— APPENDIX B—

Water Quality Report

DESCHUTES RIVER BASIN BIOLOGICAL ASSESSMENT - WATER QUALITY

INTRODUCTION

Water quality in the Deschutes River basin is managed by the state of Oregon under a framework provided in the Clean Water Act (CWA). The state of Oregon promulgates water quality standards in the Deschutes River Basin for specific physical and chemical parameters in order to provide suitable conditions for support of recognized beneficial uses (Table 1).

On March 31, 2003, U.S. District Court Judge Ancer Haggerty ordered the EPA to void its earlier approval of Oregon's water temperature standards. Oregon has initiated rulemaking and is working in concert with the Oregon Department of Fish and Wildlife, EPA, NMFS, and U.S. Fish and Wildlife Service to develop new temperature criteria. For water quality discussions in this BA, Reclamation will use Oregon's existing temperature criteria for comparison purposes.

Section 303(d) of the CWA requires states to identify and develop a list of waters for which water quality is inadequate to fully support beneficial uses. The states then use the list to develop and implement water quality management plans, including pollutant load allocations. These water quality management plans and pollutant load allocations, commonly called Total Maximum Daily Load (TMDL), are scheduled for completion in 2005 for the Upper Deschutes subbasin, the Lower and Upper Crooked subbasins, and the Lower Deschutes subbasin. Water bodies, or stream reaches, that are potentially influenced by Reclamation projects in the Deschutes River basin that have been identified as not supporting beneficial uses and the pollutant causing the impairment are listed in Table 2.

Table 1. Recognized Beneficial Uses for the Deschutes Basin
(Source: State of Oregon ,Oregon Administrative Rules, Table 9, 2002)

Beneficial Uses	Columbia River (RM 203 to 218)	Deschutes River Main Stem from Mouth to Pelton Regulating Dam	Deschutes River Main Stem from Pelton Regulating Dam to Bend Diversion Dam and for the Crooked River Main Stem	Deschutes River Main Stem above Bend Diversion Dam and for the Metolius River Main Stem	All Other Basin Streams
Public Domestic Water Supply [1]	X	X	X	X	X
Private Domestic Water Supply [1]	X	X	X	X	X
Industrial Water Supply	X	X	X	X	X
Irrigation	X	X	X	X	X
Livestock Watering	X	X	X	X	X
Anadromous Fish Passage	X	X	X	X	X
Salmonid Fish Rearing	X	X	X	X	X
Salmonid Fish Spawning		X	X	X	X
Resident Fish and Aquatic Life	X	X	X	X	X
Wildlife and Hunting	X	X	X	X	X
Fishing	X	X	X	X	X
Boating	X	X	X	X	X
Water Contact Recreation	X	X	X	X	X
Aesthetic Quality	X	X	X	X	X
Hydro Power	X		X		
Commercial Navigation and Transportation	X				

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

Table 2. 303(d) Listed Waters in the Deschutes River Basin

(Source: Oregon Department of Environmental Quality 2002, Oregon's Final 1998 Water Quality Limited Streams - 303(d) List)

Waterbody or Stream Reach	Impairment Parameter	Criteria
Crooked River: Mouth to Baldwin Dam	1. Temperature - Summer 2. Bacteria - Summer 3. pH - year around 4. Flow Modification	1. Rearing 64°F (17.8°C) 2. Water Contact Recreation - fecal coliform 400 cfu/100mL (listing based on the 1996 standard) 3. 6.5 - 8.5 4. No Criteria
Crooked River: Baldwin Dam to Prineville Reservoir	Total Dissolved Gas	110%
Ochoco Creek: Mouth to Camp Branch	Temperature - Summer	Rearing 64°F (17.8°C)
Clear Creek: Mouth to headwaters	Temperature - Summer	Rearing 64°F (17.8°C)
Deschutes River: Mouth to White River	1. pH 2. Temperature - Summer	1. 6.5 - 8.5 2. Rearing 64°F (17.8°C)
Deschutes River: White River to Reregulating Dam	1. Dissolved Oxygen - Oct - July 2. Temperature - Summer	1. Salmonid Spawning 11 mg/L 2. Oregon Bull Trout 50°F (10°C)
Wapinitia Creek: Mouth to Headwaters	Temperature - Summer	Rearing 64°F (17.8°C)
White River: Mouth to Rock Creek	Temperature - Summer	Rearing 64°F (17.8°C)
Deschutes River: Lake Billy Chinook to Steelhead Falls	pH - May - Sep	6.5 - 8.5
Deschutes River: Steelhead Falls to North Unit Main Canal	1. pH - May - Sep 2. Temperature - Summer 3. Flow Modification	1. 6.5 - 8.5 2. Rearing 64°F (17.8°C) 3. No Criteria

