DESCHUTES BASIN HABITAT CONSERVATION PLAN

STUDY REPORT

Study 2: Potential Effects of Covered Activities on Surface Water Temperature Phase 1: Releases, Return Flows, and Discharges

Prepared for:

Deschutes Basin Board of Control, and
City of Prineville, Oregon

Prepared by:

R2 Resource Consultant, Inc. and
Biota Pacific Environmental Sciences, Inc.

March 2013

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Study 2: Potential Effects of Covered Activities on Surface Water Temperature Phase 1: Releases, Return Flows, and Discharges

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Acronym, Symbol, Abbreviation	Definition
@	At
Ac-Ft	Acre-feet
AID	Arnold Irrigation District
Alt	Alternative
App.	Appendix/Appendices
Approx.	Approximate
AV	Approach Velocity (fps)
avg.	Average
BA	Biological Assessment
BC	British Columbia
Bdg	Bridge
BFW	Bank Full Width
BiOP	Biological Opinion
BLM	United States Bureau of Land Management
blw	Below
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
BPA	Bonneville Power Administration
ºC	Degrees Celsius
CCI	Construction Cost Index
CDWR	California Department of Water Resources
CFR	Code of Federal Regulations
cfs	Cubic feet per second
Cm	Centimeter
COCO	Central Oregon Cities Organization
COIC	Central Oregon Intergovernmental Council
COID	Central Oregon Irrigation District
Cr	Creek
CRK	Crooked River
CREP	Conservation Reserve Enhancement Program
CRSO	Crooked River at Smith Rocks; Hydromet Gauge #14087300 code
CRWC	Crooked River Watershed Council
CTWS	Confederated Tribes of Warm Springs
Cu Ft	Cubic Feet
CWA	Clean Water Act
D	Drain
DBBC	Deschutes Basin Board of Control
DBHCP	Deschutes Basin Habitat Conservation Plan
DEQ	Oregon Department of Environmental Quality
DES	Deschutes River
DMR	Discharge Monitoring Report
DO	Dissolved oxygen
DR	Deschutes River
DRC	Deschutes River Conservancy

Acronym, Symbol, Abbreviation	Definition
DWA	Deschutes Water Alliance
$	Dollar
DN	Downstream Passage Alternative
d/s	Downstream
Ecology	Washington State Department of Ecology
eds.	Editors
EF	East Fork
e.g.	exempli gratia; For Example
EL.	Elevation
ENR	Engineering News Record
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
et al.	And others
etc.	et cetera; and so on
Eval.	Evaluation
ºF	Degrees Fahrenheit
FEMA	Federal Emergency Management Agency
f/m^2	Fish per square meter
FERC	Federal Energy Regulatory Agency
FS	Forest Service
FSC	Floating Surface Collector
‘	Foot
ft	Feet
ft^2	Square Feet
FTE	Full Time Equivalent
fps	Feet per second
gal	Gallon
GIS	Geographic Information Systems
GBD	Gas Bubble Disease
GBT	Gas Bubble Trauma
gpm	Gallons per minute
>	Greater than
≥	Greater than or equal to:
GW	Groundwater
HDQrs	Headquarters
HCP	Habitat Conservation Plan
HEC-RAS	Hydrologic Engineering Center-River Analysis System
Hwy	Highway
HSI	Habitat Suitability Index
“	Inch
in.	Inch
I.D.	Inside Diameter
IFIM	Instream Flow Incremental Methodology
IHA	Indicators of Hydrologic Alteration
ITP	Incidental Take Permit
kg	Kilogram
kWh	Kilowatt-hour
LASAR	Laboratory Analytical Storage and Retrieval Database

Acronym, Symbol, Abbreviation	Definition
Lb	Pound
LiDAR	LIght Detection And Ranging
LPID	Lone Pine Irrigation District
LYT	Lytle Creek
<	Less than
≤	Less than or equal to:
m	Meter
m^2	Square Meter
mm	Millimeter
max	Maximum
MCK	McKay Creek
Mg	Milligram
mg/L	Milligrams/liter
min	Minimum
MLCO	Mill Creek nr Schoolhouse; Hydromet Gauge #14083400 code
MP	Mile Post
mpg	Miles per gallon
MSL	Mean Sea Level
MT	Montana
MW	Megawatt
MWMT	Maximum Weekly Maximum Temperature
#	Number
N	North
No.	Number
NA	Not Applicable
ND	No Data Reviewed
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NPDES	National Pollutant Discharge Elimination System
nr	Near
NRCS	Natural Resources Conservation Service
NUID	North Unit Irrigation District
O & M	Operation and Maintenance
0+ age	Juvenile fish – less than a year in age
OAR	Oregon Administrative Rule
OCH	Ochoco Creek
OCRO	Ochoco Creek blw Marks Creek; Hydromet Gauge #14082550 code
OCHO	Ochoco Creek blw Reservoir; Hydromet Gauge #14085300 code
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ODOT	Oregon Department of Transportation
OID	Ochoco Irrigation District
OR	Oregon
OSU	Oregon State University
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Department of Water Resources

Acronym, Symbol, Abbreviation	Definition
%	Percent
P	Probability
p.	Page/pages
Pers. Comm.	Personal Communication
PGE	Portland General Electric
PHABSIM	Physical Habitat Simulation
±	Plus or Minus
POD	Point-of-Diversion
PROC.	Proceedings
PSE	Puget Sound Energy
Q	Discharge (cfs)
R.	River
R^2	Coefficient of Determination; Square of the Correlation Coefficient
r^2	Coefficient of Determination; Square of the Correlation Coefficient
R2	R2 Resource Consultants, Inc.
RBT	Rainbow Trout
Rd	Road
Reclamation	United State Bureau of Reclamation
Res.	Reservoir
RM	River Mile
§	Section
SA	Surface Area (ft^2)
SA_e	Effective Surface Area (ft^2)
SC	Screen Contact
SID	Swalley Irrigation District
SOP	Standard Operating Procedure
STH	Steelhead Trout
SWCD	Soil and Water Conservation District
SWW	Selective Water Withdrawal
3D	Three Dimensional
TDG	Total Dissolved Gas
TFW	Timber, Fish, Wildlife
TID	Tumalo Irrigation District
TIR	Thermal Infrared
TMDL	Total Maximum Daily Load
TR	Transect
TSID	Three Sisters Irrigation District
TSS	Total Suspended Solids
UCM	Unit Characteristic Method
UDLAC	Upper Deschutes Local Advisory Committee
UDWC	Upper Deschutes Watershed Council
ug	Microgram
UGB	Urban Growth Boundary
UP	Upstream Passage Alternative
US	United States
USACOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USBR	United State Bureau of Reclamation

Acronym, Symbol, Abbreviation	Definition
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
u/s	Upstream
VAF	Velocity Adjustment Factor
Vol.	Volume
vs.	Versus
VSP	Viable Spawning Population
w/	With
WA	Washington
WF	West Fork
WHY	Whychus Creek
WP	Wetted Perimeter
WPN	Watershed Professional Network
WSE	Water Surface Elevation
WUA	Weighted Useable Area
ww	Wetted Width
WWTP	Wastewater Treatment Plant
XS	Cross Section
Yr	Year
Z	Depth

1.0 Introduction

1.1. Background

Seven central Oregon irrigation districts (Arnold, Central Oregon, North Unit, Ochoco, Swalley, Three Sisters, and Tumalo) and the City of Prineville, Oregon (City) are seeking Federal Endangered Species Act (ESA) incidental take permits for the Middle Columbia River steelhead trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and up to 12 other listed and unlisted species inhabiting the Deschutes River basin. As required by Section 10 of the ESA, the City and the irrigation districts (collectively the Applicants) are preparing the Deschutes Basin Multi-species Habitat Conservation Plan (DBHCP) to minimize and mitigate the effects of the proposed incidental take on the covered species. The DBHCP is being prepared in cooperation with a multi-stakeholder Working Group representing the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), U.S. Bureau of Reclamation (Reclamation), U.S. Bureau of Land Management (BLM), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), Oregon Water Resources Department (OWRD), the Confederated Tribes of the Warm Springs, Crook County, and several non-governmental entities.

This study has been completed to support development of the DBHCP. The scope of work for the study was reviewed and approved by the Working Group prior to initiation. Drafts of this report were provided to the Working Group for review and comment, and this final report reflects their input. The report does not necessarily represent the consensus view of the Working Group. Rather, it is intended to serve as a reference document for the members of the group as they collaboratively develop plans for additional studies and conduct analyses of the effects of the covered activities and the benefits of various minimization and mitigation options.

