UPPER DESCHUTES WATERSHED COUNCIL

A Review of Water Quality Monitoring in the Upper Deschutes and Little Deschutes Subbasins

2000-2002

Prepared by

Nancy Breuner

EXECUTIVE SUMMARY

This water quality monitoring review report describes the water quality issues present in the Upper Deschutes and Little Deschutes subbasins and summarizes monitoring efforts which are addressing these issues. The report focuses on local monitoring activities conducted during 2000, 2001 and 2002. In the future, as funding allows, a water quality monitoring report will be published on an annual basis to assess subbasin-wide monitoring efforts and discuss key findings or newly arising issues.

The report covers two subbasins: the Upper Deschutes River and the Little Deschutes River. Although the Metolius River is within the Upper Deschutes subbasin, it is not included in this report. The two subbasins span approximately 1.6 million acres and include over 1,800 miles of rivers and tributaries. Many of these streams and rivers violate Oregon water quality standards for temperature, dissolved oxygen, pH, chlorophyll a, sedimentation and turbidity, are listed as impaired under the federal Clean Water Act and are found on the state's 2002 303(d) list.

In 2000-2002, ten agencies and local partners conducted thirty-one monitoring activities throughout the study area. This provided data to evaluate trends and conditions in eleven types of water quality related parameters that may affect fisheries and aquatic life. This data is essential to local natural resource management agencies to address specific research needs or evaluate local management changes.

By summarizing region-wide monitoring activities, this monitoring review report and subsequent annual reports will help to strengthen the communication and collaboration among monitoring entities which is necessary for a regionalized and integrated long-term water quality monitoring program. By describing on-going monitoring activities, this review of "who is doing what, where and why" will also serve as an outreach tool to interested community members and stakeholders. Lastly, this report is intended to show the benefits and uses of the information gathered from an integrated long term monitoring program.

TABLE OF CONTENTS

FIGURES

TABLES

APPENDIX A

ACKNOWLEDGMENTS

Upper Deschutes Water Quality Monitoring Committee:

Member	Affiliation
Ryan Houston	UDWC
Bonnie Lamb	ODEQ
Kyle Gorman	OWRD
Jonathan LaMarche	OWRD
Michele McSwain	BLM, Prineville
Larry Zakrajsek	BOR
Mollie Chaudet	USFS, Bend/Fort Rock Ranger District
Marc Wilcox	USFS, Deschutes National Forest
Louis Wasniewski	USFS, Deschutes National Forest
Ted Wise	ODFW

Other Contributors:

Nate Dachtler	USFS, Deschutes National Forest
Tom Walker	USFS, Bend/Fort Rock Ranger District
Wayne Skladal	OWRD
Scott Lewis	PGE
Jim Seymour	USFS, Ochoco National Forest
Roger Prowell	Public Works, City of Bend
Kolleen Yake	UDWC

1.0 INTRODUCTION

1.1 Purpose

The purpose of this water quality monitoring review report is to describe the water quality issues present in the Upper Deschutes and Little Deschutes subbasins and to summarize existing monitoring efforts. The report will focus on local monitoring activities conducted during 2000, 2001 and 2002. In the future, as funding allows, a water quality monitoring report will be published on an annual basis to assess subbasin-wide monitoring efforts and discuss key findings and new issues.

This report will provide the Upper Deschutes Watershed Council (UDWC) and its partners with an important outreach and planning tool. The report will help stakeholders, interested community members and potential granting sources increase their awareness and understanding of water quality conditions and the benefits of monitoring activities within the Upper Deschutes and Little Deschutes subbasins.

Since the initiation of the UDWC's regional water quality monitoring program in 2001, there have been improvements in communication and cooperation among local monitoring entities. Many redundancies, gaps and inconsistencies in monitoring efforts have been identified and are being rectified. By summarizing region-wide monitoring activities on a yearly basis, it is hoped that this monitoring review report and subsequent reports will help to strengthen the partnerships necessary for a successful integrated long-term water quality monitoring program.

One immediate result of the regional water quality monitoring program has been the compilation and analysis of water quality data and the subsequent development of two technical water quality reports (Breuner, 2003a, 2003b). One report describes the results of temperature data analyses and the second report describes other water quality parameters of concern within the two subbasins. It is hoped that this review report will augment the technical reports by describing some of the recent monitoring activities which have provided the data used for these analyses.

