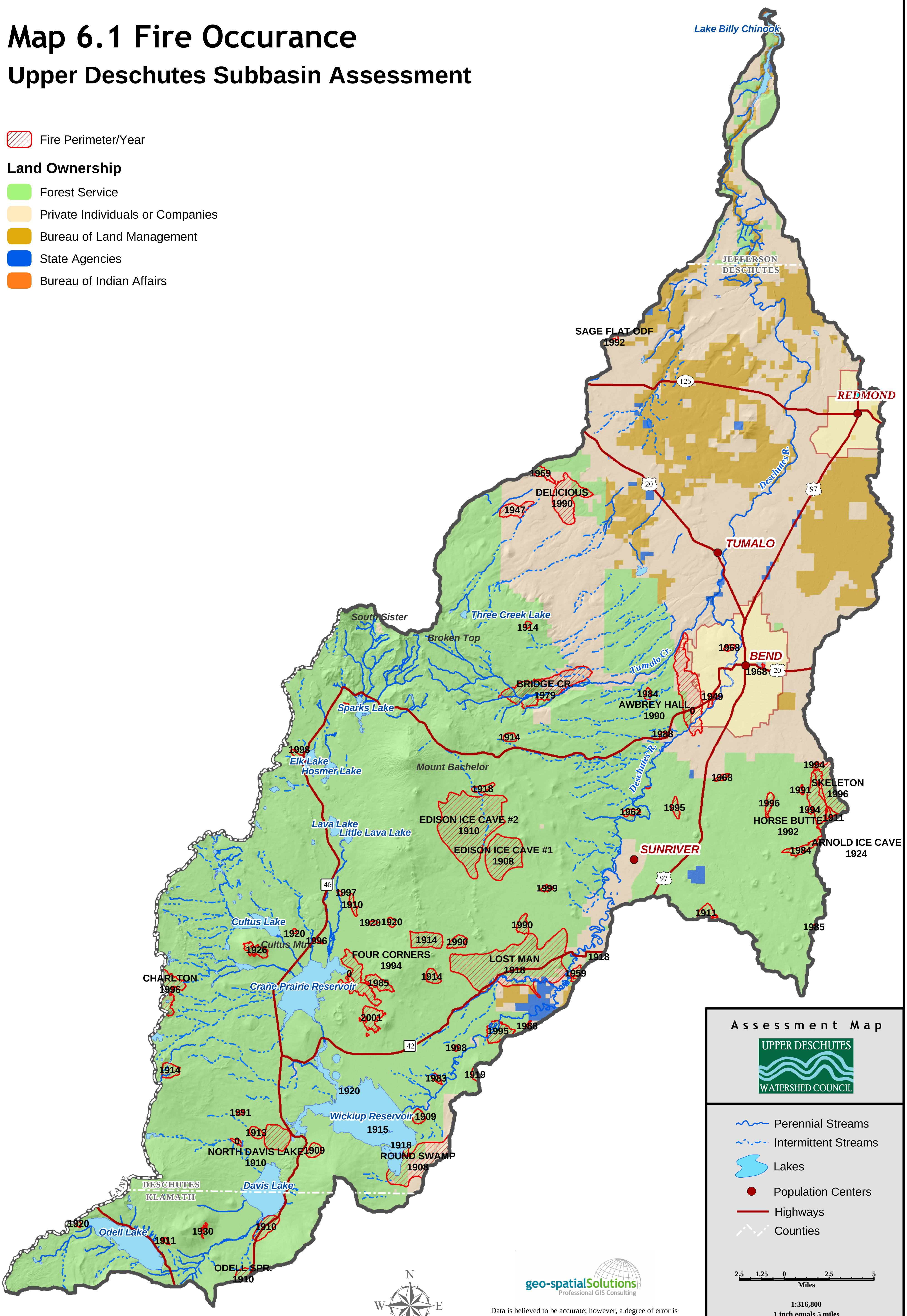


Data Source: US Environmental Protection Agency 1995

Data is believed to be accurate; however, a degree of error is inherent in all maps. This map is distributed "AS-IS" without warranties of any kind, including but not limited to warranties of suitability to a particular purpose or use.

Map 6.1 Fire Occurance

Upper Deschutes Subbasin Assessment



Data Source: Deschutes National Forest 2002

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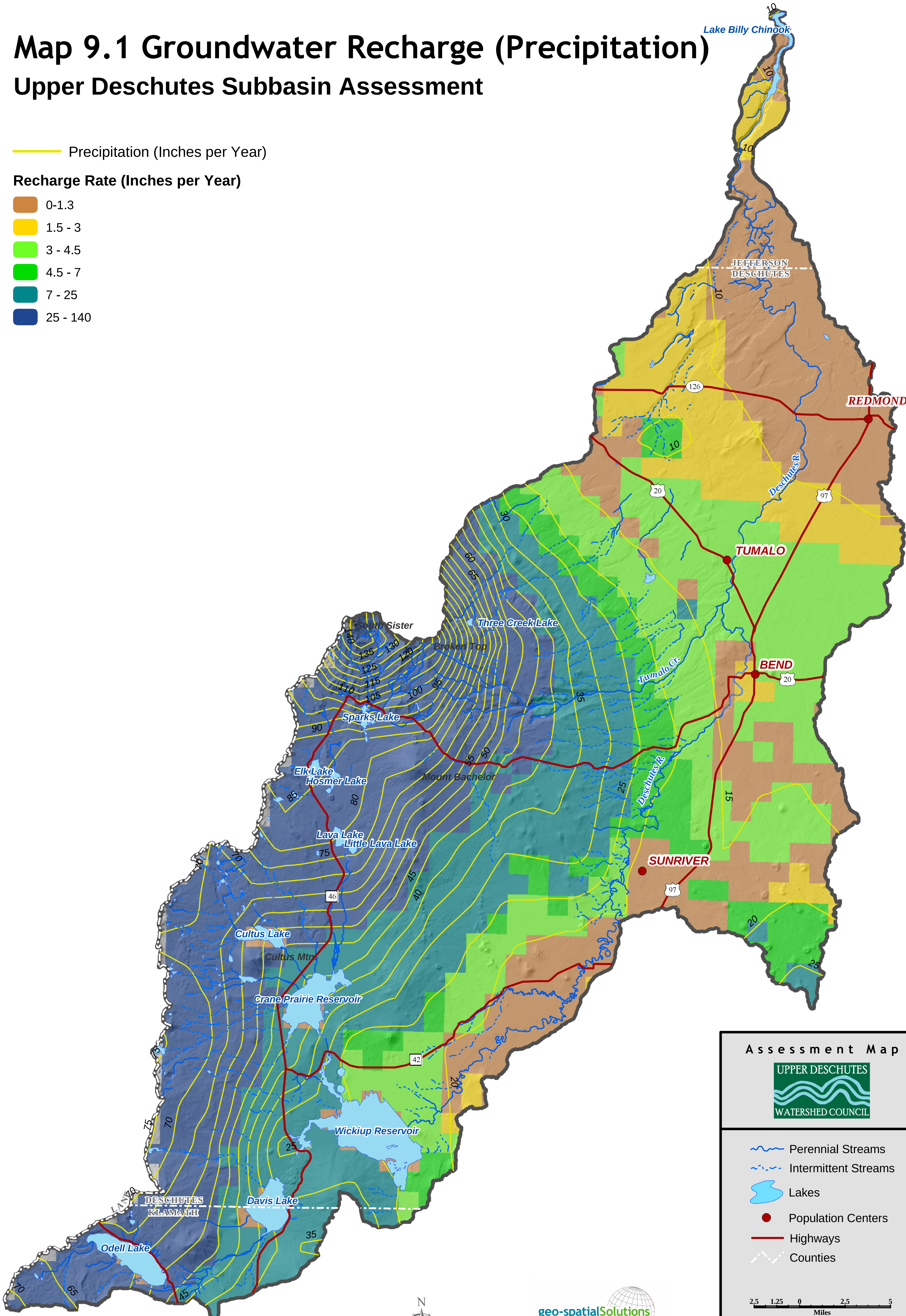
Map 9.1 Groundwater Recharge (Precipitation)