1.2. Purpose and Scope of the Study

Phase 1 of this study provides an initial screening-level evaluation of the potential for covered releases, discharges, return flows, and spills to measurably affect surface water temperatures and potentially generate adverse effects to covered fish species. Storage and diversion effects on water temperature will be addressed in later phases of this study. For purpose of the current study is to prioritize releases, discharges, returns and spills for future assessment. Criteria used for prioritization include: 1) release rate, timing, and thermal properties of the return; 2) flow rate and ambient temperatures of the receiving water; and 3) the seasonal presence and temperature requirements of various life stages of covered fish species. The covered fish species are steelhead trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), Chinook salmon (*O. tshawytscha)*, and sockeye salmon *(O. nerka).*

Steelhead trout are currently being reintroduced above the Pelton Round Butte Project, and will eventually have access up to Big Falls at river mile (RM) 132.0 on the Deschutes River, to a natural falls at RM 37.1 on Whychus Creek, to Bowman Dam at RM 70.5 on the Crooked River, to Ochoco Dam at RM 11.1 on Ochoco Creek, and to various downstream tributary waters to these locations. Suitable temperature ranges for various life history stages of steelhead trout are summarized in Table 1-1. Preferred water temperatures for steelhead vary with life stage, but generally occur below 14°C (57°F), while temperatures above 23.9°C (75°F) can be lethal to adults (Pauley et al. 1989; USEPA 2001; McCullough et al. 2001; and NMFS 2008).

Bull trout are present up to Big Falls on the Deschutes River, to Opal Springs Dam at RM 7.2 on the Crooked River, and upstream of Alder Springs (RM 1.6) to the USFS 6360 road crossing at RM 5.7 on Whychus Creek. The species was historically present in the upper Deschutes River, but they are currently considered extirpated above Big Falls (Buchanan et al. 1997) except for an isolated population in Odell Lake and Odell Creek at the extreme upper (southern) end of the basin. The Odell Lake basin is upstream of the DBHCP covered lands and zone of the potential influence of covered activities.

Volitional upstream fish passage will be in place at Opal Springs Dam on the Crooked River no later than 2016, but it is not known whether and how far bull trout will travel above the dam once they are given the opportunity. Critical habitat for the bull trout has been designated in the Crooked River upstream to the State Route 97 crossing (RM 18) and in Whychus Creek upstream to RM 5.7 (USFWS 2010). Suitable temperature ranges for various life history stages of bull trout are summarized in Table 1-1. Preferred water temperatures for bull trout vary with life stage, but generally occur below 9°C (48°F) for spawning and below 15°C (59°F) for juvenile rearing (McPhail and Murray 1979; Fraley and Shepard 1989; Goetz 1989; Kraemer 1994; Martin et al. 1992; McMahon et al. 1998, 1999, 2000; USEPA 2001; McCullough et al. 2001; Myrick 2002; Essig et al. 2003; and USFWS 2012). The general distribution of bull trout in watersheds is usually limited to waters below 18°C (64°F). Exposure of rearing juveniles to temperatures above 20.8°C (69°F) for more than 60 days, or 23.0°C (73°F) for more than 7 days can be lethal (McMahon et al. 1999).

Chinook salmon are currently being reintroduced above the Pelton Round Butte Project, and will eventually have access up to Big Falls at RM 132.0 on the Deschutes River, to a natural falls at RM 37.1 on Whychus Creek, to Bowman Dam at RM 70.5 on the Crooked River, to Ochoco Dam at RM 11.1 on Ochoco Creek, and to various downstream tributary waters to these locations. Suitable temperature ranges for various life history stages of Chinook salmon are summarized in Table 1-1. Preferred water temperatures for Chinook salmon vary with life stage, but generally occur below 14°C (57°F) for spawning, below 13°C (55°F) for incubation, and below 16°C (61°F) for juvenile rearing (Brett 1952; CDWR 1988; and McCullough et al. 2001). The lethal limit lies in excess of 22.0°C (72°F) for rearing juveniles and in excess of 25°C (77°F) for adults (Bell 1991).

The anadromous form of sockeye salmon is currently being reintroduced above the Pelton Round Butte Project when existing kokanee salmon (landlocked sockeye) find their way to the Round Butte downstream collection facility. Trapped kokanee salmon are marked and released downstream of the Pelton-Round Butte Project. Returning adults from these liberations are then released upstream to spawn naturally in tributaries draining to Lake Billy Chinook or potentially along the reservoir shoreline. The existing kokanee population spawns primarily in the Metolius River basin outside of the DBHCP covered lands, but some spawning is reported in the Deschutes River downstream of Steelhead Falls (RM 128) and in the lower sections of Whychus Creek. Juvenile rearing and maturation occur within Lake Billy Chinook. Returning adult sockeye will presumably spawn and rear in a similar fashion. Although sockeye salmon are not anticipated to use tributary waters within the covered lands to a large extent, their presence cannot be discounted. As a result, sockeye salmon could have access up to Big Falls at RM 132.0 on the Deschutes River, to a natural falls at RM 37.1 on Whychus Creek, to Bowman Dam at RM 70.5 on the Crooked River, to Ochoco Dam at RM 11.1 on Ochoco Creek, and to various downstream tributary waters to these locations. Suitable temperature ranges for various life

Table 1-1. Water temperature suitability for salmonid fish species covered by the DBHCP.

Species	Life History Stage	Season[#]	Water Temperature Suitability (°C)				
			Preference	Avoidance	Stress/ Disease	Delay	Lethal
Chinook salmon	Adult Migration[1]	May-Aug	< 19.0	> 19.4	ND	> 21.0	> 25.0
	Spawning[2]	Aug-Sep	6.0 – 14.0	< 5.6; > 16.0	ND	> 16.0	ND
	Incubation[3]	Aug-Feb	4.5 – 12.8	< 1.7; > 14.4	>15.6	ND	13.9 - 19.4
	Juvenile Rearing[4]	All Year	7.2 – 15.6	ND	19.1	ND	> 22.0
	Outmigration[5]	Feb-May	ND	ND	ND	17.0 – 20.0	ND
Sockeye salmon	Adult Migration[6]	Fall	7.2 – 15.5	ND	ND	18.0 – 22.8	23.5 – 24.8
	Spawning[7]	Fall	8.0 – 13.0	ND	ND	ND	ND
	Incubation[8]	Fall-Winter	4.4 – 12.7	ND	>15.6	ND	16.7 – 18.3
	Juvenile Rearing[9]	all year (in LBC)	11.6 – 14.4	>18.0	< 7.2; > 23.0	ND	24.4
	Outmigration[10]	Spring	> 7.0	ND	ND	<5.0; >12.0	ND
Steelhead trout	Adult Migration[11]	Oct-Mar	10.0 – 12.8	< 7.2; > 14.4	ND	> 21.0	> 23.9
	Spawning[12]	Mar-May	4.0 – 12.0	< 3.9; > 9.4	ND	ND	> 21.0
	Incubation[13]	Mar-Jun	5.6 – 11.1	ND	> 15.0	ND	ND
	Juvenile Rearing[14]	All Year	< 14.0	> 19.0	> 22.0	ND	ND
	Outmigration[15]	Apr-Jun	ND	ND	ND	12.0 – 13.6	ND
Bull trout	Adult Migration[16]	Apr-Jun	< 15.0	> 18.0	ND	ND	ND

Species	Life History Stage	Season[#]	Water Temperature Suitability (°C)				
			Preference	Avoidance	Stress/ Disease	Delay	Lethal
	Spawning[17]	Aug-Oct	5.6 – 9.0	> 11.0	ND	ND	ND
	Incubation[18]	Aug-Mar	2.0 – 6.0	ND	> 6.0	ND	ND
	Rearing[19]	All Year	7.0 – 15.0	> 16.0	> 16.0	ND	20.8[20] 23.0[21]

ND = No Data Reviewed

References:

#) **NPCC 2004; PGE 2012**
1) California Department of Water Resources 1988
2) Brett 1952; McCullough et al. 2001
3) California Department of Water Resources 1988
4) Bjornn and Reiser 1991; Bell 1991
5) Lindsay et al. 1989 *in NPCC 2004*; McCullough et al. 2001
6) Brett 1952; Brett 1971; Bell 1991; Fies et al. 1998 *in NPCC 2004*; McCullough et al. 2001
7) Pauley et al. 1989; Bell 1991; Bjornn and Reiser 1991; Fies et al. 1998 *in NPCC 2004*
8) Reiser and Bjornn 1979; Pauley et al. 1989; Fies et al. 1998 *in NPCC 2004;* USEPA 2001
9) Donaldson and Foster 1941 ; Brett 1952; Brett 1964 ; Brett et al. 1969; Pauley et al. 1989; Bell 1991
10) Foerster 1968; Hart 1973; McCullough et al. 2001
11) McCullough et al. 2001
12) USEPA 2001
13) Bell 1991; USEPA 2001
14) USEPA 2001
15) McCullough et al. 2001
16) Rieman and McIntyre 1993; Dunham et al. 2003; USFWS 2012
17) USEPA 2001; USFWS 2012
18) McPhail and Murray 1979; Batt 1996, Brun and Dodson 2000; USEPA 2001
19) McPhail and Murray 1979; Wydoski and Whitney 1979; Weaver and White 1985; Fraley and Shepard 1989; Goetz 1989; Kraemer 1994 Martin et al. 1992; Brown 1992; Batt 1996; McMahon et al. 1998, 1999, 2000; Myrick 2002; Essig et al. 2003
20) 60-day exposure (McMahon et al. 1999)
21) 7-day exposure (McMahon et al. 1999)

history stages of sockeye salmon are summarized in Table 1-1. Preferred water temperatures for sockeye salmon vary with life stage, but generally occur below 13°C (55°F) for spawning, below 12.7°C (54.9°F) for incubation, and below 14.4°C (58°F) for juvenile rearing (Brett 1952; Brett et al. 1969; Pauley et al. 1989; Bell 1991; Bjornn and Reiser 1991; McCullough et al. 2001; and USEPA 2001). The lethal limit lies in excess of 22.0°C (72°F) for rearing juveniles and in excess of 25°C (77°F) for adults (Bell 1991).

Covered activities with the potential to affect surface water temperature are the storage of irrigation water, the release of stored irrigation water, the diversion of irrigation water, operational spills of irrigation water, return of tailwater, discharge of sewage treatment plant effluent, return of water from a hydroelectric project, and inter-basin transfer of water. The storage and release of irrigation water occur at five reservoirs covered by the DBHCP (Crescent Lake, Crane Prairie, Wickiup, Prineville and Ochoco). Temperature effects from water releases at all five reservoirs are addressed in this report. Diversion of irrigation water occurs at several dozen locations within the covered irrigation districts. The effects of diversion and storage on instream water temperature will be addressed in Phase 2 of this study, and are not addressed in this report.

Diverted irrigation water that is allowed to flow back into a natural river or creek is known as return flow. Two types of return flow may occur on the covered lands, tailwater and operational spills. Tailwater is water that has been delivered to irrigated lands and subsequently returned to a river or creek through surface or shallow subsurface flow. Tailwater may enter a river or creek directly from irrigated land, or through a drain or canal operated by an irrigation district. Eight instances of tailwater are addressed in this report.

Operational spills represent diverted irrigation water that returns to a river or creek without being delivered to irrigated lands. Operational spills are used to manage flows within district canals, flush canals, or drain canals during emergencies or at the end of the irrigation season. The amount of spill varies by irrigation district and is largely a function of system design. Some districts are able to operate without spilling, while others require spills to maintain reliable water delivery. Twenty-nine operational spills are evaluated in this report.

One sewage treatment plant discharge operated by the City of Prineville is covered by the DBHCP and addressed in this report. The seasonal discharge occurs on the Crooked River at RM 46.8, and is covered by a National Pollutant Discharge Elimination System (NPDES) permit.

One hydroelectric project covered by the DBHCP returns water to the Deschutes River, and one inter-basin transfer of water occurs in the headwaters of Tumalo Creek. Both are also addressed in this report.

Key terms used in this study are defined below:

Storage: Water stored in any of the five covered reservoirs for later release.

Release: Flows released from storage at any of the five covered reservoirs for use in irrigation.

Tailwater Return: Water delivered to irrigated lands and subsequently returned to a river or stream through surface or shallow subsurface flow. Tailwater may enter surface waters directly from irrigated land, or through a drain or canal operated by an irrigation district.

Operational Spill: Diverted irrigation water that returns to surface waters without delivery to irrigated lands.

Discharge: City of Prineville's sewage treatment plant discharge.

This first phase of study is an examination of the potential for each release, return flow, discharge, or inter-basin transfer to adversely affect surface water temperature based on the season of flow and estimates of mass balance (quantity of release / return flow, compared to total flow in the receiving water). The purpose of this phase of Study 2 is to identify those releases, discharges, returns, and spills with the greatest potential to influence covered fish species to help focus future assessments. Those releases, discharges, returns and spills with the potential to adversely affect surface water temperature will be evaluated in greater detail in subsequent phases of this study.

2.0 Covered Releases, Returns, and Discharges of Water

2.1. Overview

This report addresses the potential effects on surface water temperature associated with the release of irrigation water from five reservoirs, operation spills of irrigation water at 29 locations, return of tailwater at eight locations, one hydroelectric project tailrace, one municipal sewage treatment plant discharge, and one small inter-basin transfer of water from Crater Creek to Tumalo Creek. These activities are summarized in Table 2-1, shown in Figure 2-1, and described in greater detail below.

2.2. Crescent Creek

2.2.1. Crescent Lake Dam

Crescent Creek is a tributary to the Little Deschutes River. The storage and release of irrigation water occur at Crescent Lake Dam, a 40-foot high earthen structure at RM 29.0 on Crescent Creek, about 114 miles upstream of Bend. The dam enlarges a natural lake to form Crescent Lake Reservoir. The current dam has a crest elevation of 4,847 feet above MSL, a length of 450 feet, an uncontrolled spillway, and concrete outlet works with a capacity of 1,325 cfs. The reservoir has an active storage capacity of 86,900 acre-feet and a surface area of about 4,008 acres at full pool. The reservoir is generally filled from November through June, and then drawn down from July through mid-October. Irrigation water released from Crescent Lake is conveyed down Crescent Creek, the Little Deschutes River, and the Deschutes River until it is diverted at the Bend (Stiedl) Diversion. Peak releases occur in mid-July through September. According to Conserved Water Agreement CW-37 between Tumalo Irrigation District and the State of Oregon, a flow of at least 5 cfs is maintained in Crescent Creek below Crescent Lake Dam at all times.