1.2 Study Area

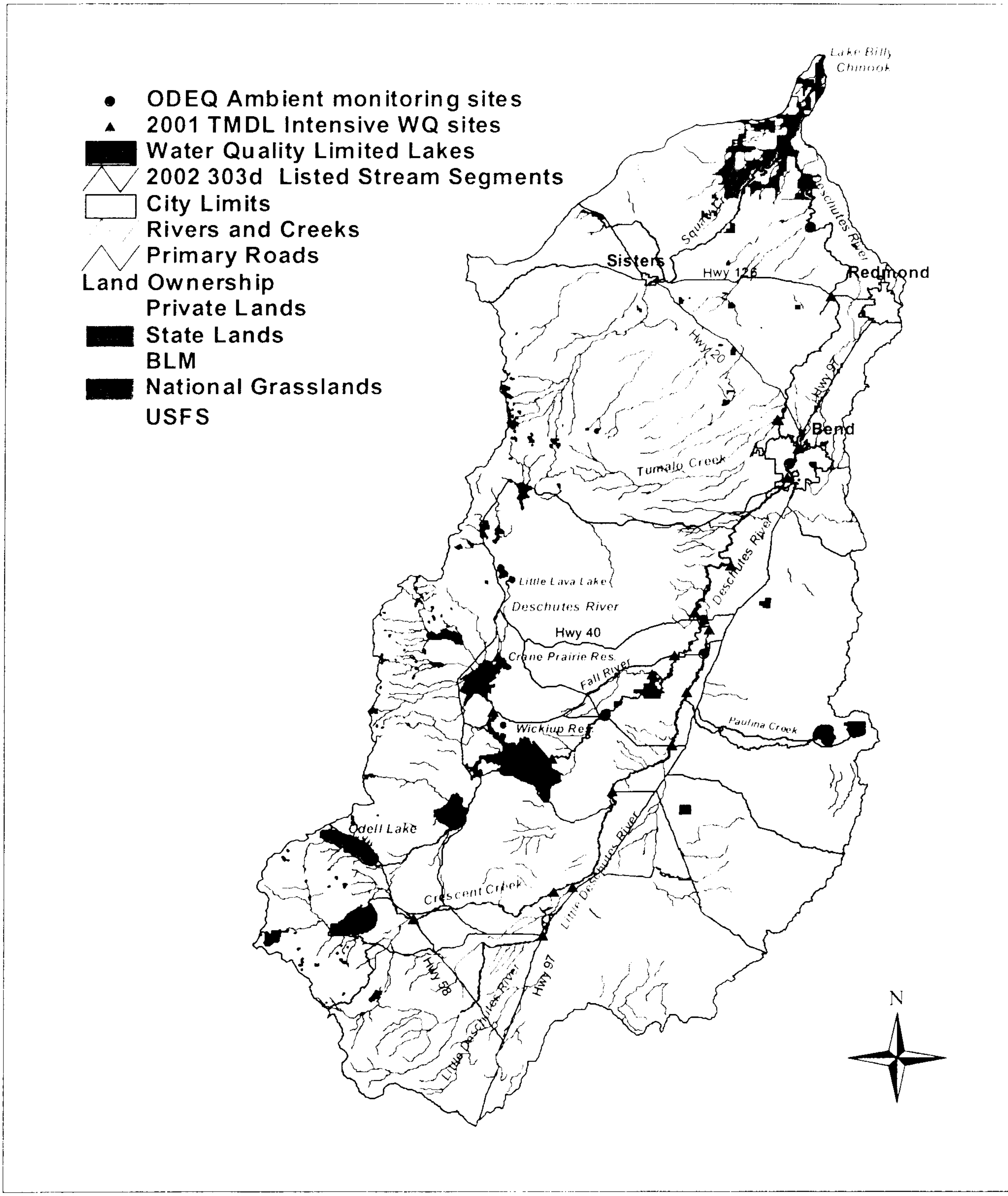
This water quality review report covers two subbasins: the Upper Deschutes River and the Little Deschutes River. Although the Metolius River is within the Upper Deschutes subbasin, it is not included in this report. Approximately 63% of the land in the two subbasins is within the Deschutes National Forest, 27% is in private ownership, 5.5% is managed by the Bureau of Land Management, 3% is owned by the Confederated Tribes of the Warm Springs Reservation and the remaining 1.5% is managed either by the State or the Crooked River National Grasslands. There are several urban areas, including Bend, Redmond, Sisters and La Pine. Major land uses include irrigated agriculture, livestock pastureland and dairies, urban/residential/industrial lands and recreational areas especially within the region's federally managed lands (Anderson, 2000).

Most streams within the two subbasins are greatly affected by water storage and withdrawals via canals and other water diversions. There are three reservoirs (Wickiup, Crane Prairie and Crescent Lake) which are used to store water for irrigation purposes. Management of these reservoirs can greatly influence the amount of water flowing in the Little Deschutes and Upper Deschutes rivers. Flow management decisions (e.g. the quantity and duration of water releases from the reservoirs) are generally based on demand and annual precipitation. These management decisions may have significant localized impacts on water quality depending not only on the amount of flows released or withdrawn but also on the timing and the duration of these releases and withdrawals.

At the bottom of the Upper Deschutes system, the Deschutes River drains into Lake Billy Chinook, a reservoir which is managed mainly for hydropower and recreational uses.

Figure 1 shows a map of the two subbasins and includes major land ownership, cities, major roads, streams and those water bodies which violate state water quality standards.

Figure 1. Upper Deschutes and Little Deschutes subbasins.



The two subbasins span approximately 1.6 million acres and include over 1,800 miles of rivers and tributaries. Many of these streams violate Oregon water quality standards for temperature, dissolved oxygen, pH, chlorophyll a, sedimentation and turbidity, are listed as impaired under the federal Clean Water Act and are found on the state's 2002 303(d) list. Total Maximum Daily Loads (TMDLs) are being developed by Oregon Department of Environmental Quality (ODEQ) for these parameters as required by the federal Clean Water Act (Lamb, et al, 2001). Many of the monitoring efforts during 2000 and 2001 were conducted by ODEQ in partnership with local natural resource agencies to provide the water quality data needed to develop the TMDLs.

1.3 Framework for Regional Coordinated Monitoring

Water quality monitoring in the Upper Deschutes and Little Deschutes subbasins has been conducted by a variety of federal, state and local organizations for several years and for a multitude of purposes. Until recently these monitoring activities had not been coordinated and regionalized. This resulted in an inefficient system with data gaps, duplication of effort, inconsistent monitoring protocols and lack of communication and sharing of data.

The Upper Deschutes Water Quality Monitoring Committee was formed several years ago to identify water quality issues, provide information about past and current monitoring activities, improve local monitoring efforts and finally to develop a subbasin-wide coordinated monitoring strategy. The Committee includes representatives from state and federal agencies and the Upper Deschutes Watershed Council.