Waterbody or Stream Reach	Impairment Parameter	Criteria
Deschutes River: North Unit Canal to Central Oregon Canal	pH - Summer	6.5 - 8.5
Deschutes River: Central Oregon Canal to Little Deschutes	1. Dissolved Oxygen - Oct - July 2. Sedimentation 3. Turbidity - Spring/Summer 4. Flow Modification 5. Habitat Modification	1. Salmonid Spawning 11 mg/L 2. Formation of appreciable bottom deposits deleterious to fish is not allowed 3. No more than a 10% cumulative increase in natural stream turbidities 4. No Criteria 5. No Criteria
Deschutes River: Little Deschutes to Wickiup Reservoir	1. Dissolved Oxygen - Oct - July 2. Sedimentation 3. Turbidity - Spring/Summer 4. Flow Modification 5. Habitat Modification	1. Salmonid Spawning 11 mg/L 2. Formation of appreciable bottom deposits deleterious to fish is not allowed 3. No more than a 10% cumulative increase in natural stream turbidities 4. No Criteria 5. No Criteria
Deschutes River: Wickiup Reservoir to Crane Prairie Reservoir	Temperature - Summer	Rearing 64°F (17.8°C)
Lake Billy Chinook	1. Chlorophyll a - Spring/Summer/Fall 2. pH - Summer	1. 0.015 mg/L 2. 6.5 - 8.5
Squaw Creek: Alder Springs to Maxwell Ditch	1. Temperature - Summer 2. Flow Modification	1. Rearing 64°F (17.8°C) 2. No Criteria

°C = Degrees Celsius °F = Degrees Fahrenheit mg/L = Milligrams per liter or parts per million cfu/100mL = Colony forming unit per milliliter

CROOKED RIVER PROJECT

Prineville Reservoir

Water quality in Prineville Reservoir is generally good and is suitable for all beneficial uses as identified by the state of Oregon. Surface water quality data collected by Reclamation (1978-1995) indicates that the water quality criteria are met under most conditions.

Prineville Reservoir surface water temperatures during July and August often exceed the cold water aquatic life temperature standard (17.8^{o}C). Reservoir profile data collected during July and August of 1985 and 1995 show that there are temperatures less than 17.8^{o}C in the lower 50 percent of the reservoir. The temperature cycle in the reservoir is typical of reservoirs in Oregon. During the spring, the reservoir has a relatively uniform vertical temperature profile. During the summer, the epilimnion is generally warm, turbulent, and well mixed. The hypolimnion is cold and relatively undisturbed. As the surface water cools during the fall, the reservoir turns over, returning to a near uniform temperature profile.

Increased turbidity in the reservoir is from two major sources: the reservoir proper and the watershed. Camp Creek, Bear Creek, Eagle Creek, Lost Creek, Klootchman Creek, Newsome Creek, and the Upper Crooked River were all shown to contain a high amount of suspended montmorillonite clays (OSU 1976). Since 1960, the estimated average annual rate of reservoir capacity lost to sediment accumulation is 122.3 acre-feet. This represents a 2.96 percent loss in reservoir volume (Reclamation 1999). Upstream land use practices including logging, road building, and livestock grazing contribute to erosion in the watershed. Wind induced waves and boat wakes also contribute to increased reservoir and down stream turbidity by eroding and resuspending shoreline sediments.

Nutrients (nitrogen and phosphorus) are available in sufficient quantities to support plant growth in the reservoir indicating a potential for algal blooms and eutrophic conditions. It is suspected that turbid conditions in the reservoir reduce light penetration to the extent that photosynthethic activity and plant growth are limited. This is supported by the low concentrations of chlorophyll a and minimal dissolved oxygen depletion in the lower levels of the reservoir during the summer months (ODFW 1996). Dissolved oxygen levels in the reservoir decrease somewhat during July and August, but not to the levels that would be indicative of eutrophic conditions.

Crooked River below Arthur R. Bowman Dam

Water released through Bowman Dam is of suitable quality to support beneficial uses. On occasion during periods of high flow, total dissolved gas levels rise above 110 percent and may cause some gas bubble disease in the rainbow trout population in the Crooked River below Bowman Dam. Total dissolved gas below Bowman Dam will be addressed through Oregon's TMDL process in 2005.

Turbidity in Prineville Reservoir is noticeable downstream of Bowman Dam, especially when irrigation releases begin in the spring. Primary sources of turbidity and sedimentation include land management activities upstream of Prineville Reservoir and wave action within the reservoir. The stream flow regime is sufficient to transport the undesirable finer sediment through the Crooked River system. Turbidity levels decline as the irrigation season progresses.

Large diversions from the Crooked River lead to low flow in the river during the irrigation season. This reduced flow along with high air temperature and lack of riparian vegetation results in elevated stream temperature below the Prineville valley. Sedimentation, streambank erosion, and nutrient loading in the lower stretches of the Crooked River result from land practices and agricultural return flows. Nutrient concentrations in the Lower Crooked River near Terrebonne are sufficient to allow excessive algal growth to occur. Opal Springs provides dilution flows to the Crooked River upstream from its confluence with Lake Billy Chinook.