Upper Deschutes Subbasin Assessment

Precipitation (Inches per Year)

Recharge Rate (Inches per Year)

- 0-1.3
- 1.5 - 3
- 3 - 4.5
- 4.5 - 7
- 7 - 25
- 25 - 140



Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

- Perennial Streams
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Professional GIS Consulting

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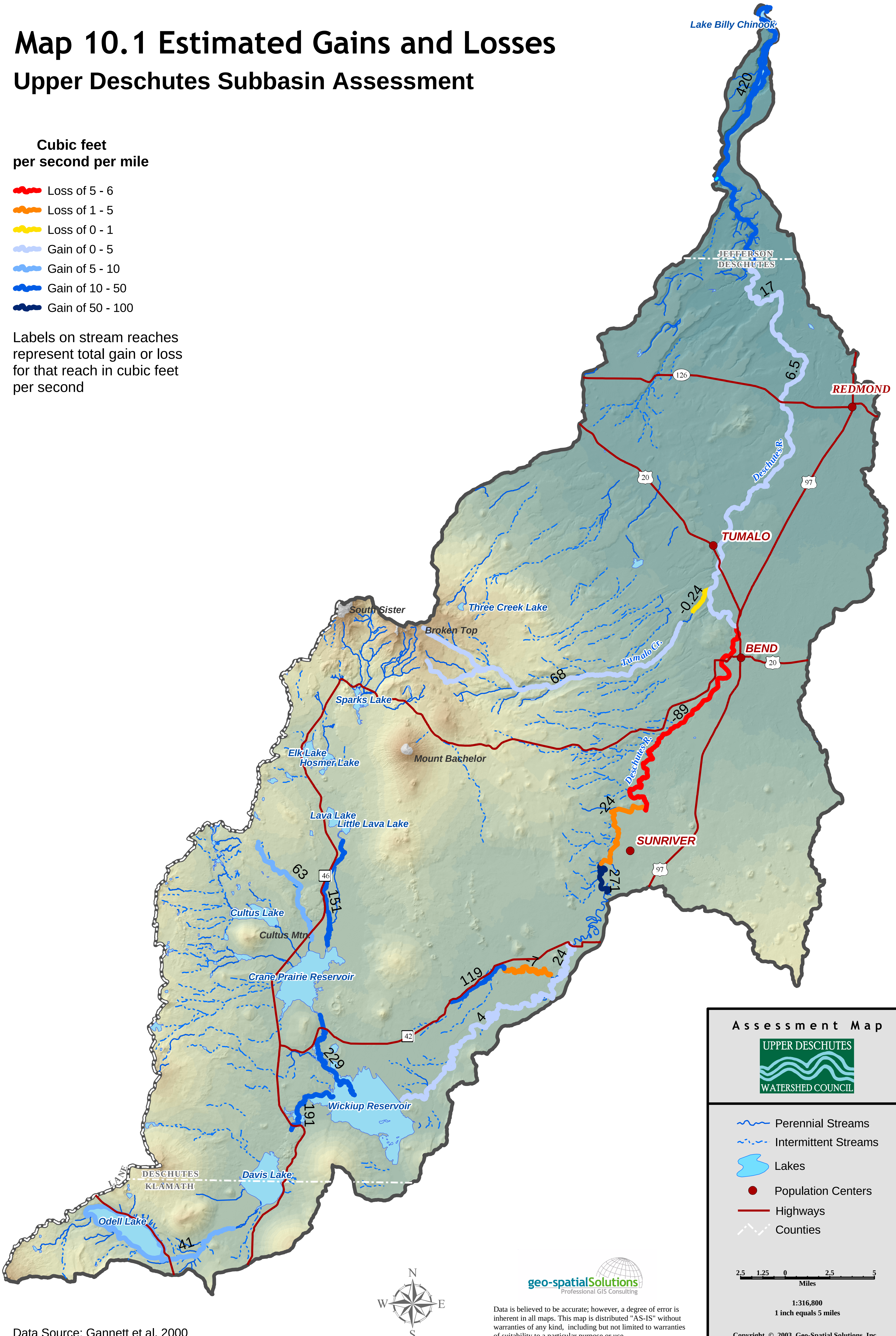
Data Source: Gannett et al. 2000

Map 10.1 Estimated Gains and Losses

Upper Deschutes Subbasin Assessment



Data Source: Gannett et al. 2000

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Map 11.1 2002 303(d) Listed Water Bodies