Ten organizations conduct some type of water quality related monitoring in the region. Stream temperatures and water flows are the most common measurements taken. Flows have been measured since the early 1900s by the Oregon Department of Water Resources, as part of its management of water rights. The most consistent long term water quality monitoring program in the area is conducted by Oregon Department of Environmental Quality at five sites as part of its state-wide Ambient Monitoring Program. The City of Bend has consistently monitored its Bridge Creek site for several years for drinking water protection. Portland General Electric has collected basic field parameters since 1994 at a single site, at the inflow to Lake Billy Chinook, as part of its hydropower management requirements. The other organizations have conducted numerous short term data collection projects to address specific research needs or evaluate local natural resource management changes.

To improve the efficacy of these varied monitoring programs, the US Geological Survey (USGS) was contracted by the Upper Deschutes Watershed Council to develop the *Framework for Regional, Coordinated Monitoring in the Middle and Upper Deschutes River Basin, Oregon (USGS Report 00-386)*, ("Regional Framework") published in 2000. This Regional Framework described water quality issues in the basin and the existing monitoring programs in place before 2000. The Framework then gave specific suggestions and recommendations for a phased approach to improve future long-term water quality monitoring. The Upper Deschutes Watershed Council (UDWC) entered into a Memorandum of Understanding (MOU) with Oregon Department of Environmental Quality (ODEQ), Oregon Water Resources Department (OWRD), Oregon Department of Fish and Wildlife (ODFW), U.S. Forest Service (USFS), Bureau of Land Management (BLM) and Bureau of Reclamation (BOR) to implement the recommendations given in the Regional Framework.

With funding from Oregon Watershed Enhancement Board (OWEB) and ODEQ's 319 nonpoint source grant program, the UDWC was able to develop the Upper Deschutes Water Quality Monitoring Program to implement a regional water quality monitoring strategy. The primary purpose of the program is to provide high quality, scientifically valid data to evaluate the status and trends of water quality related resources within the two subbasins. The goals of the program are: 1) to understand the condition of a resource or changes in the status of critical parameters over time, 2) to determine whether local conditions meet established criteria, standards or reference levels, and 3) to assess the effects of land use or effectiveness of changes in resource management. The Upper Deschutes Water Quality Monitoring Committee currently serves in an advisory role for the program.

1.4 Water Quality Issues

Water quality is affected by many factors: natural background levels of nutrients and sediment, soil types, hydrology, geomorphology, flows 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 in some streams and lakes. These conditions have resulted in the listing of many stream segments on the state's water quality impaired 303(d) list.

The primary issues of concern identified in the Regional Framework were: water quantity (stream flow), water temperature, pH, dissolved oxygen, turbidity and sediment transport, nutrients, bacteria, and the physical status of channel configuration and habitat for aquatic biota (Anderson, 2000). These issues are discussed in further detail below.

Stream Flow

As was mentioned previously, stream flows in the Deschutes River, many of its tributaries and the Little Deschutes River are actively managed year-round. Surface water is stored in Crescent Lake, Crane Prairie and Wickiup reservoirs during the winter months to ensure sufficient water quantities for summer irrigation purposes. Because of this storage, there are extremely low flows in the streams below the reservoirs during the winter months. However, during the irrigation season when water is released from the reservoirs, the rivers exhibit very high flows above diversion points. In many streams with large diversions, reaches downstream of the point of diversion usually experience extremely low flows throughout the irrigation season.

These high and low flow extremes can impact both the geomorphology and the biological integrity of the affected streams. Streambeds and stream banks can become exposed during the winter. When large amounts of stored water are released from the reservoirs in the spring, sedimentation and turbidity can increase due to erosion from freeze and thaw action on the exposed stream banks. Riparian vegetation can lose its connection to a continuous water source (Yake, 2003). Fish and macroinvertebrate habitat can be reduced during low flows and fish redds can be exposed to near freezing stream temperatures.

An example of these fluctuating stream flows is described as follows. During 2002, the mainstem Deschutes River below Wickiup Reservoir had a mean daily flow measurement of 33 cfs during the winter months of December, January and February. During the summer months of June, July and August, the river's flows increased to a mean daily value of 1,370 cfs. However, below Bend, downstream of the major water diversions, the mainstem of the Deschutes River showed the opposite situation of low and high flows. The Deschutes River in this reach had a mean daily flow of 457 cfs in the winter and a mean daily flow of 46 cfs during the summer.

There are target minimum streamflows within the two subbasins which are set by OWRD depending on a combination of water rights, agreements among irrigation districts, instream leases and aquatic habitat needs. The instream water rights for some of the most severely depleted reaches are of such a junior priority that, especially during drought years, these instream rights often have little effect in actually increasing flows. Other natural resource agencies, specifically ODFW, USFS and BLM, have recommended minimum streamflow targets (which are higher than OWRD administered flows) to protect fish and wildlife habitat and Wild and Scenic River designation but these targets are also rarely met due to the existing senior water rights.

Water Temperature

The growth and survival of aquatic organisms is affected by the surrounding water temperature. All aquatic species have temperature 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, the amount of dissolved oxygen available in water is reduced as water temperature increases, and this reduced oxygen can lead to stress or eventual death. Temperature increases the sensitivity of organisms to toxic wastes, parasites, and diseases and temperature also affects photosynthesis by aquatic plants (EPA, 1997).

Water temperature is typically measured using monitoring devices deployed in the water column which take continuous readings at pre-determined intervals throughout the monitoring season. Temperature can be measured in either degrees of Fahrenheit (°F) or Celsius (°C).

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. In some stream reaches within the two subbasins, fluctuating water withdrawals and diversions also impact downstream temperatures. Seasonal fluctuations are a response to changes 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 measured during the summer months from June through September, thus temperature monitoring is usually focused during these months. However, water temperatures may be monitored during other seasons as natural resource agencies examine potential temperature impacts during salmonid spawning, for example.

Some causes of increased water temperature include: the removal of streambank (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 temperature can decrease as a result of groundwater inflows (springs), the inflow of cooler tributaries, and cooling water discharges.