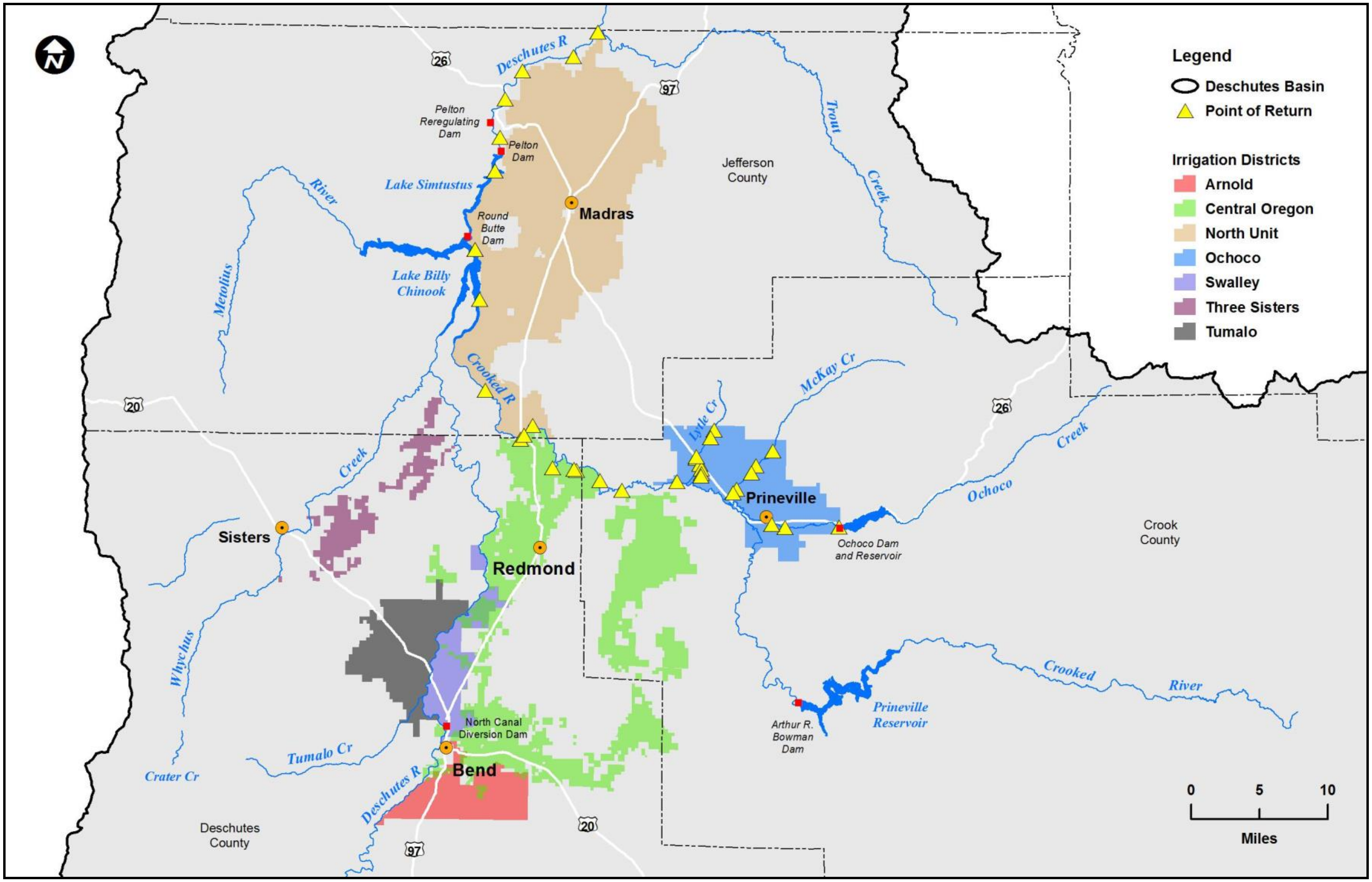

Figure 2-1. Points of return covered by the DBHCP.

Table 2-1. Points of release, return, and discharge of water covered by the DBHCP.

Receiving Water	Location (RM) [1]	Release / Return Name	Maximum Rate of Release/ Return (cfs)	Maximum Annual Release/ Return (acre-feet)	Description
Crescent Creek	29.0	Crescent Lake Dam	1,325.0		Storage and release of irrigation water
Deschutes River	238.5	Crane Prairie Dam	1,800.0		Storage and release of irrigation water
Deschutes River	226.8	Wickiup Dam	4,000.0		Storage and release of irrigation water
Deschutes River	169.4	Siphon Hydroelectric Project tailrace	640.0		Hydroelectric Project tailrace flow
Lake Billy Chinook	112.1	NUID Lateral 41 Drain	1.1	396.0	Operational spill throughout the irrigation season
Lake Billy Chinook	112.1	NUID Lateral 43 Drain	1.2	432.0	Operational spill throughout the irrigation season
Willow Creek to Lake Simtustus	104.6	NUID Lateral 51 Drain	1.2	432.0	Operational spill throughout the irrigation season
Willow Creek to Lake Simtustus	104.6	North Unit Main Canal crossing at Willow Creek	100.0	100.0	Operational spill once/year, plus emergencies
Campbell Creek to Pelton Reregulating Reservoir	101.7	NUID Laterals 57/59 Drain	1.3	469.0	Operational spill throughout the irrigation season
Deschutes River	97.8	NUID Lateral 63 Drain	1.0	360.0	Operational spill throughout the irrigation season
Deschutes River	94.5	NUID Lateral 64 Drain	1.0	360.0	Operational spill throughout the irrigation season
Frog Springs Creek to Deschutes River	90.1	North Unit Main Canal terminus at Frog Springs	10.0 (avg.)	3,600.0	Operational spill throughout the irrigation season
Sagebrush Creek to Trout Creek to Deschutes River	2.6 / 87.2	NUID Lateral 58-11 Drain	50.0	10.0	Operational spill once/year, plus emergencies

Receiving Water	Location (RM) [1]	Release / Return Name	Maximum Rate of Release/ Return (cfs)	Maximum Annual Release/ Return (acre-feet)	Description
Mud Springs Creek to Trout Creek to Deschutes River	2.6 / 87.2	North Unit Main Canal terminus at Mud Springs	5.0	1,800.0	Operational spill throughout the irrigation season
Tumalo Creek to Deschutes River	21.7 / 160	TID ditch release	75.0		During spring snowmelt
Crooked River	70.5	Bowman Dam	3,300.0		Storage and release of irrigation water
Crooked River	49.4	Juniper Canyon flood control channel	8.0		Local tailwater during the irrigation season
Crooked River	46.8	Prineville Sewage Treatment Plant discharge	1.5		Winter discharge as receiving flows permit, as per NPDES permit.
Crooked River	44.9	McKay Creek confluence	11.0		See description for McKay Creek below
Crooked River	41.0	Lytle Creek confluence	37.2	8,982.4	See description for Lytle Creek below
Crooked River	39.6	The Gap	18.5	2,220.0	Operational spill throughout the irrigation season
Crooked River	34.1	COID Dry Canyon return	64.0		Operational spill from the terminus of the Central Oregon Canal throughout the irrigation season
Crooked River	30.2	Lone Pine Irrigation District Canal return	10.0		Local tailwater during the irrigation season
Crooked River	27.7	Lone Pine Delivery Spill	10.0	500.0	Operational spill throughout the irrigation season
Crooked River	27.5	North Unit Main Canal crossing	200.0	50.0	Operational spill less than once/year, plus emergencies
Crooked River	25.0	Pilot Butte Canal J Waste	1.0		Operational spill less than once/year, plus emergencies
Crooked River	19.6	NUID Lateral 31 Drain	1.0	360.0	Operational spill throughout the irrigation season

Receiving Water	Location (RM) [1]	Release / Return Name	Maximum Rate of Release/ Return (cfs)	Maximum Annual Release/ Return (acre-feet)	Description
Crooked River	18.4	NUID Lateral 34 Drain	1.0	360.0	Operational spill throughout the irrigation season
Crooked River	18.0	Pilot Butte Canal H-17 Return	3.0		Operational spill less than once/year, plus emergencies
Crooked River	11.9	North Unit Main Canal return at Mile Post 37	100.0	35.0	Operational spill once/year, plus emergencies
Lake Billy Chinook	2.7	NUID Lateral 37 Drain	1.0	360.0	Operational spill throughout the irrigation season
Ochoco Creek	11.1	Ochoco Dam	20.0		Storage and release of irrigation water to Ochoco Cr.
Ochoco Creek	6.3	OID D-2 Drain	2.0		Local tailwater during the irrigation season
Ochoco Creek	5.1	Crooked River Diversion Canal spill	75.0	8,010.1	Operational spill throughout the irrigation season
McKay Creek	5.8	Ochoco Main Canal spill			Operational spill throughout the irrigation season
McKay Creek	3.9	Dry Creek live flow and spill			Live flow plus operational spill
McKay Creek	3.2	Crooked River Distribution Canal spill at Reynolds	54.0	3,228.0	Operational spill throughout the irrigation season
McKay Creek	1.3	OID D-8 Drain			Local tailwater during the irrigation season
McKay Creek	1.0	Ryegrass Canal spill	25.0		Operational spill throughout the irrigation season
Lytle Creek	5.7	Grimes Flat West Canal spill			Operational spill throughout the irrigation season
Lytle Creek	5.0	Ochoco Main Canal spill			Operational spill throughout the irrigation season
Lytle Creek	3.2	OID D-7 Drain			Local tailwater during the irrigation season

Receiving Water	Location (RM) [1]	Release / Return Name	Maximum Rate of Release/ Return (cfs)	Maximum Annual Release/ Return (acre-feet)	Description
Lytle Creek	3.0	Crooked River Distribution Canal spill			Operational spill throughout the irrigation season
Lytle Creek	2.3	OID 827 Drain			Local tailwater during the irrigation season
Lytle Creek	1.9	OID 825 Drain			Local tailwater during the irrigation season
Lytle Creek	1.5	OID 823 Drain			Local tailwater during the irrigation season
Lytle Creek	1.3	Ryegrass Canal spill			Operational spill throughout the irrigation season

[1] The RM corresponds to the receiving water body in the left column. The RMs for the named reservoirs are derived from the inundated mainstem river. Two RMs are provided where releases occur into tributaries prior to flowing into mainstem rivers.

2.3. Deschutes River

2.3.1. Crane Prairie Dam

Crane Prairie Dam is a federally-owned facility located at RM 238.5 on the mainstem Deschutes River. It is operated by Central Oregon Irrigation District (COID) as a transferred works under the jurisdiction of Reclamation. The dam has a controlled outlet capacity of 1,800 cfs and an uncontrolled spillway with a capacity of 2,500 cfs. The reservoir has a storage capacity of 55,300 acre-feet and a surface area of about 4,900 acres at full pool. Reservoir refill is managed to maximize storage while maintaining relatively uniform flow downstream in the Deschutes River. This approach is accomplished by monitoring snow pack and streamflow to predict water availability, and storing only at the rate needed to achieve refill. There is no requirement to release for instream flow below Crane Prairie Dam, but COID and the other districts storing water behind the dam have an informal, non-binding agreement with the Oregon Watermaster to release a minimum of 30 cfs for fish and wildlife purposes.