Ochoco Reservoir

Water quality in Ochoco Reservoir is suitable to support the beneficial uses identified by the state of Oregon. Historical data show thermal stratification and some dissolved oxygen depletion in Ochoco Reservoir during the summer months. Generally the reservoir fully mixes in the fall, resulting in uniform temperature and dissolved oxygen concentrations through the reservoir profile. During low flow years, the reservoir may be drafted to low levels to meet irrigation demands thus reducing the amount of cool water in the hypolimnion.

Ochoco Creek below Ochoco Dam

Ochoco Dam release temperature increases in the late summer when the reservoir is at low levels. In most years, except dry water years, release temperatures meet the Oregon temperature standard for salmonid rearing. Crooked River basin streams monitored for temperature between 1997 and 1998 as part of the Regional Environmental Monitoring and Assessment Program (REMAP) project showed elevated temperatures. Additional monitoring and correlation work is needed to identify specific causes of the elevated stream temperatures downstream of Ochoco Dam.

DESCHUTES PROJECT

Crane Prairie Reservoir

Crane Prairie Reservoir water quality currently supports the beneficial uses as identified by the state of Oregon. Limited water quality data for Crane Prairie Reservoir indicate that the reservoir exhibits weak thermal stratification with minimal dissolved oxygen depletion. Some data suggest eutrophic conditions, while others suggest a healthy reservoir system. When the reservoir is drafted to low levels during the summer, often during low water years, release temperatures often exceed 17.8^{o}C.

Average loss due to seepage between 1939 and 1950 at Crane Prairie Reservoir is approximately 60,000 acre-feet per year or 83 cfs. Depending on the stage of the reservoir, the rate of loss ranges from 30 to 135 cfs. USGS estimates that some of the seepage returns to the Deschutes River through springs three to four miles downstream of Crane Prairie Dam along what is now an arm of Wickiup Reservoir. Some of the seepage loss may contribute to the regional groundwater flow system and likely benefits downstream water quality.

Wickiup Reservoir

The primary water supply to Wickiup Reservoir is Crane Prairie Reservoir and springs. Historical water quality data indicate that mild algal growth may occur in the reservoir during the later part of summer. Water quality within Wickiup Reservoir currently supports beneficial uses identified by the state of Oregon.

Deschutes River below Wickiup Dam

The segment of the Deschutes River from below Wickiup Dam to the Central Oregon Canal is included on Oregon's 303(d) list for turbidity, sedimentation, and dissolved oxygen. Increases in turbidity occur when irrigation water deliveries from Wickiup Dam begin in the spring and decrease as the irrigation season progresses. These spring irrigation releases tend to erode the loose soil in the bed and banks of the stream resulting in increased turbidity level. These loose soils are caused by frost heave conditions during the winter months. Turbidity in the mid-summer to fall is likely from algae blooms in Wickiup Reservoir. Potential sources of pollutants to the Deschutes River include residential and commercial development, failing septic systems, recreation, and forestry and agricultural land use practices.

Some reduced dissolved oxygen levels have been observed in the Deschutes River (RM 191.7, ODEQ Site 402363) between October and July. A minimum concentration of 7.3 mg/L was detected between water year 1985 and 1995. A concentration of 11.0 mg/L has been identified by the state of Oregon for protection of salmonid spawning. Sedimentation (collection of fines in spawning gravels that limit embryo survival rates for trout), has been identified as an impairment in the Deschutes River below Wickiup Dam to Central Oregon Canal.

In the reaches of the Deschutes River just upstream of Lake Billy Chinook, flows are greatly influenced by groundwater. A USGS Water-Resources Investigations Report (WRI 97-4233) describes the stream flow in the lower reaches of the Deschutes and Crooked Rivers above Lake Billy Chinook to be dominated by groundwater discharge from April through November (Caldwell 1998). The groundwater inflow affects the water chemistry of the Deschutes River. The USGS concluded that, based on specific conductance, the initial gains in the Deschutes River flow (RM 138 to 134) are probably due to groundwater flowing from the southeast or east, whereas the most significant gains (RM 134 to 123) are dominated by the discharge of groundwater with lower dissolved solids concentrations flowing from the south or west (Caldwell 1998). The primary sources of this groundwater flow are Deschutes River losses in the upper reaches, canal seepage, and deep percolation of water applied to irrigated lands.

Water quality in the Pelton-Round Butte Project reservoirs is generally good, even though natural phosphorous and silicon levels from local geology and introduced nitrogen from upstream activities create seasonal algal blooms that some what degrade reservoir water quality. The reservoirs act as a nutrient sink for the upper and middle Deschutes River subbasins and the Crooked River subbasin. Natural phosphorus is associated with the geology of the watershed, especially in the Metolius River subbasin. Although upstream uses adversely influence the quality of water in the middle Deschutes and lower Crooked Rivers, these subbasins contribute generally fair to good water quality to Lake Billy Chinook because of groundwater recharge upstream of the lake in both subbasins.