ODEQ has set general numeric criteria for water temperatures to protect the most sensitive beneficial uses in the Deschutes Basin, which is identified as: Salmonid Fish Rearing and Salmonid Fish Spawning and native bull trout viability. The numeric criteria are: the maximum temperature to protect salmonid fish rearing is a seven day average of the daily maximum temperature of 64°F (17.8°C). The maximum temperature to protect salmonid fish during spawning (generally September 1 to June 30) is a seven day average of the daily maximum temperature of 55°F (12.8°C). In those water determined by ODEQ to support, or to be necessary to maintain, the viability of native Oregon bull trout, the numeric criterion is a daily maximum of 10.0°C (50°F).

The mainstem of the Deschutes River, from above Steelhead Falls upstream to Sunriver, is listed for exceeding the temperature criterion for salmonid fish spawning. Most of this same reach, from above Steelhead Falls to Bend, is also listed for exceeding the temperature criterion for salmonid rearing. Part of Squaw Creek, a tributary of the Deschutes River is listed for exceeding both the rearing and spawning temperature criteria. Eleven miles of Indian Ford Creek, a tributary of Squaw Creek, are listed for exceeding the rearing criterion. Twenty-four river miles of the Little Deschutes River and the entire length of two tributaries, Paulina Creek and Crescent Creek, are listed for exceeding the rearing criterion. The same reach of the Little Deschutes River is also listed for exceeding the spawning criterion. Eleven miles of Odell Creek are also listed for exceeding both the rearing and spawning criteria.

pH

pH is a measure of the hydrogen ion concentration, 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 8.0. Water pH can impact both aquatic insect populations and salmonids by affecting egg and embryo development and egg hatching. The pH of water also affects the availability and toxicity of certain pollutants such as heavy metals and ammonia.

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. Seasonal fluctuations in pH are due to the differences in the photosynthetic activity of aquatic plants, with highest production during the summer and low or no production during the winter.

pH values can be altered by increased aquatic plant growth due to excessive nutrients introduced into the aquatic system from a variety of human sources. These sources include nutrients from failing septic systems, agricultural runoff, stormwater runoff or from 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 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. These ranges are set to protect the beneficial uses of Resident Fish and Aquatic Life and Water Contact Recreation.

The mainstem Deschutes River, from RM 126.4 (near Steelhead Falls) to RM 168.2, (upstream of Bend), is listed for exceeding the state's pH criteria of 6.5 to 8.5. Odell Lake, parts of Odell Creek which drains from Odell Lake, and Lake Billy Chinook are also listed for exceeding the pH standard of 6.0-8.5. Odell Lake is especially susceptible to eutrophication due to increased human recreational use and recreational residence development around the lake (USFS, 1999). Phytoplankton blooms during the summer are evident in Odell Lake (ODFW, 1996). Odell Lake is especially susceptible to eutrophication due to the increased human use and recreational development around the lake (USFS, 1999). ODEQ and the Deschutes National Forest (USFS) cooperated in an intensive water quality study of nutrient and pH conditions in Odell Lake in 2001. Results showed that Odell Lake exceeded the 8.5 standard on five separate occasions, with a peak pH value of 9.8 due to algal blooms in the lake. Odell Creek which drains into the lake also contributed high pH water with a peak pH measurement of 10 (Houslet, 2002). The USFS and ODEQ are hoping to do a more detailed study of Odell Lake in 2004 as part of continued TMDL monitoring.

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 (EPA, 1997).

High concentrations of dissolved oxygen in the water column are essential to support aquatic life. Dissolved oxygen (DO) is important to a stream's biological community and to the breakdown of organic material. Salmon and trout, especially in their early life stages as eggs and alevins (newly hatched fish with egg sac still attached), are very susceptible to low dissolved oxygen concentrations. In their adult life stage, decreases in DO can lead to metabolic stress and increased susceptibility to disease (Oregon Plan, 1999).

Sedimentation in the intergravel spaces of fish redds can reduce DO availability to eggs. As stream water temperatures rise, availability of DO to aquatic life decreases. Nitrates, algae, and large quantities of organic matter place a high demand on in-stream oxygen and can cause a critical reduction in DO.

Dissolved oxygen concentrations naturally vary over the course of a day due to aquatic plant photosynthesis. DO levels are lowest 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. DO levels peak in the afternoon as concentration levels build up following aquatic plant photosynthesis.

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: for spawning: not less than 11mg/l or 95% saturation during September 1 - June 30, for cold water: not less than 8mg/l or 90% saturation during July 1 - August 31 and for cool water: not less than 6.5 mg/L during July 1 – September 30.

In those reaches of the Deschutes River where water temperatures are high, dissolved oxygen is usually also affected. As temperatures rise, water holds less dissolved oxygen and especially at higher altitudes (less atmospheric pressure). The entire reach of the Deschutes River below Wickiup Reservoir to the city of Bend is listed on ODEQ's 2002 303(d) list for poor dissolved oxygen levels.

The Little Deschutes River also shows poor dissolved oxygen levels, from the confluence where it enters the Deschutes River upstream to rivermile 54. The hydrology and geomorphology of the Little Deschutes River make it very susceptible to poor water circulation. The river has many meanders and oxbows with a low gradient along this reach. Stream temperatures are high which leads to reduced dissolved oxygen levels.

Sedimentation / Turbidity

Sedimentation

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). This erosional process consists of detaching the sediment particles, transporting the particles from their original location and depositing them elsewhere (Oregon Plan, 1999).

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. Large inputs of fine sediments such as clays or silts can lead to increased suspended sediment which increases turbidity. Fine sediments can serve as carriers of toxic chemicals which tend to attach to suspended particles. Fine sediments can degrade aquatic invertebrate and fish habitat when they settle out on the streambed (EPA, 1997).