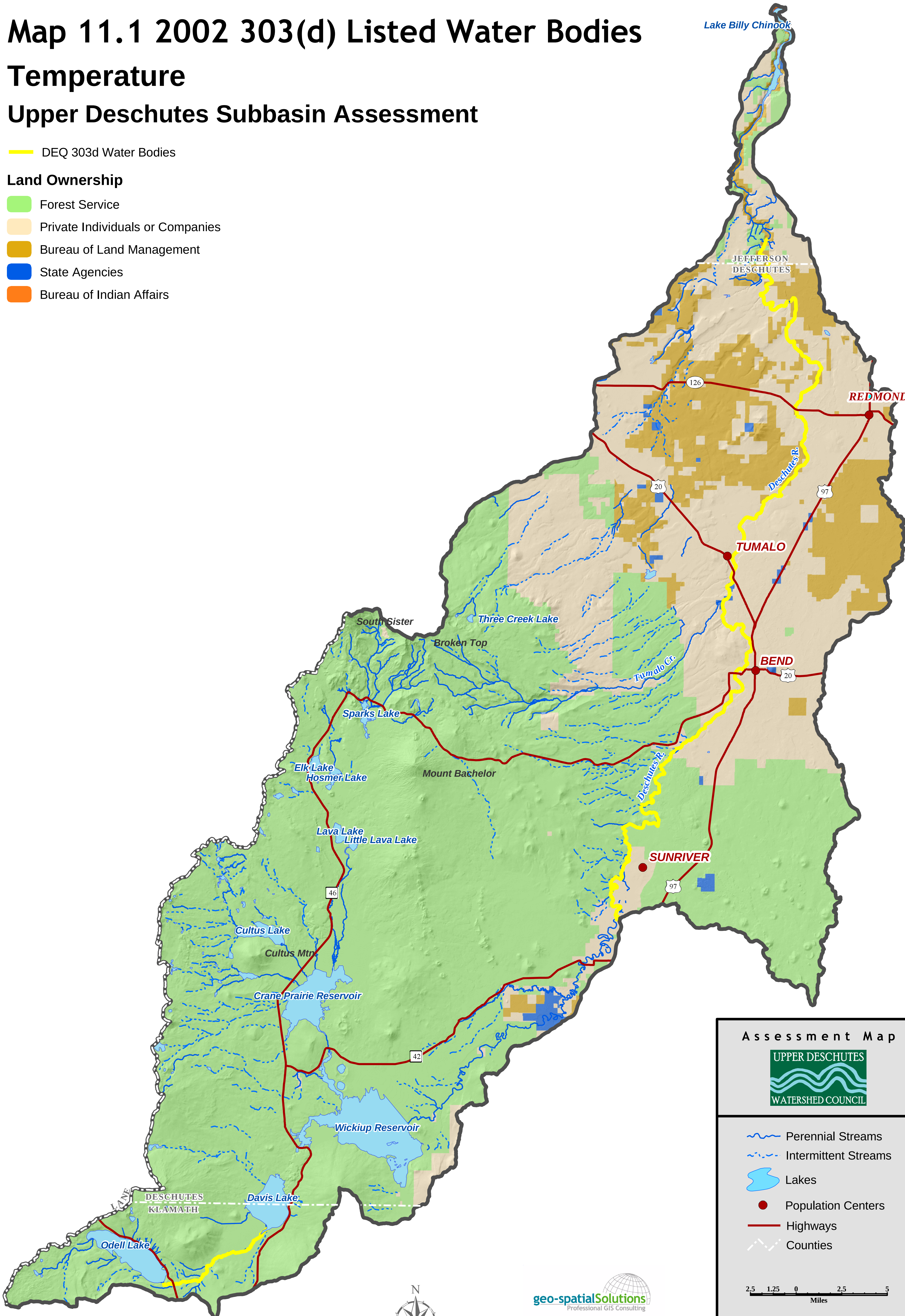
Temperature

Upper Deschutes Subbasin Assessment

DEQ 303d Water Bodies

Land Ownership

- Forest Service
- Private Individuals or Companies
- Bureau of Land Management
- State Agencies
- Bureau of Indian Affairs



Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

- Perennial Streams
- Intermittent Streams
- Lakes
- Population Centers
- Highways
- Counties

2.5 1.25 0 2.5 5
Miles

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Data Source: Oregon Dept. of Environmental Quality 2002

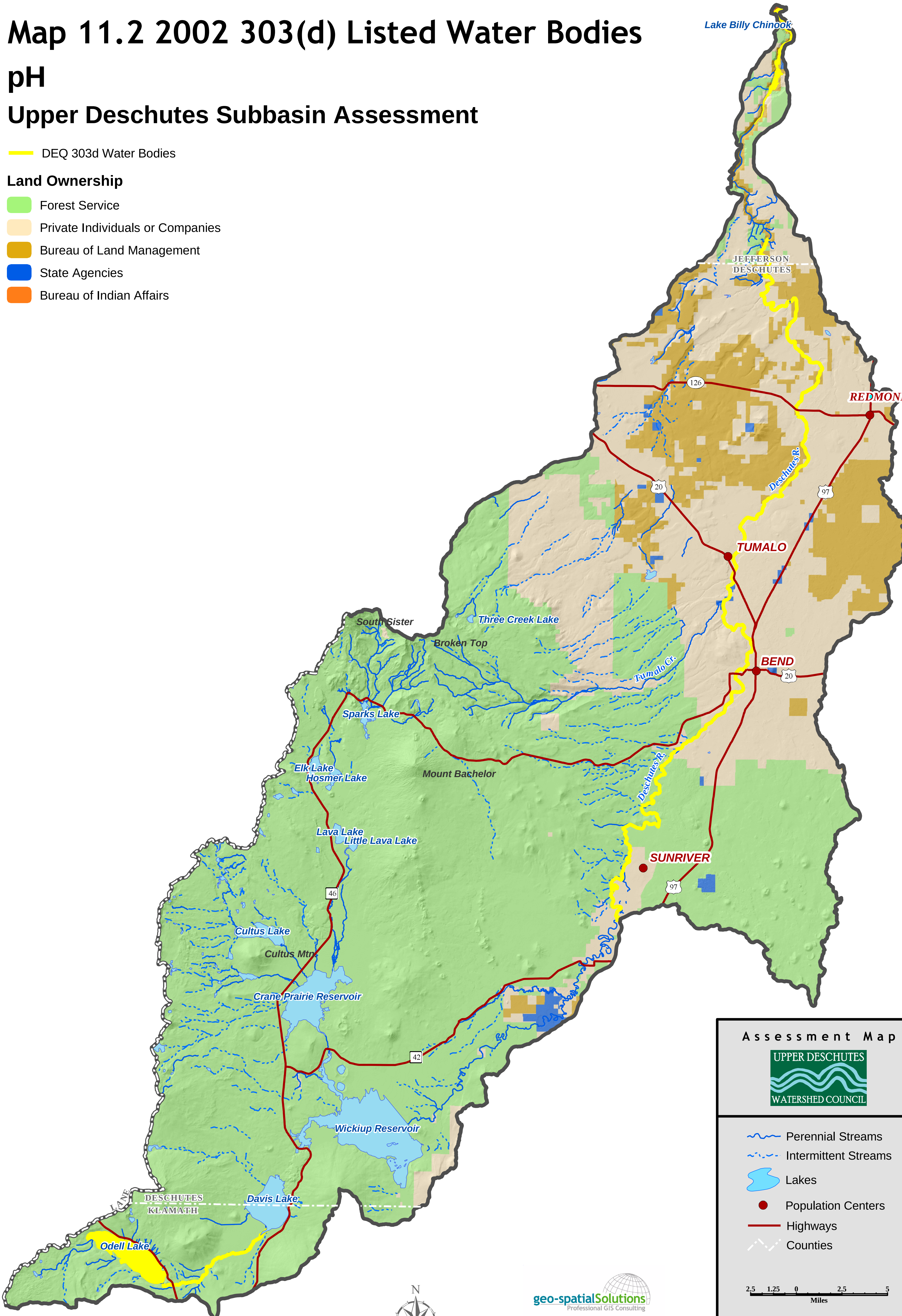
Map 11.2 2002 303(d) Listed Water Bodies
pH