Water quality of the inflows, Deschutes, Metolius, and Crooked Rivers, to Lake Billy Chinook is altered before being released to the lower Deschutes River by impoundment and the operation of the Pelton-Round Butte Project Dams. Water quality below Lake Billy Chinook is driven by operation of the dams in the Pelton Round Butte Project. The river immediately below the Pelton-Round Butte Project experiences low dissolved oxygen concentrations and modified temperature because of the hydroelectric project operations and influence of its reservoirs. Higher summer water temperatures are also influenced by ambient air temperatures in the river canyon. Sediment sources in the lower channel are limited to channel beds and banks and tributary inflows. The Deschutes River below the White River confluence is limited in pH and temperature.

Haystack Reservoir

Haystack Reservoir serves as a reregulating reservoir for the lower part of the Deschutes Project. Water quality within the reservoir is suitable for the agricultural uses and the rainbow trout that are stocked annually in the reservoir.

WAPINITIA PROJECT

Clear Lake and Clear Creek below Wasco Dam

Source water for Clear Lake is snow melt from Mount Hood. Generally the water quality is good, but runoff from Mt. Hood carries a large sediment load. Reservoirs in this area collect the phosphorus and store a portion of this natural phosphorus within the consolidated sediments, thus acting as a phosphorus sink. Water quality in the tributaries and the lower Deschutes River is good.

Water provided to the Wapinitia Project from Clear Lake usually uses the entire amount of storage available each year. Water quality effects of this water delivery on the lower Deschutes River is minimal considering water delivered is reused or collected in a pond at the lower end of the project and pumped back for reuse. Minimal pollutants from agriculture and private land use in the Wapinitia Project area affect the water quality in the lower Deschutes River.

PROJECT EFFECTS

Introduction

The proposed action for this biological assessment is the continuance of operation and maintenance of Reclamation project facilities in the Deschutes River basin. For comparison purposes, modeled hydrology was completed to show modeled flows in the Deschutes River basin at specific points under current operations (with Reclamation) and without Reclamation operations, but with the facilities still in place (without).

Reclamation Storage Reservoirs

The general operation of the Reclamation storage facilities in the Deschutes River and Crooked River basins include storage, delivery, and flood control (formal and informal). Specific operation of the Reclamation projects in the Deschutes River and Crooked River basins are described in the *Operations Description of the Deschutes River Basin Projects* report (USBR 2003). Crane Prairie, Wickiup, and Prineville Reservoirs provide most of the flow regulation on the Deschutes and Crooked Rivers. Water quality within the reservoirs is determined, in part, by the timing of storage and release operations resulting in changes in reservoir elevations. The other component of the reservoir water quality is inflow and land use practices in the watershed draining into the reservoirs.

Crane Prairie and Wickiup Reservoirs

Crane Prairie and Wickiup Reservoirs are operated jointly. Water quality of the inflows to these reservoirs is of relatively high quality and providing suitable water quality within the reservoirs. Over the summer period when the reservoirs are drafted, the thermal stratification in both reservoirs becomes less defined. The average water temperature in the water column becomes warmer as the reservoir elevation drops. During the fall or under windy conditions, the reservoir will mix from top to bottom resulting in a near uniform temperature in the water column. Under certain conditions, natural phosphorus entering the reservoirs and limited nitrogen introduced into the system will result in late season algal blooms. The intensity of these blooms is low and likely do not cause depleted dissolved oxygen conditions from decaying algae or under ice conditions.

Deschutes River below Wickiup Dam (Upper and Middle Deschutes Rivers)

Water quality in the upper and middle reaches of the Deschutes River is affected by urbanization, dam operations, private land use practices, groundwater returns, and Federal and non-Federal irrigation diversions and returns. The state of Oregon has identified temperature, turbidity, and sedimentation as water quality problems in these two reaches. A 1997 report completed as part of the Pelton Round Butte Limnology Study (project number 2030) provides a substantial amount of discussion concerning the effects of the major tributaries on the limnology of Lake Billy Chinook, Lake Simtustus, and the water quality of the water being released to the lower Deschutes River (see Raymond and Eilers 1997). The major tributaries to Lake Billy Chinook are the Crooked River, the Deschutes River, and the Metolius River. The report presents an interpretation of data collected from July 1994 through October 1996 and associated conclusions.

Turbidity and sedimentation increases in the Deschutes River between Wickiup Dam and Bend are primarily associated with private land use activities and elevated runoff associated with snow melt and storm events. Without Reclamation, river flows in the upper and middle Deschutes reaches would be higher during snow melt and storm events. These elevated flows would carry more sediment in the water column and result in a larger sediment load to the Pelton Round Butte Complex. Store and release operations at Reclamation reservoirs in the upper reaches of the Deschutes River capture sediment and reduce downstream loads. Under the proposed action, reduced flows due to storage operations are not effective in flushing sediment that enters the Deschutes River below the Reclamation reservoirs through the Deschutes River system. When irrigation releases are made during the early spring, some of the sediment that accumulates in the Deschutes River below Reclamation dams during storage operations is transported further downstream.