Irrigation releases from Crane Prairie Reservoir typically begin in April, but the reservoir does not draft appreciably until late May or early June when irrigation demand begins to exceed the live flow water rights of the districts. In most years, irrigation releases reach a peak between 200 and 500 cfs in June and July. Releases may be higher in years of abundant water, or they may be lower in years of limited storage to ensure availability through the end of the irrigation season. Irrigation releases typically end by early October.

2.3.2. Wickiup Dam

Wickiup Dam is located at RM 226.8 on the mainstem Deschutes River, approximately 32 miles southwest of Bend. The project is a federal facility under the jurisdiction of Reclamation. The dam is a 100-foot high rock-faced earthen structure with a crest elevation of 4,347 feet above MSL and length of 13,860 feet. The dam has a controlled outlet capacity of 4,000 cfs and the East Dike has an emergency spillway with a capacity of 5,000 cfs. The emergency spillway is designed to be used only if the controlled outlet works are inoperative, or in the case of an unprecedented flood when the reservoir cannot be held below elevation 4,339 feet by the outlet works alone.

Wickiup Reservoir has a storage capacity of 200,000 acre-feet and a surface area of about 11,200 acres at full pool. The reservoir is operated in coordination with Crane Prairie Dam and Reservoir, 2 miles upstream. Storage and release are directed by the Oregon Watermaster and implemented by North Unit Irrigation District (NUID) personnel operating the dam. Reservoir refill is managed to maximize storage while maintaining relatively uniform flow downstream in the Deschutes River. This approach is accomplished by monitoring snow pack and streamflow to predict water availability, and storing only at the rate needed to achieve refill. In accordance with a requirement established by the Oregon State Engineer in 1952, the flow below Wickiup Dam is not allowed to drop below 20 cfs. Full pool in Wickiup Reservoir is achieved in about seven out of ten years.

Irrigation releases from Wickiup Reservoir typically begin by mid-April, but can be delayed until May or June in wet years. They usually reach a peak of 1,400 to 1,600 cfs in July, although they can go higher. Irrigation releases decrease in September, and typically end by mid-October. NUID does not release water outside the irrigation season specifically for stock runs.

2.3.3. Siphon Hydroelectric Project

Central Oregon Irrigation District owns and operates the Siphon Hydroelectric Project (FERC Project No. 3571) on the Deschutes River within the city limits of Bend. The 5.5-megawatt (MW) project generates power from water diverted out of the Central Oregon Canal. After passing through the powerhouse, water is returned to the Deschutes River approximately 1.5 miles downstream of where it is first diverted at the Central Oregon Headworks. Flow to the powerhouse can be provided by irrigation water destined for diversion at the Pilot Butte Headworks 4.4 miles downstream of the powerhouse, or by a non-consumptive water right of 640 cfs that allows the Siphon Project to operate outside the irrigation season. The Siphon Project is operated run-of-river, as COID has no means of storing water for hydropower generation. The FERC license for the project requires a minimum instream flow of 400 cfs in the 1.5-mile bypass reach. The minimum instream flow, combined with the minimum operating flow for the project of 75 cfs, means the project only operates when the river flow above the Central Oregon Canal Headworks is at least 475 cfs. The project operates typically nine to ten months per year, and may operate year-round in years of high streamflow.

2.3.4. North Unit Irrigation District Returns

The North Unit Irrigation District returns flow to the Deschutes River or tributary streams (other than the Crooked River) at ten locations (Figure 2-2), including three from the North Unit Main Canal and seven from laterals. Five of the ten NUID returns enter the Deschutes River at one of the reservoirs associated with the Pelton Round Butte Project (Lake Billy Chinook, Lake Simtustus, and Pelton Reregulating Reservoir). Most of the return flows are spills to maintain proper water levels in the canals throughout the irrigation season. Other return flows are spills that serve the dual function of flushing the canal at the start of the irrigation season and draining the canal during emergencies. The largest of these spills occur in Frog Springs and Mud Springs creeks. Both of these spills return excess canal flow to wetlands near the northern terminus of the canal. Frog Springs is a natural wetland about 1.5 miles from the Deschutes River at RM 90.1 that has been enlarged by the addition of irrigation water. The Mud Spring spill occurs to a man-made wetland along Mud Springs Creek prior to discharging into Trout Creek at RM 2.6.

2.4. Tumalo Creek

2.4.1. Crater Creek Ditch

Tumalo Creek is a tributary to the Deschutes River at RM 160, above Big Falls. Crater Creek, Little Crater Creek, and Soda Creek are seasonal streams that drain into Sparks Lake, an alpine lake with no surface outlet west of the Tumalo Creek basin. The creeks flow primarily in response to spring snowmelt. Tumalo Irrigation District diverts a maximum of 75 cfs of Crater Creek, Little Crater Creek, and Soda Creek flows into a 2-mile ditch that empties into Tumalo Creek at about RM 21.7, where it is referred to as the Middle Fork of Tumalo Creek (Figure 2-3). There are no operational spills or other return flows to Tumalo Creek, Crater Creek, Little Crater Creek, or Soda Creek.

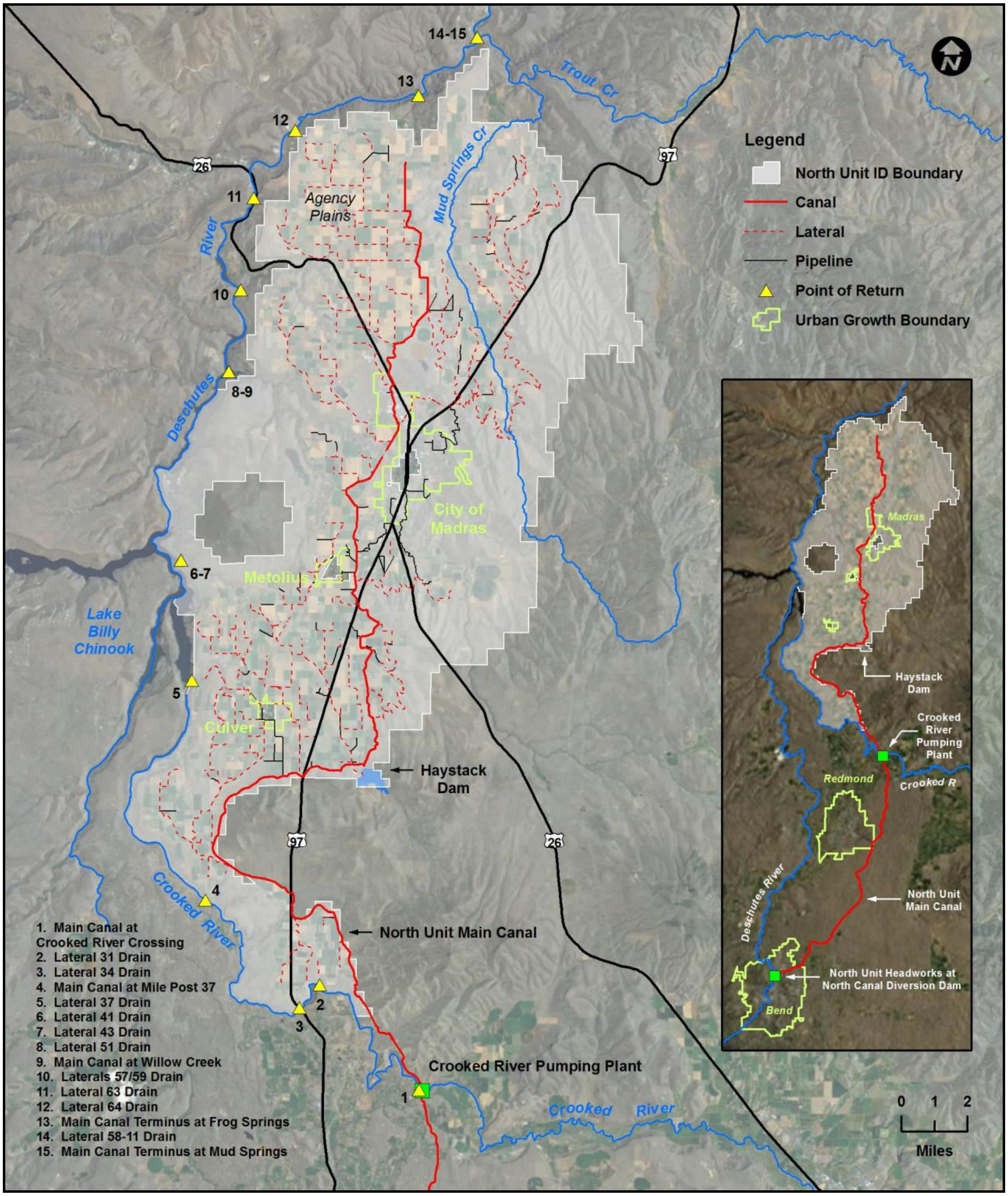

Figure 2-2. North Unit Irrigation District points of return to the Deschutes and Crooked rivers.