Upper Deschutes Subbasin Assessment

DEQ 303d Water Bodies

Land Ownership

- Forest Service
- Private Individuals or Companies
- Bureau of Land Management
- State Agencies
- Bureau of Indian Affairs



Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

- Perennial Streams
- Intermittent Streams
- Lakes
- Population Centers
- Highways
- Counties

2.5 1.25 0 2.5 5
Miles

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Professional GIS Consulting

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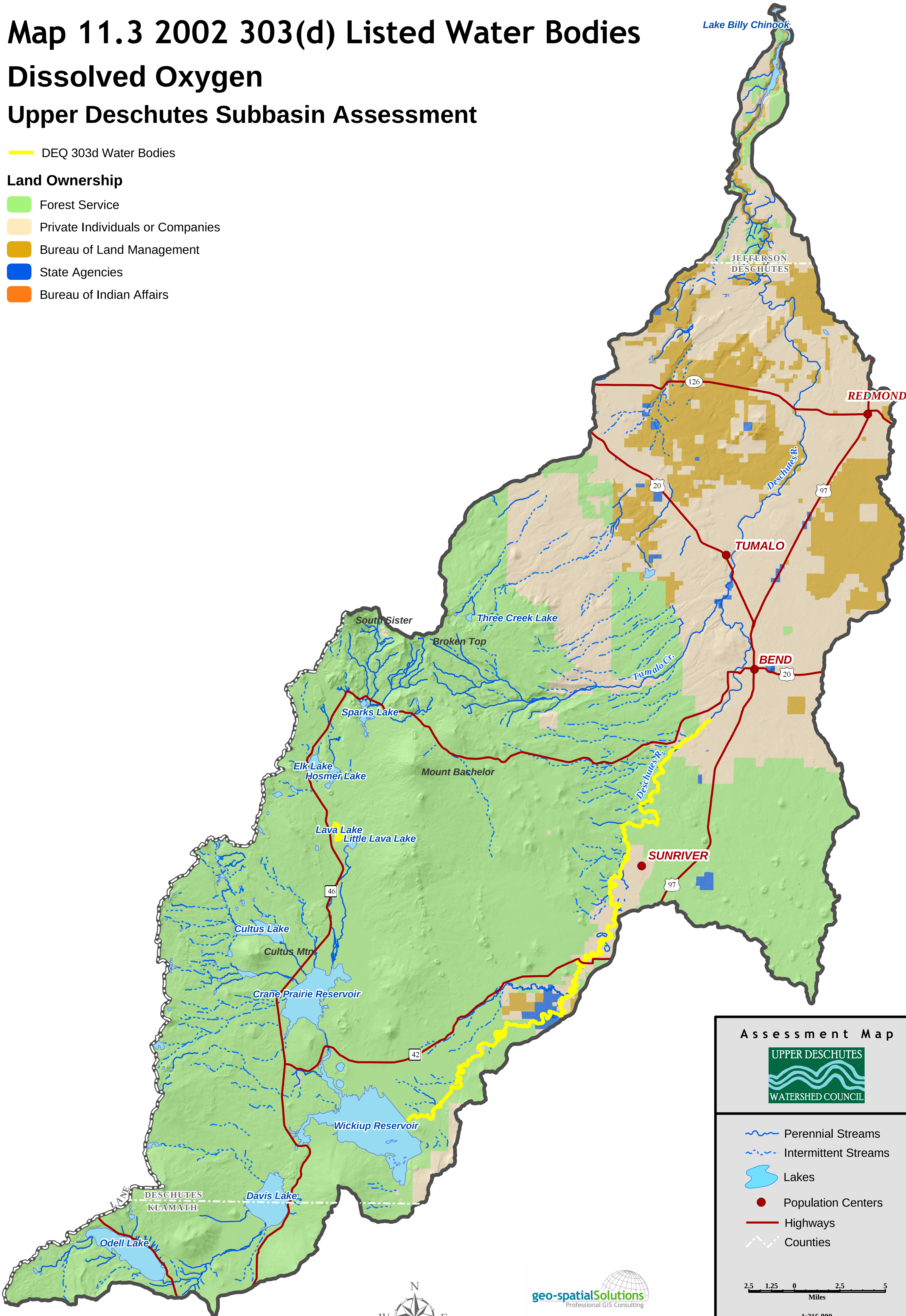
Data Source: Oregon Dept. of Environmental Quality 2002