Water temperature in the upper and middle reaches of the Deschutes River is primarily affected by ambient air temperature and flow. Temperature data gathered (1997 - 2002) from gages in the Deschutes River below Wickiup Dam, Benham Falls, and Bend were correlated with mean daily flow (cfs) and maximum daily air temperature at Madras, Oregon (Figure A). Variability in daily maximum water temperature in the Deschutes River below Wickiup Dam is accounted for, nearly equally, by flow ($r = 0.84$) and air temperature ($r = 0.83$). Periods of high flow below Wickiup Dam primarily occur during the irrigation season, when air temperature is at the highest for the year, thus resulting in a similar, positive relationship. Daily maximum water temperature below Wickiup Dam between 1997 and 2002 reached 19.4^{o}C (67^{o}F) during the summer months.

Without Reclamation, flow and temperature patterns at the upper Deschutes River gage below Wickiup would be much different than under the proposed action hydrograph, which is defined by store and release operations. Temperature of the release water is dependent upon the elevation of the outlets, ambient air temperature at the monitoring location, and thermal stratification within the reservoir. Under the proposed action, flows are higher during the irrigation season (May through September). This additional flow increases the time it takes for the water temperature to warm to an equilibrium condition with the ambient air temperature during the summer months.

Flow in the Deschutes River between Bend and Steelhead Falls is reduced by upstream diversions during the irrigation season. With this large reduction in flow, water temperature in this reach is strongly correlated with air temperature ($r = 0.91$) (Figure A). Limited riparian shading along with reduced flow in this reach (Bend to Steelhead Falls) likely intensifies the diel temperature pattern. However, groundwater recharge to the Deschutes River (below RM 136) provides additional flow and rapid cooling before the water enters Lake Billy Chinook.

Effects of Upstream Deschutes River Activities on Lake Billy Chinook and Lower Deschutes

Study of the thermal regimes in Lake Billy Chinook and Lake Simtustus, along with flow and mixing studies, were completed as part of the Pelton-Round Butte Complex FERC relicensing project. This 1997 report (Raymond and Eilers 1997) on the limnology of Lake Billy Chinook and Lake Simtustus clearly explains the thermal and chemical processes occurring in the two lakes, how flow from the tributaries mix, and how the temperature and quality of the releases to the lower Deschutes River are affected.

Depletion of dissolved oxygen in Lake Billy Chinook occurs on a seasonal basis, mostly during the summer months. This depletion occurs mostly in the deeper water as the result of algae respiration in the hypolimnion of Lake Billy Chinook. Because the major tributaries to Lake Billy Chinook are well oxygenated, the effects of respiration in the hypolimnion of Lake Billy Chinook is mitigated by the infusion at depth of the cooler tributary water. The short residence time of Lake Simtustus does not allow enough time for oxygen depletion in the hypolimnion to occur (Raymond and Eilers 1997). The 1998 303(d) dissolved oxygen listing in the lower

Deschutes River between the Reregulating Dam to the White River is based on 6 of 21 dissolved oxygen measurements between October and June (water years 1986 - 1995) were below Oregon's 11.0 mg/L or 95 percent saturation salmonid spawning criteria. The minimum dissolved oxygen value measured in that period was 8.9 mg/L (86 percent saturation).

Nutrients (phosphorus and nitrogen) are supplied to Lake Billy Chinook and Lake Simtustus by the tributaries in concentrations that are sufficient for plant growth in both lakes. A comparison of phosphorus loads between the major tributaries to Lake Billy Chinook indicated that most of the phosphorus appears to be of natural origin. Lake Simtustus has more algal growth due to the shallow epilimnion and a large amount of nitrogen load from Willow Creek. One conclusion from this study is that both lakes retain water from the most nutrient rich tributaries, the Crooked and Deschutes Rivers, in the epilimnion during the summer and discharge cooler, lower nutrient water (Raymond and Eilers 1997).

Historical water temperature data collected at various locations in the Deschutes River were used to look at annual water temperature patterns in the Deschutes River. Maximum daily water temperature data collected over multiple years were sorted by Julian day then averaged to get an average daily maximum temperature (Figures C and D). This information is used to show the effects of Reclamation storage, release, and diversion operations in the middle and upper Deschutes River and resulting impacts on the lower Deschutes River.