Figure 2-3. Tumalo Irrigation District Crater Creek Ditch transfer to Tumalo Creek.

2.5. Crooked River

2.5.1. Bowman Dam

Arthur R. Bowman Dam is a federal facility that is operated by OID at RM 70.5 on the Crooked River, approximately 20 miles upstream of Prineville. The dam is an earthfill structure with a crest height of 182 feet, a crest elevation of 3,264 feet above MSL, and a length of 790 feet. The outlet has a controlled capacity of 3,300 cfs and the spillway has an uncontrolled capacity of 8,120 cfs. Prineville Reservoir has a total volume of 150,216 acre-feet and a current active capacity of 148,633 acre-feet as determined by a sedimentation study completed in 1998. Surface area at full pool is 3,028 acres. Maximum fill capacity is reached in an average of 8 out of 10 years. Water is released from Prineville Reservoir into the Crooked River at Bowman Dam for downstream diversion by OID and its patrons. The authorizing legislation for Prineville Reservoir requires a minimum release of 10 cfs for downstream fish and wildlife habitat. In 1990, Reclamation implemented a nonbinding administrative decision to release a minimum of 75 cfs when doing so does not impact contractual obligations to store and deliver irrigation water. As a result, minimum releases from Prineville Reservoir are only less than 75 cfs in low-water years or during periods of dam inspection and maintenance. Releases may drop as low as 30 cfs in drought years.

2.5.2. Ochoco Irrigation District Returns

OID's primary direct return to the Crooked River at RM 39.6 is called The Gap (Figure 2-4). This return is the terminus of the Ochoco Main Canal, where water is spilled throughout the irrigation season to manage flows within the canal. Monthly average spill during 2006 through 2011 ranged from 3.0 to 8.2 cfs. The maximum daily average spill reported during that period was 18.5 cfs, which occurred for one day in May 2007. The minimum daily average of 0.1 cfs was reported for one day each in May 2006 and May 2009.

OID also spills water into two tributaries of the Crooked River (McKay Creek and Lytle Creek) at multiple locations. These returns are described in Sections 2.7 *McKay Creek* and 2.8 *Lytle Creek*.

An estimate of up to 8.0 cfs of tailwater from the OID system and other local sources enters the Crooked River through the Juniper Canyon flood control channel at RM 49.4. There are no data on total annual flow in this ditch.

2.5.3. Central Oregon Irrigation District Returns

Water diverted by COID from the Deschutes River is operationally spilled into the Crooked River at four locations; one from the Central Oregon Canal and three associated with the Pilot Butte Canal (Figure 2-5). Water that reaches the end of the Central Oregon Canal is spilled near the top of Dry Canyon, where it continues as surface and shallow subsurface return flow to the Crooked River at about RM 34.1, approximately 13 miles downstream of Prineville. Water is spilled directly from the Pilot Butte Canal throughout the irrigation season to manage the rate of delivery to the Lone Pine Irrigation District Canal. This water travels a short distance before reaching the Crooked River at about RM 27.7. Water is also spilled less than once per year from two Pilot Butte Canal Laterals (J-22 and H-17) to facilitate lowering of the canal for operational or emergency purposes. These flows reach the Crooked River at RM 25.0 and RM 18.0, respectively.

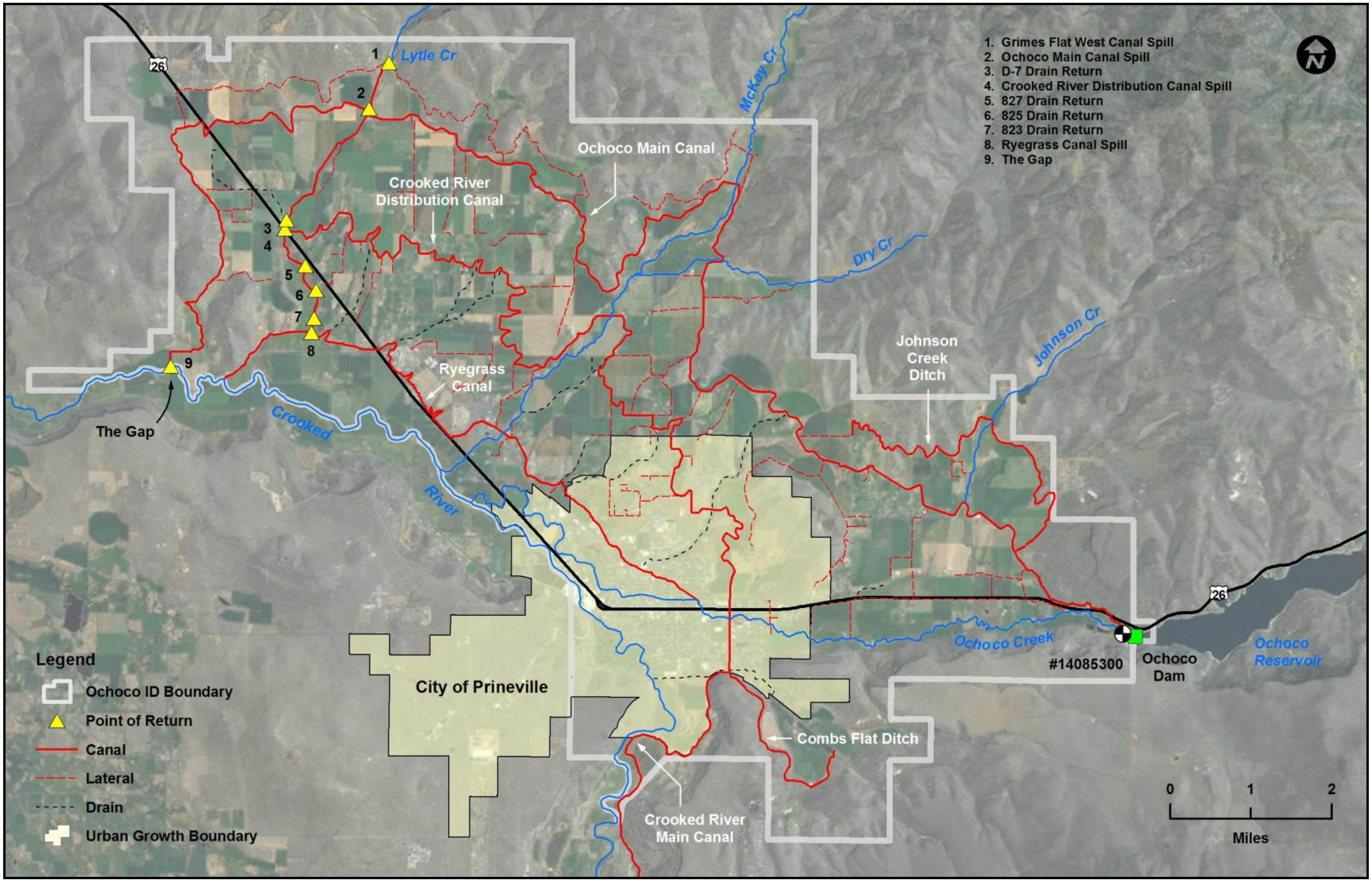

Figure 2-4. **Ochoco Irrigation District points of return at the Gap and to Lytle Creek.**