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.

Sedimentation is typically measured by the amount of total suspended solids found in the water column, which can be correlated with turbidity (see below) on a site-specific basis. Monitoring of sediment can identify the sources of sediment and the deposition of sediment during the erosional process (Oregon Plan, 1999).

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."

Turbidity

Turbidity is a measure of water clarity, and is directly affected by material suspended in water (e.g. soil particles, algae, plankton, etc.) that decreases the passage of light through the water.

Turbidity is an important parameter for both aesthetic and biological reasons. Increased turbidity affects fishing, swimming, and other water related recreational uses by making the waters less attractive and impacts the quality of drinking water. Biologically, increased turbidity reduces light penetration causing decreased production of beneficial instream productivity factors. Feeding and growth of fish are adversely affected and studies have indicated that, with prolonged exposure to increased levels of sediment, gill tissue becomes less efficient in the uptake of oxygen. Also as suspended material settles, it can cover the stream bottom and smother fish eggs and bottom-dwelling (benthic) aquatic organisms.

Sources of turbidity 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; excessive algal growth in a water body; and bottom feeders (e.g. carp and some waterfowl) that disrupt sediments through their feeding habits.

The ODEQ criterion for turbidity allows no more than a 10 percent cumulative increase in natural stream turbidities. However, 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.

Turbidity is also an important parameter from a human aesthetic and recreational perspective. Increased turbidity reduces fishing, swimming, and other water related recreational uses when water is less attractive. Increased turbidity can also impact drinking water quality.

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. The soils which are exposed during the low flows of winter are vulnerable to frost heave and loosening. These loosened soils are then washed downstream by the sustained, high flows which follow during the irrigation season. This results in the movement of eroded bank material downstream. Because the Deschutes River just upstream of the city of Bend is a low gradient and, hence, low energy reach of the river, sediment transport capability is low. This has resulted in increased sediment deposition and lateral migration, causing the river to become wider and shallower in some areas (Yake, 2003).

While many reservoirs can decrease turbidity by trapping sediment, the Deschutes River reservoirs contribute to mid- and late season turbidity, not with sediment but with primary productivity. As a result of the solar radiation that warms of the reservoirs' waters, the growth of microorganisms known as "primary productivity" flourishes. Millions of organisms cloud the water in "algae blooms." In mid-summer these blooms begin to appear in the river and then become the dominant determinant of turbidity. As a result of erosion and primary productivity, turbidity levels do not meet the Oregon's water quality criteria (ODFW 1996).

Chlorophyll a

Chlorophyll a is the green pigment found in plants which allow them to photosynthesize. The measurement of chlorophyll a is an indirect measurement of the amount of photosynthesizing plants (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. 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.

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.

The mainstem Deschutes River is listed on ODEQ's 2002 303(d) list for exceeding the chlorophyll a criterion, from RM 168.2 (north end of Bend) to RM 189.4 (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 and Little Deschutes Subbasins is primarily conducted by ODEQ at five ambient monitoring stations. Chlorophyll a data is only collected during the most productive months: May, July and September. Additional data was collected by ODEQ during the summer 2001 TMDL monitoring efforts.

Nutrients

Nutrients considered within this report include phosphorus and nitrogen. Nitrogen is important to aquatic systems because it stimulates production. However, certain nitrogen compounds in relatively low concentrations can have toxic effects and can be compounded by DO, temperature, and pH. Phosphorus at high levels can trigger algal blooms, excessive plant growth, and other changes associated with nutrient-rich conditions, thus reducing beneficial stream productivity. Livestock and human wastes may be contributors to phosphorus levels.

Increased nutrient concentrations have been detected in water bodies within the Upper Deschutes and Little Deschutes subbasins. Nutrients can indirectly have an impact on pH and dissolved oxygen. There are five National Pollutant Discharge Elimination System (NPDES) permitted facilities and many non-point sources which may contribute to increased nutrient concentrations. Some non-point sources may be: failing septic systems, landscape and agricultural fertilizers, urban runoff from Bend, Redmond and Sisters and animal waste. Wickiup Reservoir and Crescent Lake may be contributing concentrated nutrients into the Deschutes River and Little Deschutes River, respectively. High nitrate-nitrogen concentrations are evident in the shallow groundwater in the unincorporated La Pine community which may be a nutrient source to the Little Deschutes River.

The water quality in the Deschutes River between Crane Prairie Reservoir and Wickiup Reservoir deteriorates during mid-summer due to warm water releases from Crane Prairie Reservoir. The warm water from Crane Prairie contains algae which triggers further algal blooms in Wickiup Reservoir and also discolors the water (ODFW, 1996).

According to historic ODEQ water quality sampling as part of the state-wide Ambient Program, there have been occasional spikes in phosphorus concentrations at the Deschutes River at Harper Bridge monitoring site, higher levels in phosphorus in Mirror Pond in Bend and still higher concentrations at the downstream site on the Deschutes River at Lower Bridge.

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.

Water contact recreation is the beneficial use most directly affected by bacterial contamination of surface waters. The ODEQ standard for bacteria has both numeric and narrative portions. The ODEQ numeric criteria for *E. coli* sets limits of: (i) a 30-day log mean of 126 *E. coli* organisms per 100 ml, based on a minimum of five samples; and no single sample shall exceed 406 E. coli organisms per 100 ml. The narrative criteria state that: "Bacterial pollution or other conditions deleterious to waters used for domestic purposes, livestock watering, irrigation, bathing or shellfish propagation, or otherwise injurious to public health shall not be allowed."

There are currently no stream reaches or water bodies within the Upper Deschutes and Little Deschutes Subbasins that are listed for exceeding ODEQ's *E. coli* standards. Bacteria data is collected 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 subbasins. 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.