In 2001, the Oregon Department of Environmental Quality (ODEQ) contracted Watershed Sciences for thermal infrared remote (TIR) sensing to map and assess stream temperatures in the Deschutes River basin. The data presented in Figure B is the median, water surface temperature of the Deschutes River collected on July 25 and 26, 2001. Although stream temperature changes that occur during the course of the temperature survey are not reflected in the longitudinal temperature profile, general stream temperature warming and cooling trends are reflected in Figure B. An overall warming trend is apparent between RM 167 (near Bend) and 139 (just upstream of Odin Falls) with some small cooling stretches. A large drop in surface water temperature occurs upstream of Lake Billy Chinook between RM 133 (Lower Bridge) and 128 (just downstream of Steelhead Falls). ODEQ measured 16 cold water inputs (springs and tributaries) between RM 132 and the inlet of Lake Billy Chinook (approximately 14.4 miles).

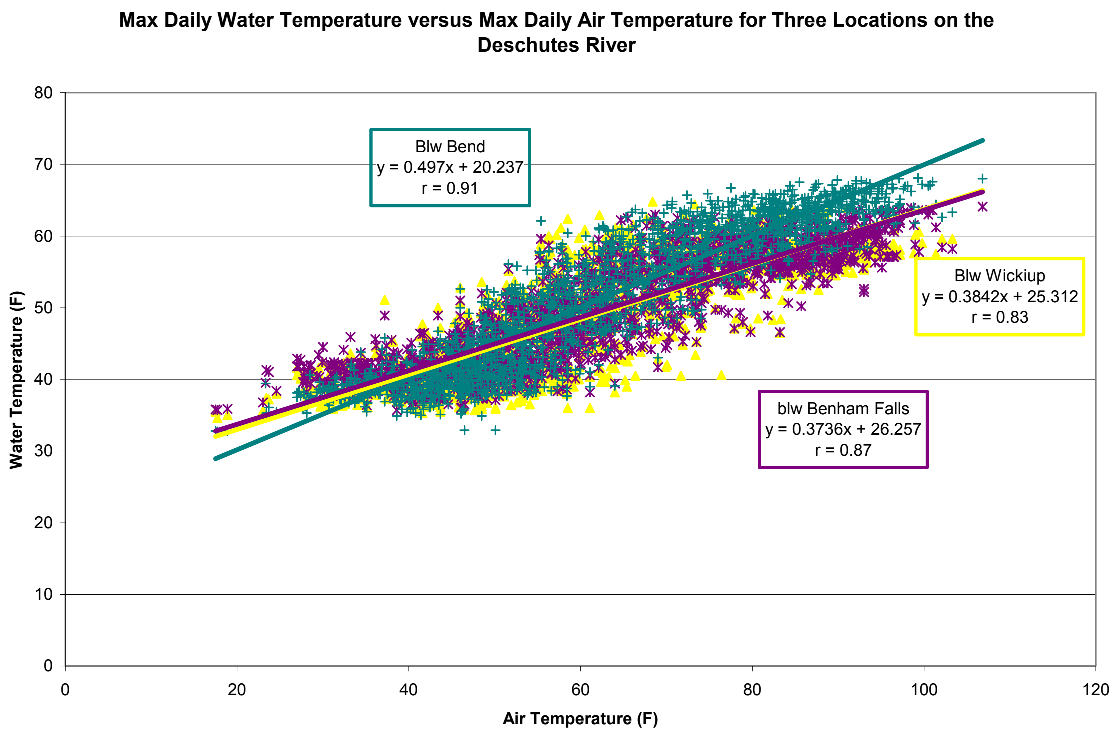

Max Daily Water Temperature versus Max Daily Air Temperature for Three Locations on the Deschutes River
Blw Bend
y = 0.497x + 20.237
r = 0.91
Blw Wickiup
y = 0.3842x + 25.312
r = 0.83
blw Benham Falls
y = 0.3736x + 26.257
r = 0.87
Water Temperature (F)
Air Temperature (F)
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120