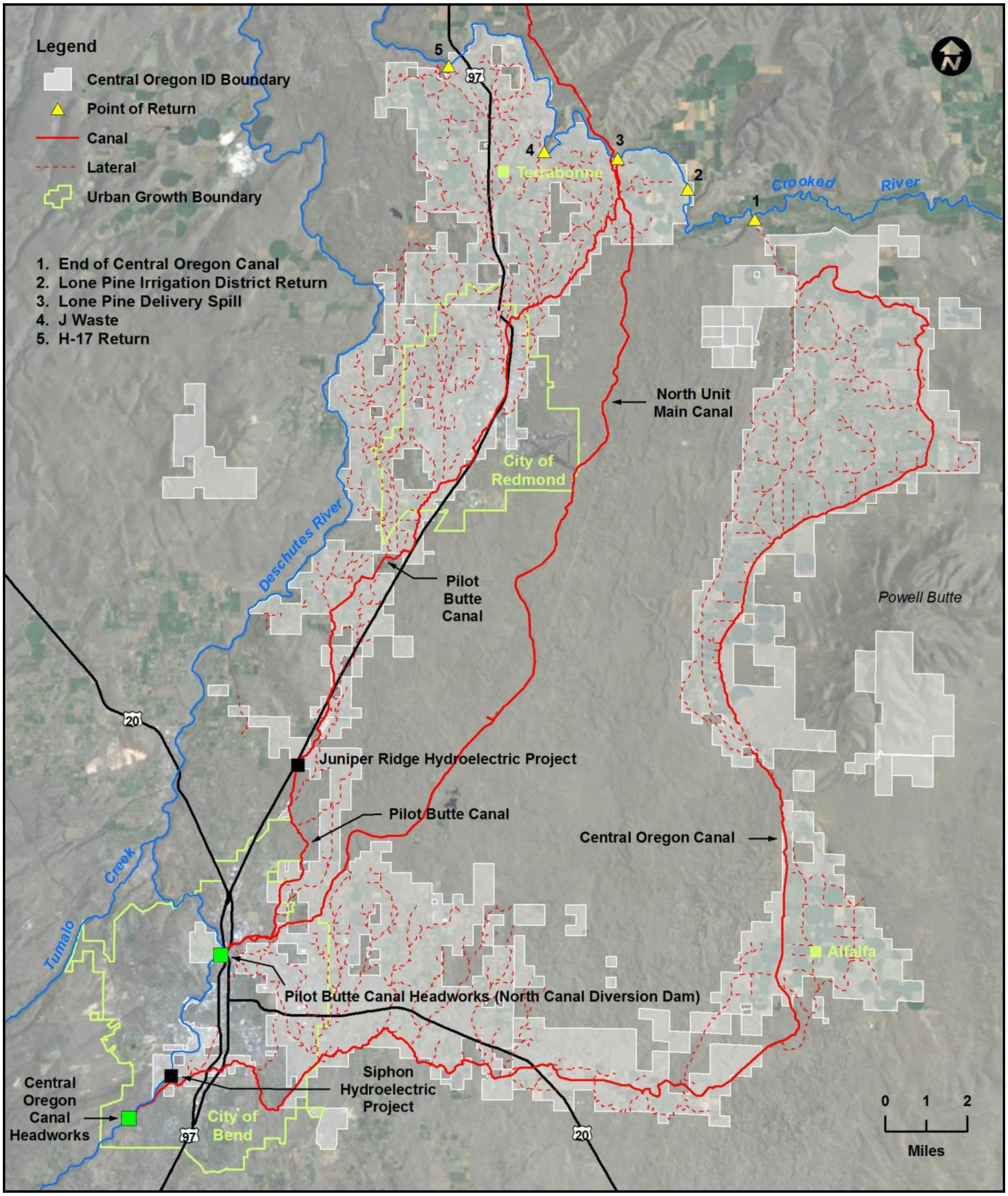

Figure 2.5. Central Oregon Irrigation District and Lone Pine Irrigation District points of return to the Crooked River.

2.5.4. North Unit Irrigation District Returns

NUID has five operational spills into the Crooked River (see Figure 2-2). Water spills from the North Unit Main Canal for one day each year during annual startup where the canal crosses the Crooked River (RM 27.5), and for one day or less in some but not all years downstream at Mile Post 37. Water is also spilled from the Lateral 31 drain (RM 19.6) and Lateral 34 drain (RM 18.4) as needed throughout the irrigation season. Lateral 37 drains to Lake Billy Chinook at Crooked River RM 2.7.

2.5.5. City of Prineville Sewage Treatment Plant Effluent

The current discharge of treated effluent from the City of Prineville's sewage treatment plant is allowed under the conditions of NPDES Permit No. 101433; ODEQ Permit No. 973920; and EPA Permit No. OR0023612 (ODEQ 2003). The NPDES permit allows wintertime discharge of effluent (November 1 to April 30, annually) to the Crooked River at RM 46.8 when river flows are greater than 15 cfs. The treatment plant currently generates about 1 mgd (1.5 cfs), but the NPDES permit limits discharges to a minimum dilution ratio of 15:1 (receiving water volume to discharge volume). When river flows are insufficient to accept all generated effluent, the excess is stored in a lagoon at the treatment plant site or used to irrigate uplands.

2.5.6. Lone Pine Irrigation District Canal Return

The Lone Pine Irrigation District (LPID) main canal terminates near the Crooked River at RM 30.2. This return is the only point of return for the district. The water, categorized as tailwater, collects in a seepage pond prior to outflowing through pumiced bedrock. It drops in stages approximately 10 feet to the rocks below the outlet before flowing into the Crooked River. The maximum return is approximately 10 cfs. However, this spill is the highest at the beginning and end of the irrigation season (Figure 2-6). During the warmest part of the season, the maximum tailwater returns are on the order of 6 cfs.

2.6. Ochoco Creek

2.6.1. Ochoco Dam

Ochoco Dam is an earthfill structure owned and operated by OID at RM 11.1 on Ochoco Creek, approximately 6 miles east of Prineville. It has a crest height of 125 feet, a crest elevation of 3,131 feet above MSL, and a length of 1,350 feet. The outlet has a controlled capacity of 430 cfs and the spillway has an uncontrolled capacity of 30,000 cfs at reservoir elevation 3,143.0 feet.

Ochoco Reservoir has a total volume of 44,330 acre-feet and an active storage capacity of 43,520 acre-feet, but 5,266 acre-feet of the active storage are only accessible by pumping. At full pool, the reservoir has a surface area of approximately 1,060 acres. On average, it reaches full pool in only about 4 years out of 10 because Ochoco Creek flow consists almost entirely of snow melt and surface runoff that are quite variable from year to year. Water released from Ochoco Reservoir is diverted directly into the Ochoco Main Canal, where some water is subsequently returned to Ochoco Creek for downstream diversion by OID and others. In recent times, the State of Oregon, through the Deschutes River Conservancy, has annually leased water from OID to provide between 7 and 10 cfs of instream flow during the summer months.

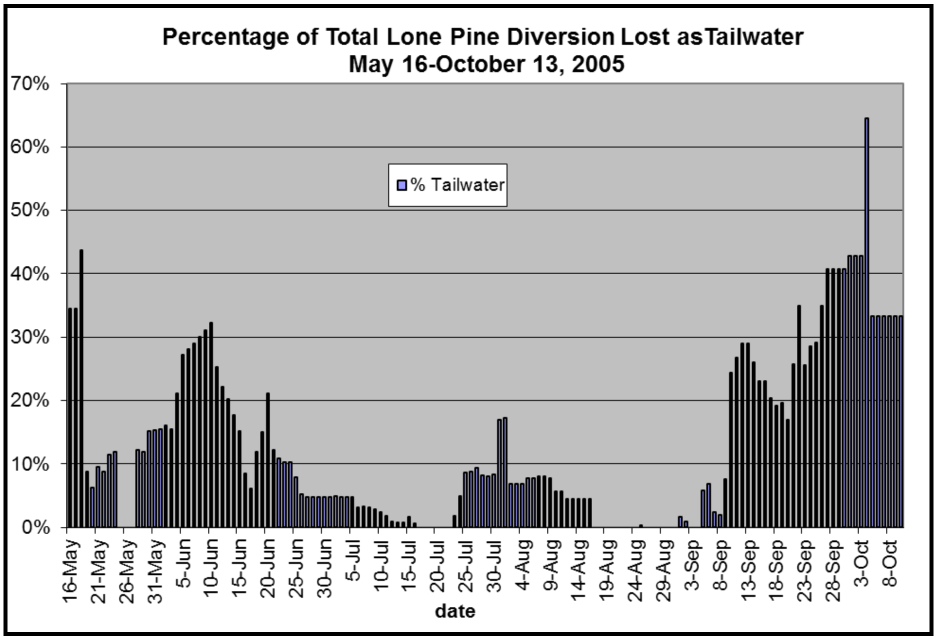

Figure 2-6. Proportion of Lone Pine diversion lost as tailwater during the 2005 irrigation season.
Source: Fitzpatrick (2005).

2.6.2. Ochoco Irrigation District Returns

The Crooked River Diversion Canal crosses Ochoco Creek at RM 5.1. Water is spilled from the canal into the creek at this location throughout the irrigation season to manage flows within the canal (Figure 2-7). Monthly average spill during 2006 through 2011 ranged from 10.0 to 33.5 cfs. The maximum daily average spill reported during that period was 75.0 cfs, which occurred for a total of three days in June and July of 2007, and the minimum daily average was 4.0 cfs during one day in May 2007.

The D-2 drain conveys local tailwater to Ochoco Creek at RM 6.3. Average monthly return flow data for the drain are not available.