Map 11.3 2002 303(d) Listed Water Bodies

Dissolved Oxygen

Upper Deschutes Subbasin Assessment

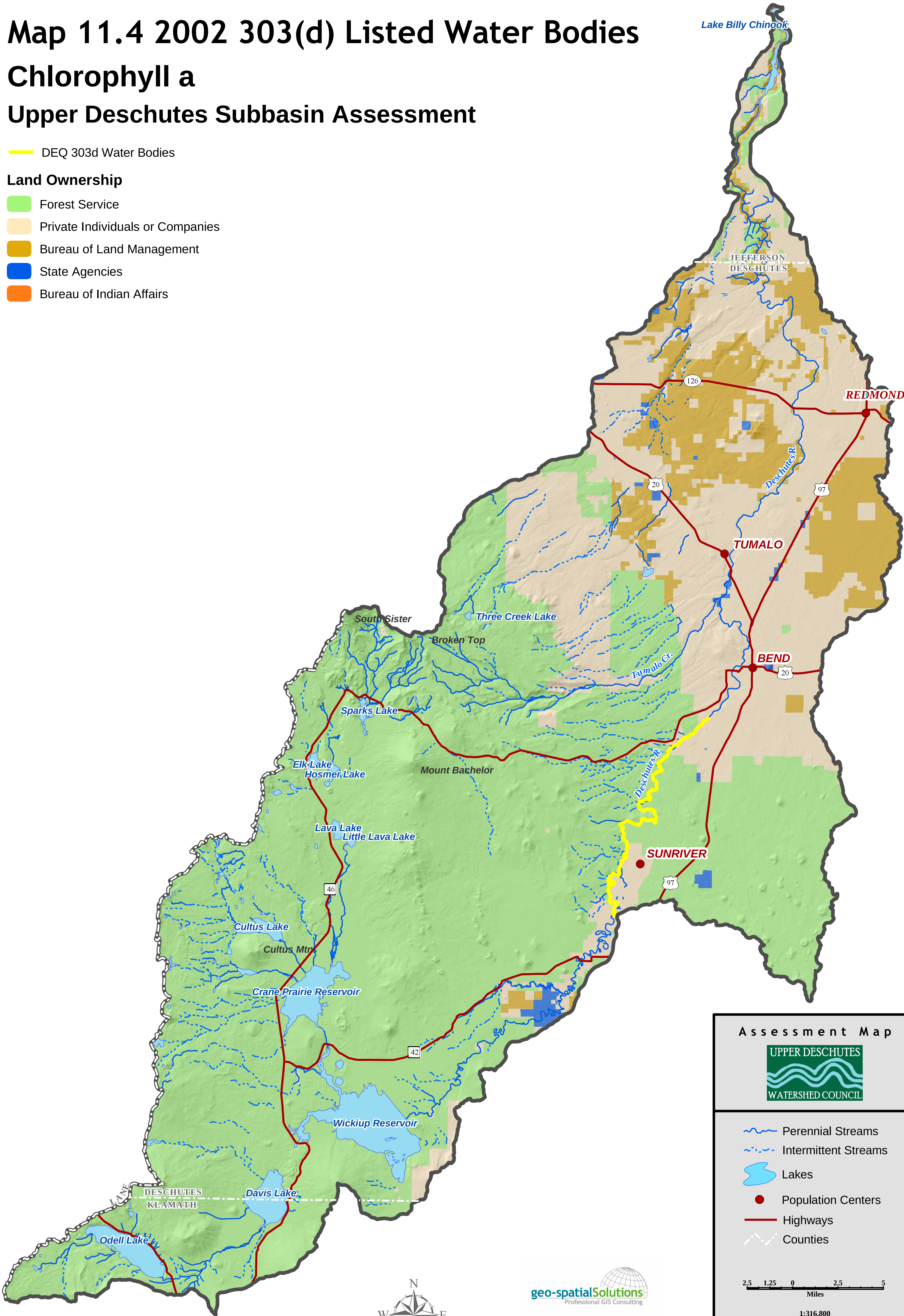


Data Source: Oregon Dept. of Environmental Quality 2002

Map 11.4 2002 303(d) Listed Water Bodies

Chlorophyll a

Upper Deschutes Subbasin Assessment



Data Source: Oregon Dept. of Environmental Quality 2002

Data is believed to be accurate; however, a degree of error is inherent in all maps. This map is distributed "AS-IS" without warranties of any kind, including but not limited to warranties of suitability to a particular purpose or use.

Map 11.5 2002 303(d) Listed Water Bodies

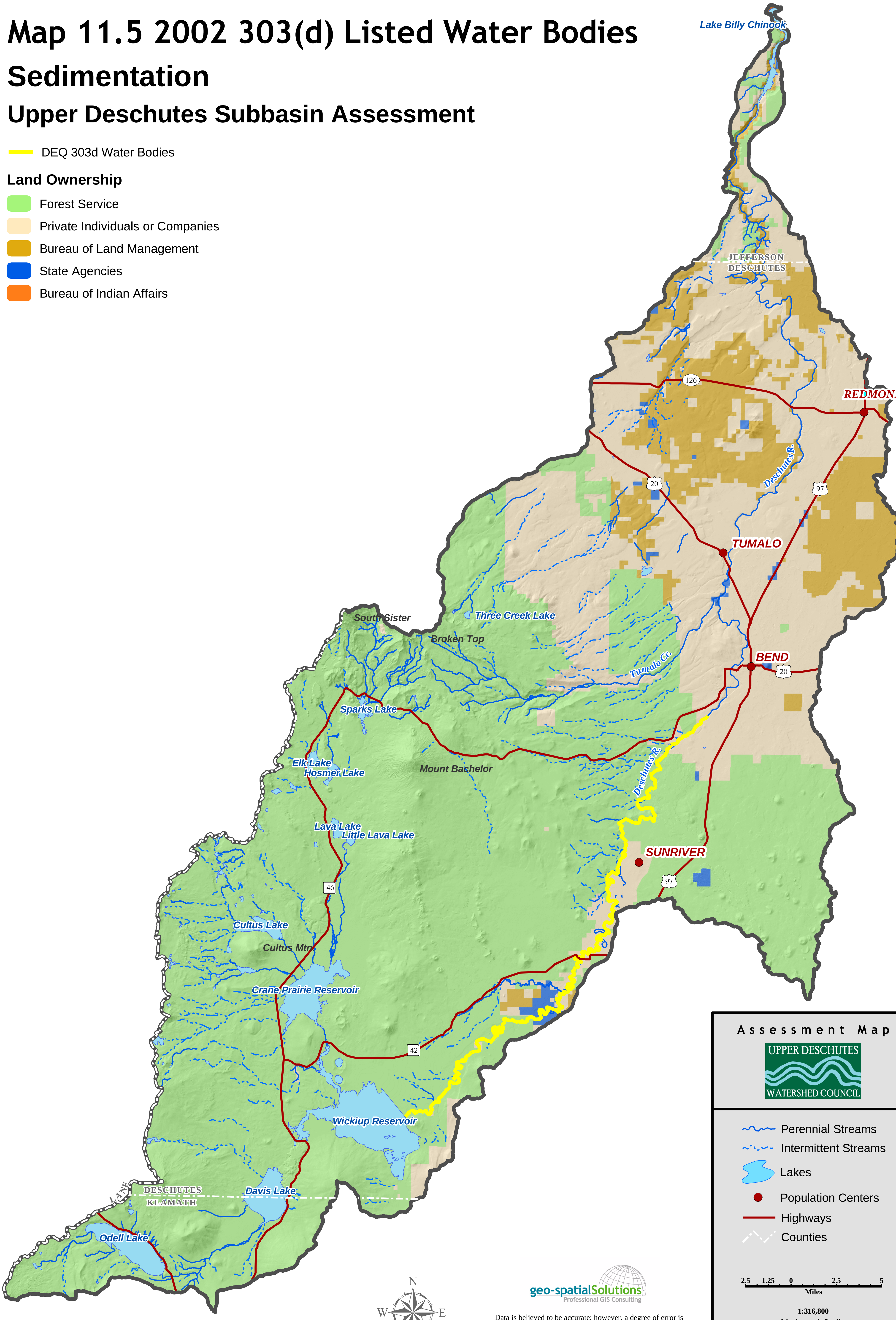
Sedimentation

Upper Deschutes Subbasin Assessment

DEQ 303d Water Bodies

Land Ownership

- Forest Service
- Private Individuals or Companies
- Bureau of Land Management
- State Agencies
- Bureau of Indian Affairs



Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

- Perennial Streams
- Intermittent Streams
- Lakes
- Population Centers
- Highways
- Counties