Figure A

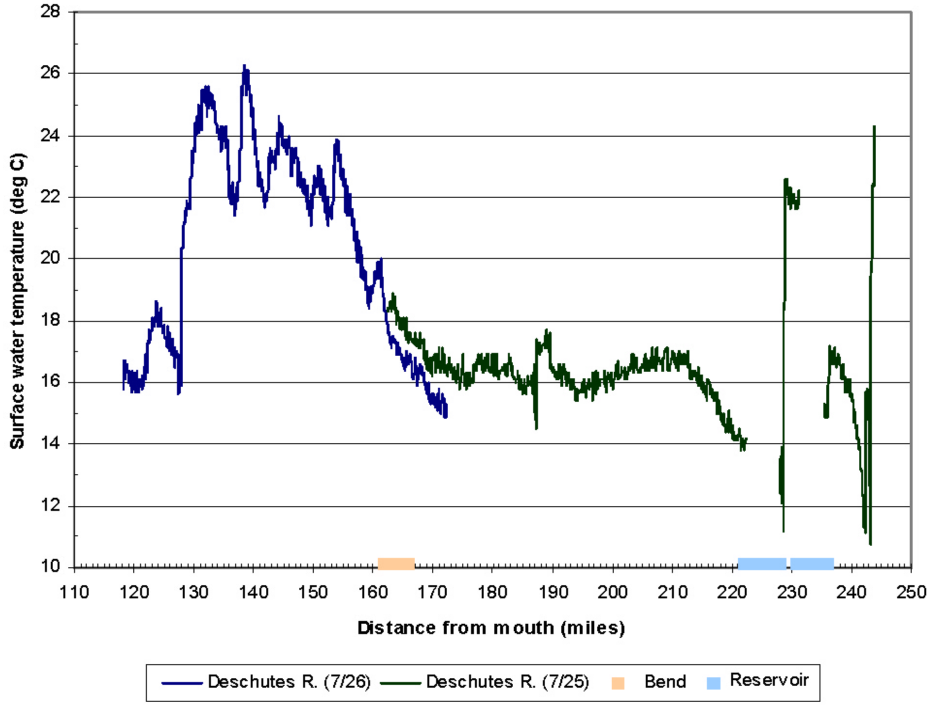


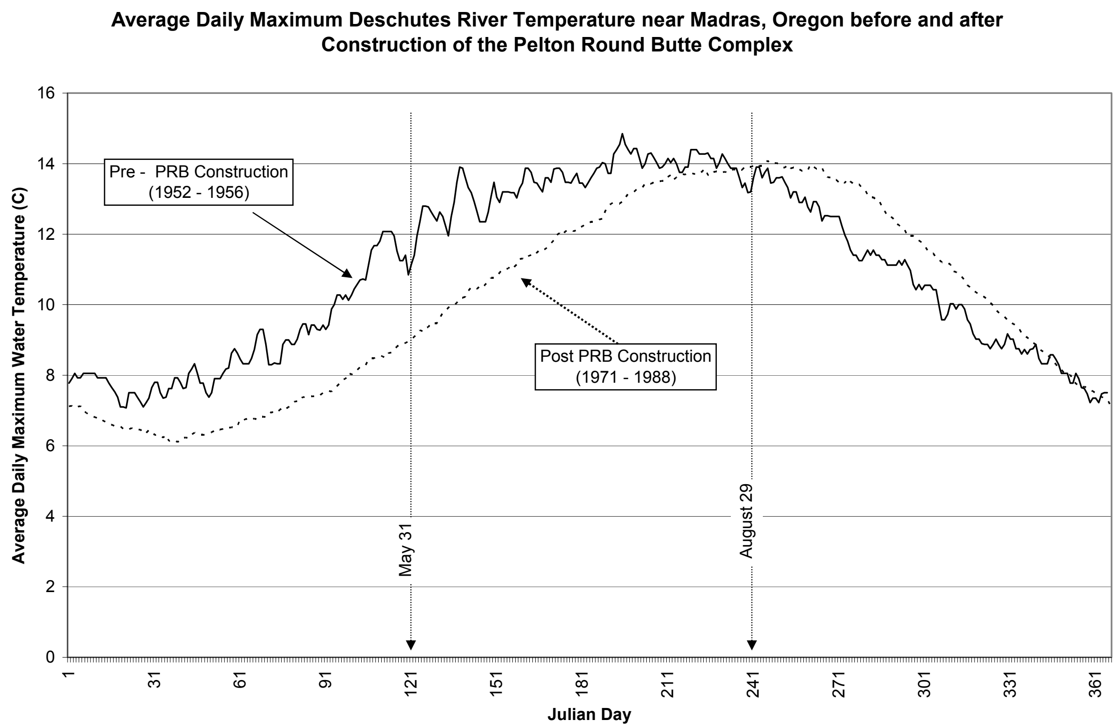
Figure B. Median channel temperature versus river mile for the Deschutes River, OR from Lake Billy Chinook to the headwaters at Little Lava Lake (7/25/01 – 7/26/01).

The water temperature of the Deschutes River above Lake Billy Chinook has a pronounced seasonal variation, with the highest temperatures occurring in July and August and the coolest temperatures in January. The seasonal trend of water temperature measured just downstream from Bend, Oregon closely reflects the seasonality of the air temperature. Maximum water temperature just downstream from Bend, Oregon approaches $20^{o}C$ during the summer period, but the inflow of groundwater near Culver reduces the summer maximum water temperature, on average, by approximately $3.5^{o}C$. Water temperatures near Culver rarely exceed $15^{o}C$ during the peak summer months.

Reduced flow near Bend due to diversions may allow water temperatures between Bend and Culver to come to equilibrium with the ambient air temperature at a faster rate, but also improves the effectiveness of the returning groundwater to cool the flow. If higher flows existed during the summer months between Bend and Culver, the resulting temperatures after mixing with groundwater returns would likely be warmer due to dilution of cool groundwater returns. Groundwater inflow determines the temperature of the Deschutes River immediately upstream from Lake Billy Chinook thus the smaller the amount of warm water mixing with the cool groundwater, the cooler the Deschutes will be when entering Lake Billy Chinook.