Bacteria sampling was conducted by ODEQ at the five ambient sites for a period of five years, from 1996 to 2001. Both *E. coli* and fecal coliform were sampled every other month at the ambient sites. ODEQ also took one bacteria sample (both *E. coli* and fecal coliform) at all monitoring sites during January 1996, as part of the 1995-1996 Upper Deschutes Water Quality Survey.

Fecal coliform levels in Bridge Creek, a tributary of Tumalo Creek, are monitored by the City of Bend to protect its municipal drinking water supply.

1.5 2002 303(d) List of Impaired Water Bodies

Beneficial Uses

Human uses and aquatic species that are to be protected by water quality standards are considered beneficial uses. Water quality standards are developed to protect the most sensitive beneficial use within a water body of the State. **Table 1** shows the beneficial uses identified in the Upper and Little Deschutes subbasins.

Table 1. Beneficial Uses in the Upper Deschutes and Little Deschutes subbasins (ODEQ, 2001).

Public Domestic Water Supply	Water Contact Recreation
Private Domestic Water Supply	Irrigation
Industrial Water Supply	Livestock Watering
Anadromous Fish Passage	Wildlife and Hunting
Salmonid Fish Rearing	Fishing
Salmonid Fish Spawning	Boating
Resident Fish and Aquatic Life	Aesthetic Quality

ODEQ 2002 303(d) list of water quality limited stream segments identifies the following parameters which contribute to compromised water quality in the Upper and Little Deschutes subbasins: temperature, pH, dissolved oxygen, sedimentation, turbidity and chlorophyll a. ODEQ's website, http://www.deq.state.or.us/wq/303dlist/303dpage.htm, describes the water quality data used to support the listing of specific waterbodies and stream segments in the two subbasins. This website also has a detailed description of the specific water bodies in the Upper Deschutes and Little Deschutes subbasins on ODEQ's 2002 303(d) list. Table 2 shows each parameter and the beneficial use which it potentially impacts. **Table 2** shows the beneficial uses potentially impacted by the water quality parameter.

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

Table 2. Water Quality Parameter and Associated Beneficial Uses (ODEQ, 2001)

Water Quality Parameter	Associated Beneficial Use
Temperature	Resident Fish and Aquatic Life, Salmonid Fish Rearing and Spawning
pH	Resident Fish and Aquatic Life, Water Contact Recreation
Dissolved Oxygen	Resident Fish and Aquatic Life, Salmonid Fish Rearing and Spawning
Sedimentation	Resident Fish and Aquatic Life, Salmonid Fish Rearing and Spawning

Turbidity	Resident Fish and Aquatic Life, Water Supply, Aesthetic Quality
Chlorophyll a	Water Supply, Livestock Watering, Water Contact Recreation, Fishing, Aesthetic Quality,
Nutrients	Resident Fish and Aquatic Life, Water Contact Recreation, Aesthetic Quality
Bacteria (*Esherichia coli*)	Water Contact Recreation

2.0 SAMPLING METHODS AND PROTOCOLS

Types of Monitoring

Many agencies have conducted water quality monitoring for many reasons. The Regional Framework report identified three types of water quality monitoring:

1) Status and Trends monitoring - understanding the condition of a resource or changes in the status of a parameter over time. Status monitoring is also called baseline monitoring.
2) Compliance monitoring – determining whether conditions are meeting established criteria, reference levels or standards
3) Evaluation monitoring – assessing the effects of land use or changes in resource management. Evaluation monitoring is also known as effectiveness monitoring.

Other types of monitoring used by local agencies include Implementation monitoring and Project monitoring (Dachtler, 2003). These types are used by various agencies to assess whether specific treatments or activities occurred as planned or are having the desired effect of improving conditions.

Monitoring Protocols

The protocols used to gather water quality data have been as varied as the purposes for collecting the data. Because of these varied protocols, the quality of the data has ranged from poor or unknown (Level E) to the highest level (Level A) which can be used for legal and regulatory purposes. Improving the quality assurance and quality control (QA/QC) of data collection efforts is of primary importance to the Upper Deschutes Water Quality Monitoring program.

To help improve the level of water quality data gathering efforts throughout the state, a water quality monitoring technical guidebook was published by the Oregon Plan for Salmon and Watersheds in 1999. The protocols described in the guidebook were developed in consultation with several state and federal natural resource agencies. The guidebook serves as a standardized tool to gather scientifically valid water quality data and is written for use by watershed councils, local agencies, volunteer groups and landowners.

This guidebook and the Regional Framework (Anderson, 2000) are the central technical documents currently being used to implement the Upper Deschutes Water Quality Monitoring program.

One important component of monitoring (which is often ignored because it can be time consuming) is the development of a monitoring plan. The components of a plan include: problem definition, goal, objective, hypothesis, site description, data gathering strategy, methods, data quality, data storage and analysis, timetable and staff requirements and confidentiality and landowner relations (Oregon Plan, 1999).

In 2002, the UDWC developed a temperature sampling and analysis monitoring plan to which was submitted to ODEQ for review. The plan describes the purpose of the UDWC's monitoring activities, the QA/QC procedures to be followed, the locations of 22 monitoring sites within the two subbasins and the usage of resulting data. The plan also describes the coordination with other local natural resource monitoring entities. In 2003, the UDWC expanded its monitoring to 25 sites to fill in data gaps.