2.5 1.25 0 2.5 5

Miles

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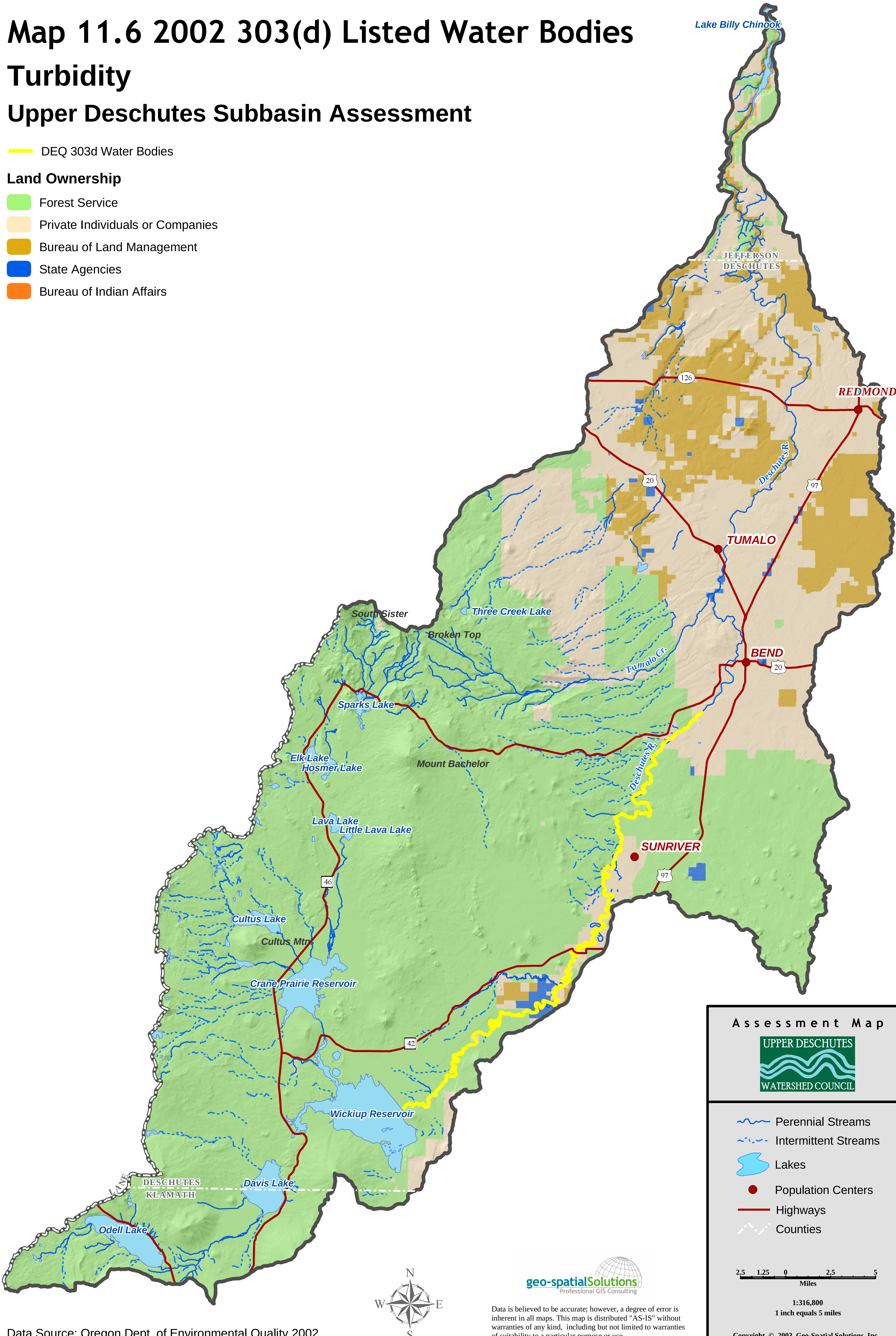
Data Source: Oregon Dept. of Environmental Quality 2002

Map 11.6 2002 303(d) Listed Water Bodies Turbidity

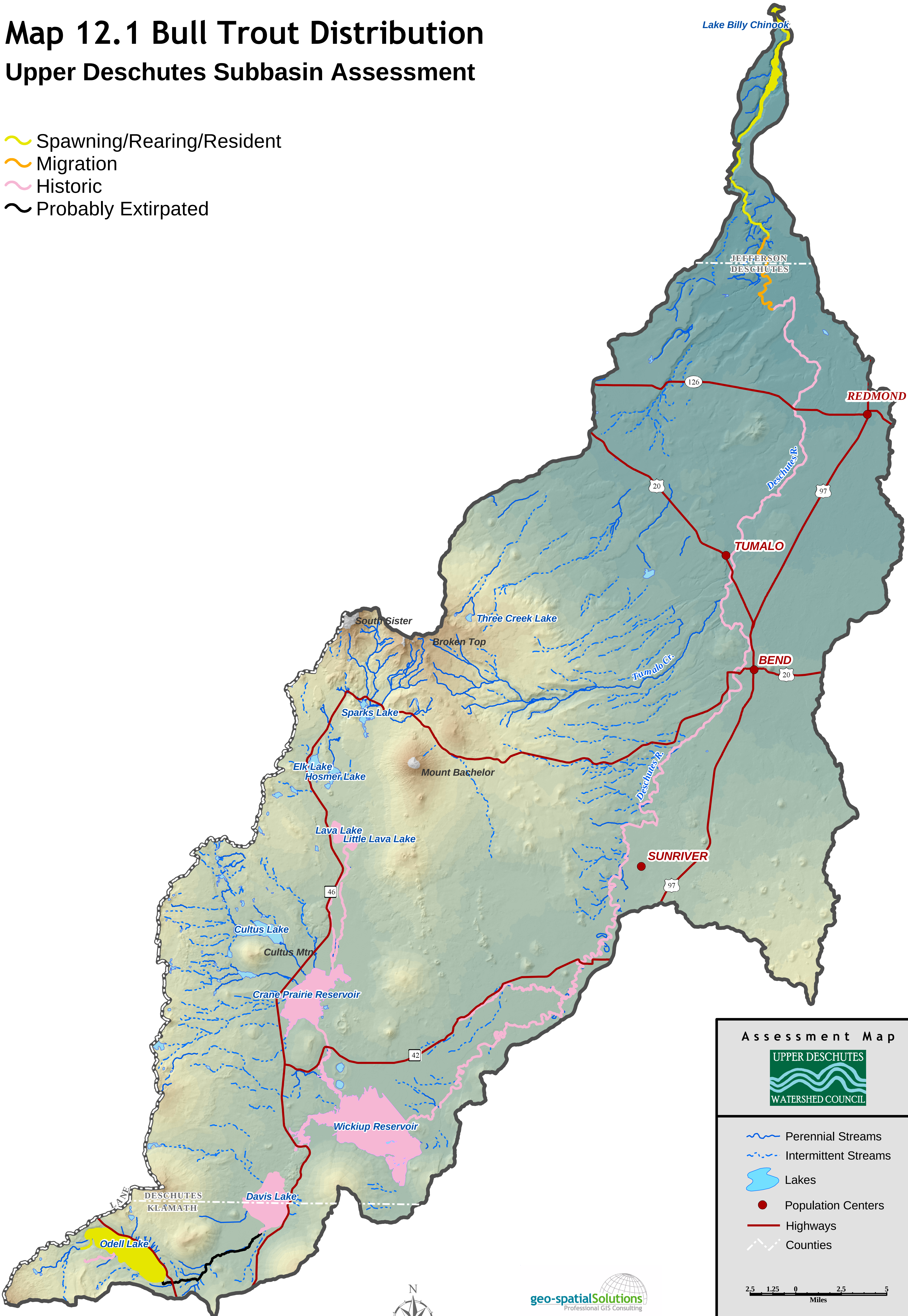
Upper Deschutes Subbasin Assessment



Data Source: Oregon Dept. of Environmental Quality 2002

Map 12.1 Bull Trout Distribution

Upper Deschutes Subbasin Assessment



Data Source: Oregon Department of Fish and Wildlife 1996 Upper Deschutes River Subbasin Fish Management Plan