The Deschutes River temperature immediately below the Pelton Round Butte Complex is primarily driven by the operation of the Pelton Round Butte Complex. Historical data indicate changes in the timing of annual temperature extremes in the Lower Deschutes River but show little change in the magnitude of the extremes (Huntington et al. 1999) (Figure C). Considering the travel time in Lake Billy Chinook and Lake Simtustus, 66 to 83 days depending on the amount of thermal stratification, warm Deschutes River water that enters Lake Billy Chinook during the hottest period of the summer does not reach the lower Deschutes until 66 to 83 days later. Even when the warmest water is released into the lower Deschutes reach, between late August and early October, the amount of natural warming that occurs during a day is reduced, thus daily maximums are lower.

Examination of available water temperature data above and below the Pelton Round Butte Complex, indicates that the Deschutes River water temperature between Bend and Culver approaches equilibrium with the ambient air temperature quickly due to reduced flow, but groundwater returns near Culver provide beneficial cool flows that reduce the Deschutes River temperature to levels (around $14^{o}C$) that are generally suitable for salmonids before it enters Lake Billy Chinook. Water temperature immediately below the Pelton Round Butte Complex is usually suitable for salmonids. The thermal pattern of water temperature for the Deschutes River at Culver and at Madras are similar but maximum and minimum water temperatures occur at different times of the year due to the hydraulic resident time of the Pelton Round Butte Complex (Figure D).



Average Daily Maximum Deschutes River Temperature near Madras, Oregon before and after Construction of the Pelton Round Butte Complex
Average Daily Maximum Water Temperature (C)
16
14
12
10
8
6
4
2
0
Pre - PRB Construction (1952 - 1956)
Post PRB Construction (1971 - 1988)
May 31
August 29
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day

Figure C

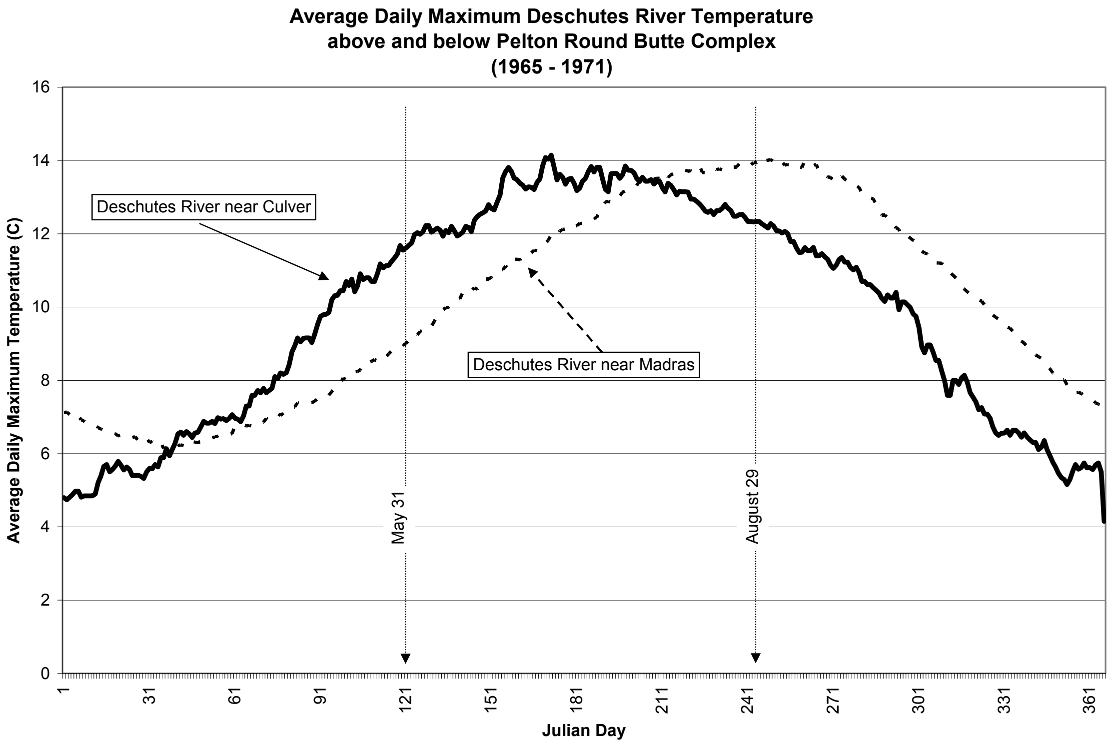


Figure D

Below the Pelton Round Butte Complex, the Deschutes River water temperature is cooler during peak summer months than it would likely be without the Pelton Round Butte Complex. The thermal effects in the lower Deschutes River of the proposed action and other water and land use activities on water temperature upstream from the Pelton Round Butte Complex are buffered by the groundwater flow above Lake Billy Chinook and operation of the Pelton Round Butte Complex. The effects, if any, of Reclamation activities occurring upstream from the Pelton Round Butte Complex on the thermal regimes in the lower Deschutes River are not apparent.

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