3.0 SUMMARY OF MONITORING EVENTS DURING 2000, 2001 AND 2002

Twelve organizations conducted some type of monitoring in the region from 2000 to 2002. Stream temperatures and water flows were the most common measurements taken. Flows have been measured by the Oregon Department of Water Resources, as part of its management of water rights, since the early 1900s. The most consistent long term water quality monitoring program in the area is conducted by Oregon Department of Environmental Quality at three sites as part of its state-wide ambient monitoring program. The City of Bend has also consistently monitored its Bridge Creek site for several years for drinking water protection. Portland General Electric has collected basic field parameters since 1994 at a single site, at the inflow to Lake Billy Chinook, as part of its hydropower management requirements. The other organizations have conducted numerous short term data collection projects to address specific research needs or evaluate specific localized natural resource management changes.

Although the emphasis of this report is on water quality monitoring, there are many other monitoring activities which add to our understanding of water quality conditions. These include many 'fish-centric' surveys (e.g. fish population and distribution surveys, redd counts, aquatic habitat condition assessments and macroinvertebrate surveys) and physical stream structure studies (e.g. channel morphology cross-sections, riparian condition assessments and bank erosion pin monitoring). These are mentioned in this report to show the broad range of activities occurring in the two subbasins and to provide a regional context for all of the monitoring efforts.

Table 3 shows the water quality parameters which were monitored throughout the two subbasins. Other related surveys are also shown in the table.

Appendix A gives a description of "who, what, where, and why" of monitoring activities conducted by local entities in the Upper Deschutes and Little Deschutes subbasins from 2000 to 2002. It is important to note that many of the monitoring activities described below have multiple objectives such as improving both water quality and aquatic habitat. Because of these overlapping objectives, the primary purpose of the project is listed to avoid redundancy.

Table 3. Water Quality Parameters monitored and surveys conducted during 2000, 2001 and 2002.

Entity	Location	Activity										
City of Bend	Bridge Cr., a trib. of Tumalo Cr.	Stream Flow	Continuous Temperature	pH	DO	Sedimentation / Turbidity	Nutrients	Chlorophyll a	Bacteria	Channel Morphology	Fish / Redd Surveys	Riparian Conditions
PGE	Deschutes River inflow to Lake Billy Chinook		X	X	X	X			X			
ODFW	Several sites throughout the two subbasins		X							X	X	X
OWRD	Flow at 32 gauges, temps at 6 flow gauges	X	X									
UDWC	Approx. 24 sites throughout the two subbasins		X									
ODEQ	At five ambient sites			X	X	X	X	X	X	X		X
Bureau of Reclamation	Crane Prairie, Wickiup and Crescent L. Reservoirs	X										
USFS, Ochocos	3 sites on Squaw Cr.		X									
USFS, Deschutes	Numerous sites throughout the two subbasins	X	X	X	X	X				X	X	
BLM, Prineville	3 sites on middle Deschutes R.		X							X		

4.0 REFERENCES

Anderson, C.W. 2000. Framework for Regional, Coordinated Monitoring in the Middle and Deschutes River Basin, Oregon, USGS Open-File Report 00-386. Portland, Oregon

Breuner, N. 2003a. Temperature Characterization of Watersheds in the Upper Deschutes and Little Deschutes Subbasins. Upper Deschutes Watershed Council. Bend, Oregon

Breuner, N. 2003b. Water Quality Characterization of the Upper Deschutes and Little Deschutes Subbasins. Upper Deschutes Watershed Council. Bend, Oregon

Dachtler, N. 2003. Deschutes National Forest Aquatic Resource Monitoring Report 2002 Fisheries/ Hydrology. USFS, Deschutes National Forest. Bend, Oregon

EPA, 1997. Volunteer Stream Monitoring: A Methods Manual. U.S. Environmental Protection Agency. EPA 841-B-97-003, Washington D.C.

Gannett, M., K. Lite, Jr., D. Morgan and C. Collins, 2001. Ground-Water Hydrology of the Upper Deschutes Basin, Oregon. U.S. Geological Survey, Water-Resources Investigative Report 00-4162 Portland, Oregon

Houslet, B.S. 2002. Summer Dynamics of pH and Nutrients in Odell Lake, Oregon 2001. Deschutes National Forest, Crescent Ranger District, Crescent Oregon

La Marche, J. 2001. Upper and Middle Deschutes Basin Surface Water Distribution Model. OWRD Surface Water Open File Report #SW02-001. Bend, Oregon

Lamb, B. R. Haynes, G. Pettit, and L. Marxer. 2001. Quality assurance project plan, Upper and Little Deschutes TMDL water quality monitoring study. Oregon Department of Environmental Quality. Bend and Portland, Oregon

ODEQ, 2001. State-wide water quality management plan; beneficial uses, policies, standards and treatment criteria for Oregon. Oregon Administrative Rules 340-41, Oregon Department of Environmental Quality. Portland, OR.

ODEQ, 2002. Aerial Surveys in the Deschutes River Basin, Thermal Infrared and Color Videography. Oregon Department of Environmental Quality, Portland, Oregon. Report prepared by: Watershed Sciences. Corvallis, Oregon

ODEQ, 2003. Oregon's final 2002 water quality limited streams (303d list). Oregon Department of Environmental Quality. Portland, Oregon

ODFW, 1996. Upper Deschutes River Subbasin Fish Management Plan. Upper Deschutes Fish District, Oregon Department of Fish and Wildlife. Bend, OR

Oregon Plan for Salmon and Watersheds, 1999. Water Quality Monitoring Technical Guide. Salem, Oregon

UDWC, 2000. Aerial Surveys in the Upper Deschutes River Basin, Thermal Infrared and Color Videography Upper Deschutes Watershed Council. Report prepared by: Watershed Sciences. Corvallis, Oregon

UDWC, 2002. Little Deschutes River Subbasin Assessment. Report prepared by: Watershed Professionals Network. Boise, Idaho and Corvallis, Oregon

USFS, 1999. Odell Watershed Analysis. Deschutes National Forest, Crescent Ranger District, Crescent, OR