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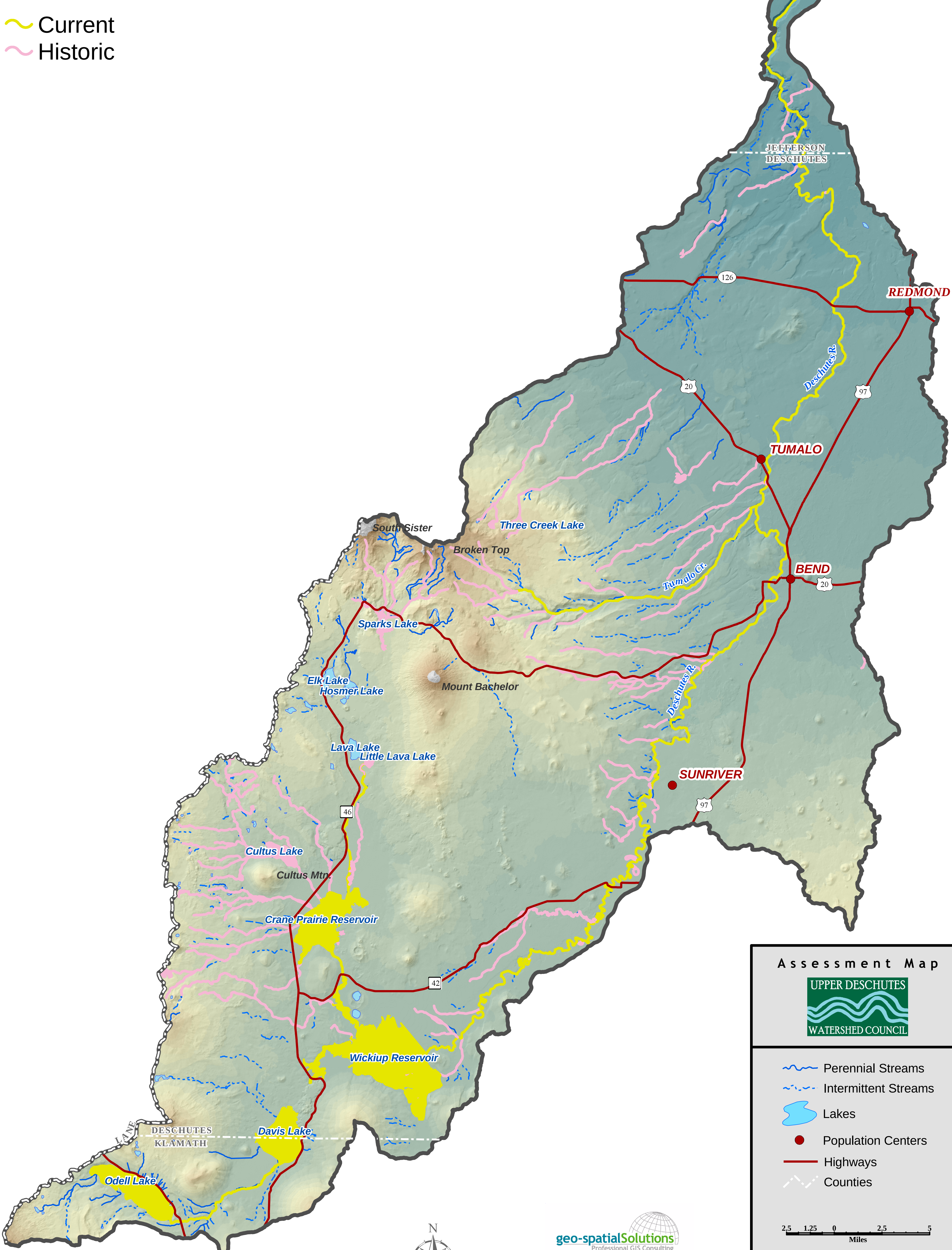
Map 12.2 Redband Trout Distribution

Upper Deschutes Subbasin Assessment



Data Source: Oregon Department of Fish and Wildlife 1996 Upper Deschutes River Subbasin Fish Management Plan