Yake, K., 2003. Upper Deschutes Subbasin Assessment. Upper Deschutes Watershed Council, Bend, OR

Appendix A
Description of Monitoring Activities

Entity	Name of Project	Activity	Location	Type of Monitoring / Purpose
City of Bend	Bridge Creek Watershed, continuous monitoring during 2000 and 2001	Continuous temperature, turbidity, fecal coliform	One site on Bridge Creek, a tributary of Tumalo Creek	Compliance / Safe Drinking Water Act requirements
OWRD	Management of flow gauges	Flow measurements, continuous temperature monitoring	32 gauges throughout the Upper and Little Deschutes subbasins, 6 gauges with continuous temperature monitors	Compliance / management of gauge stations, data for allocation of water rights
UDWC	Implementation of the Region WQ Monitoring Framework	Water quality data compilation and data analysis, QA/QC development	Throughout Upper Deschutes and Little Deschutes subbasins	Baseline, status and trends / assessment of water quality conditions, Implementation of Regional Framework
UDWC	Continuous temperature monitoring	Continuous temperature monitoring	22 sites in 2002, throughout the two subbasins	Compliance / status and trends in temperature, filling in data gaps
UDWC	Upper Deschutes River Bank Stability Characterization	Inventory of bank conditions, identify sediment sources and highly erodible banks	Upper Deschutes River from Wickiup Reservoir to Bend	Baseline assessment of erosive conditions of stream banks, to identify sources of sediment to the river
PGE	Pelton Round Butte Hydropower Operation project / monthly monitoring during 2000 and 2001	*Field parameters, continuous temperature	One site: Deschutes River at inflow to Lake Billy Chinook	Baseline, Compliance, Status and Trends / FERC hydropower re-licensing,
DEQ	Ambient WQ surveys / ongoing every other month monitoring	Grab samples for approx. 75 water chemistry parameters	Four sites in Upper Deschutes and one site in Little Deschutes subbasins	Compliance, Status and Trends / on going, grab sampling to provide data to support state-wide Water Quality Index
DEQ	Squaw Creek ** FLIR survey, July, 2000	Continuous temperature, flow measurements	Squaw Creek, Indian Ford and part of Deschutes River at mouth	Compliance / gather additional temperature data for development of temperature TMDL
DEQ	Upper Deschutes FLIR survey, July, 2001	Continuous temperature, flow measurements	Upper Deschutes R and tributaries, Little Deschutes R and tributaries	Compliance / gather additional temperature data for development of temperature TMDL
DEQ	Upper Deschutes TMDL project, July and August 2001	Continuous temperature, field parameters, intensive water quality surveys of DO, pH and nutrients, flow measurements, riparian condition assessment, and sediment and pH studies (with USFS)	At several sites throughout Upper Deschutes and Little Deschutes subbasins, sediment study along mainstem Deschutes R, pH study in Odell Lake	Compliance / gather water quality data for development of TMDLs (temperature, DO, pH and sediment)

Entity	Name of Project	Activity	Location	Type of Monitoring / Purpose
ODFW	Upper Deschutes River Subbasin Fish Management Plan, ongoing	Continuous temperature, fish surveys, redd counts, fish habitat restoration	throughout Upper Deschutes and Little Deschutes subbasins	Effectiveness / gather data for implementation of fish management plans
BOR	Reservoir Management, ongoing	Field parameters, inorganic chemistry, Chlorophyll a	Crescent Lake and Wickiup reservoirs	Baseline, Status and Trends, Compliance / Determine reservoir water quality, management of reservoirs, flood control
USFS, Deschutes NF	Water Quality Restoration projects, May – Oct 2001	pH, nutrients, DO, Chlorophyll a, dissolved phosphorus, continuous temperature	Odell Lake	Baseline, Status and Trends, Compliance/ Lake eutrophication surveys, stream surveys, reference reach surveys
USFS, Deschutes NF	Addressing 303(d) listed streams and management of threatened or endangered species	Continuous temperature	Various sites on temperature limited streams within the Upper Deschutes and Little Deschutes Subbasins	Compliance, Baseline / data for Federal water quality restoration plans to address 303(d) listed waters
USFS, Deschutes NF	Sediment studies of Deschutes River, ongoing	Channel cross-sections, bank erosion pins	sediment studies on Deschutes River below Wickiup Reservoir	Compliance, Baseline / data for Federal water quality restoration plans to address 303(d) listed waters
USFS, Deschutes NF	Regional projects such as PacFish/Infish Biological Opinion and Northwest Forest Plan	Channel morphology surveys	Soda Creek, Trapper Creek, Tumalo Creek, Deschutes River, other water bodies within the Deschutes National Forest	Implementation, Effectiveness and Project / Habitat and watershed restoration projects
USFS, Deschutes NF (with ODFW)	Fish surveys, especially related to bull trout and redband trout	Redd counts, snorkel surveys, channel morphology surveys, bull trout spawner surveys	Odell andTrapper Creek for bull trout, other streams within the Deschutes National Forest for redband surveys	Baseline, Status and Trends / Bull trout population trends and spawner distribution, fish management objectives
USDI, BLM Prineville	Addressing 303(d) listed streams on BLM managed lands, ongoing	Continuous temperature	Various sites on mainstem Deschutes R, between Redmond and Lake Billy Chinook	Compliance, Baseline / data for Federal water quality restoration plans to address 303(d) listed waters
USFS, Ochoco NF / Crooked River National Grasslands	Addressing 303(d) listed streams on Grasslands managed lands	Continuous temperature	Three sites on Squaw Creek	Compliance, Baseline / data for Federal water quality restoration plans to address 303(d) listed waters

*Field parameters: temperature, pH, dissolved oxygen, conductivity, turbidity

**FLIR: Forward Looking Infrared Radiometry