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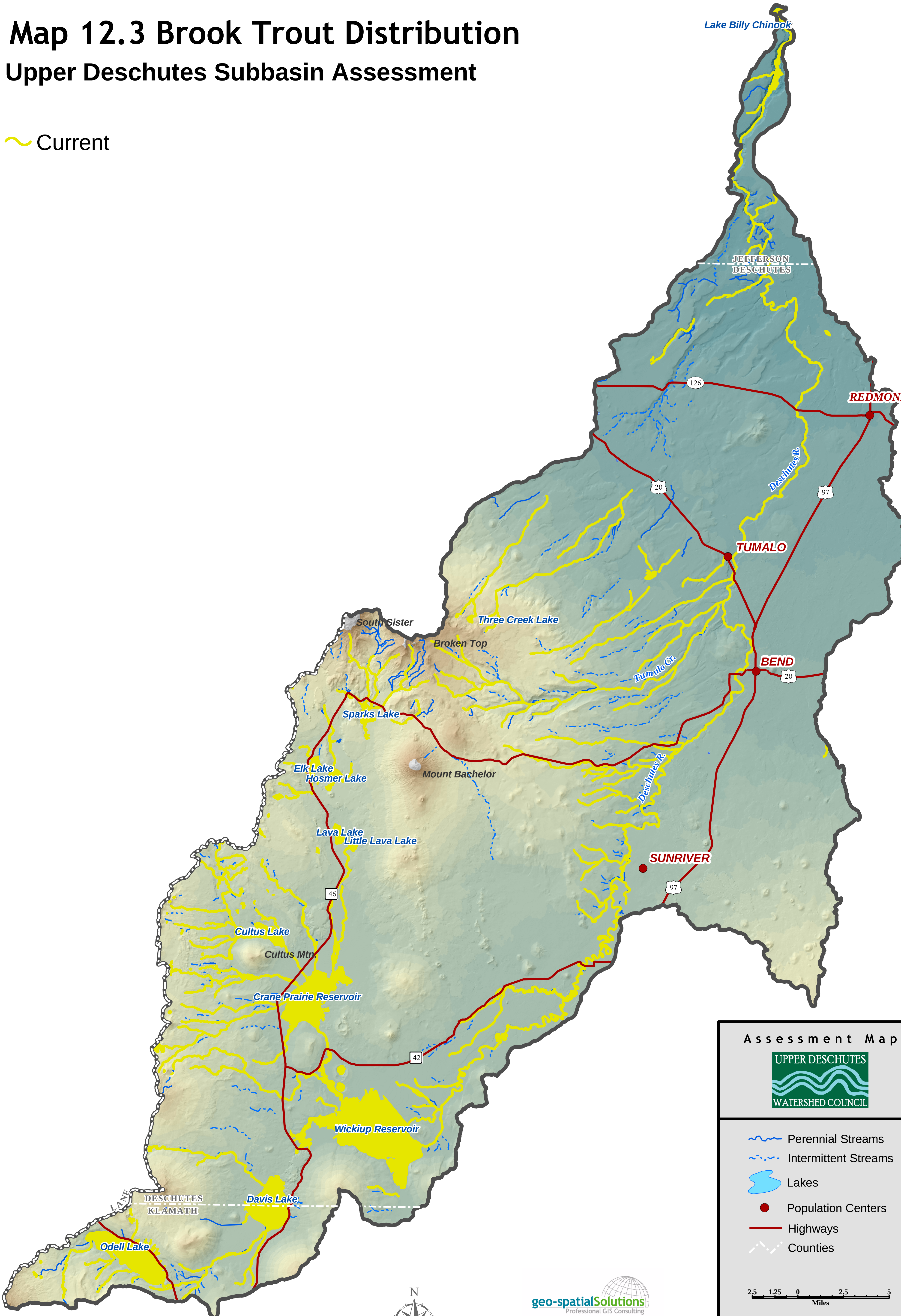
Map 12.3 Brook Trout Distribution

Upper Deschutes Subbasin Assessment

Current



Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

Perennial Streams

Intermittent Streams

Lakes

Population Centers

Highways

Counties

2.5 1.25 0 2.5 5

Miles

1:316,800

1 inch equals 5 miles

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Data Source: Oregon Department of Fish and Wildlife 1996 Upper Deschutes River Subbasin Fish Management Plan

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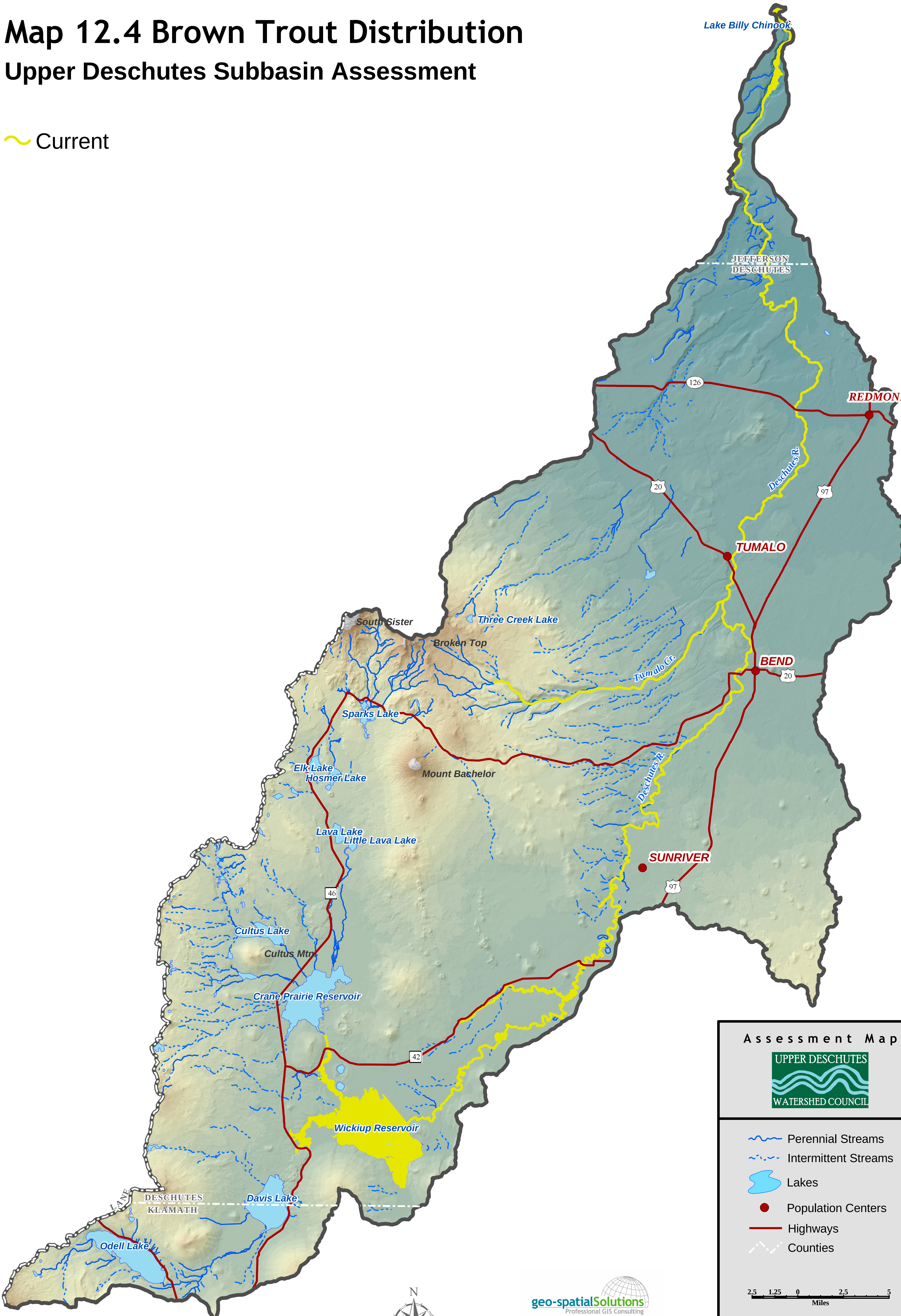
Map 12.4 Brown Trout Distribution

Upper Deschutes Subbasin Assessment

Current



Assessment Map

UPPER DESCHUTES WATERSHED COUNCIL

- Perennial Streams
- Intermittent Streams
- Lakes
- Population Centers
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- Counties

2.5 1.25 0 2.5 5
Miles
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geo-spatialSolutions
Professional GIS Consulting

Data Source: Oregon Department of Fish and Wildlife 1996 Upper Deschutes River Subbasin Fish Management Plan

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