2.7. McKay Creek

McKay Creek is a fish-bearing tributary to the Crooked River at RM 44.9. The creek receives return water at five locations within Ochoco Irrigation District (Figure 2-8; Table 2-1), including four operational spills and one drain, as described below.

2.7.1. Ochoco Main Canal Spill

The Ochoco Main Canal spills into McKay Creek at Jones Dam (RM 5.8) during the irrigation season. Average monthly return flow data for the spill are not available.

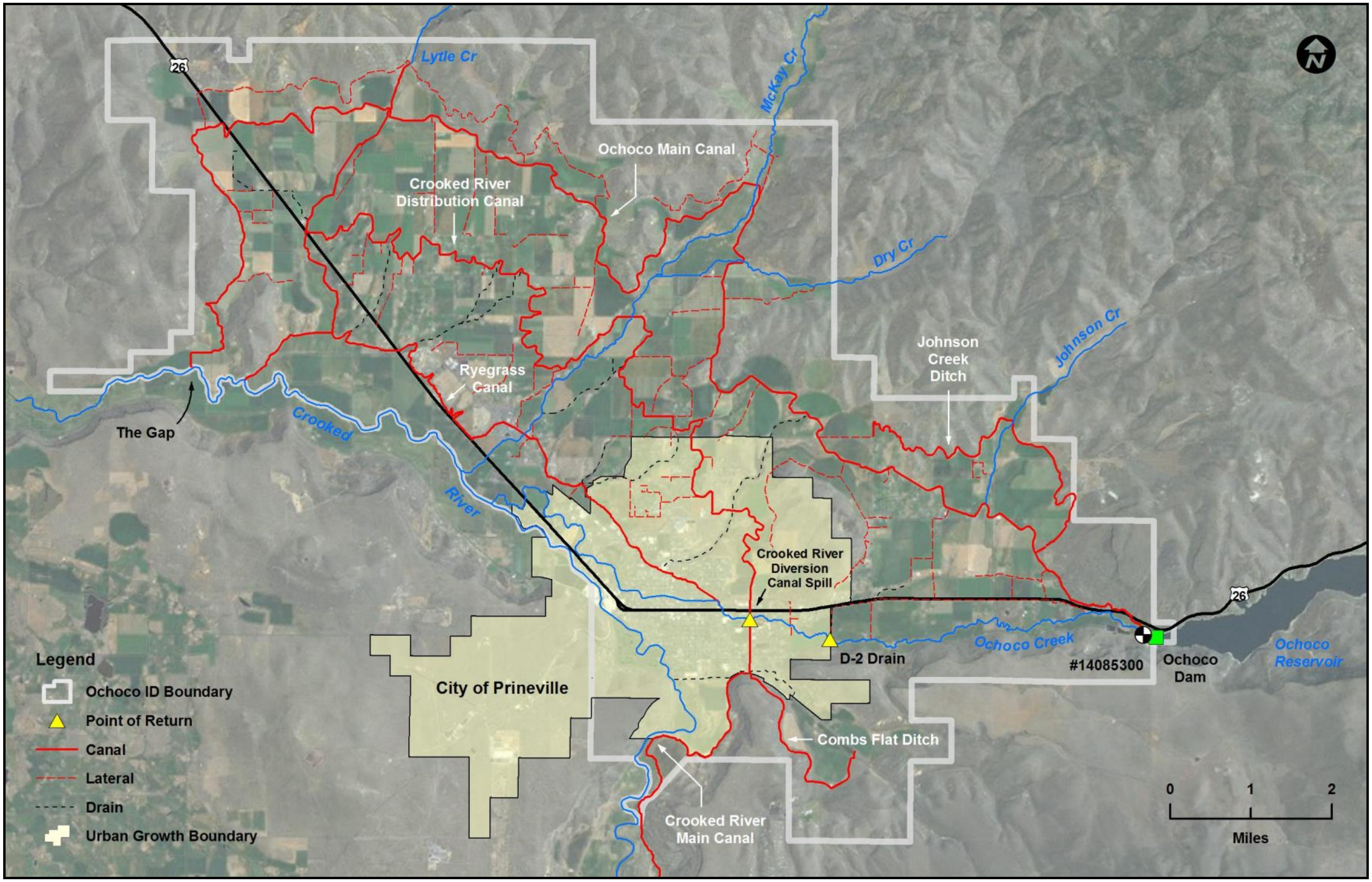

Figure 2-7. Ochoco Irrigation District points of return to Ochoco Creek.

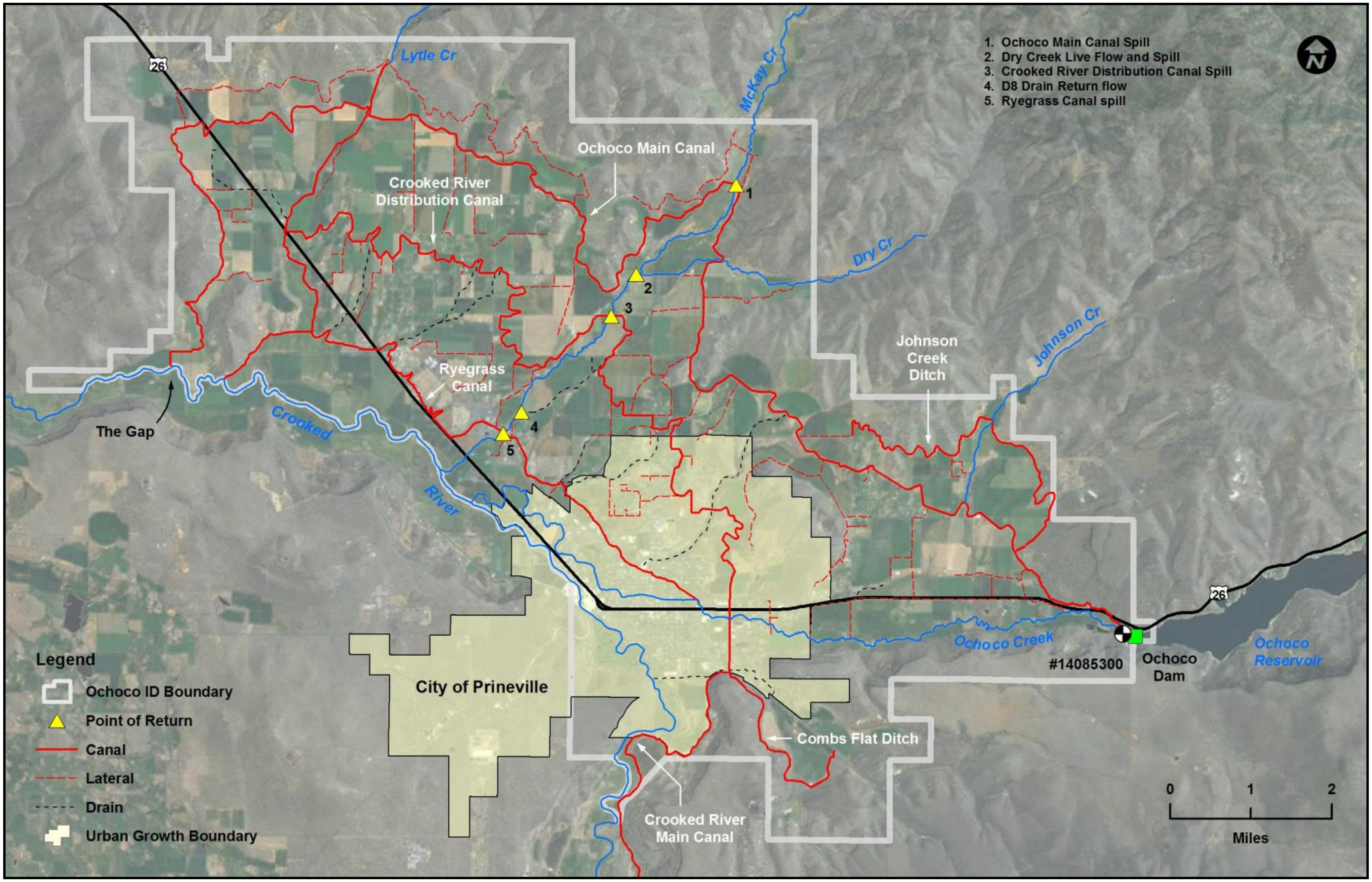

Figure 2-8. Ochoco Irrigation District points of return to McKay Creek.

2.7.2. Dry Creek Live Flow and Spill

Dry Creek carries live flow and irrigation spills into McKay Creek at RM 3.9*.* Average monthly flow data for Dry Creek are not available.

2.7.3. Crooked River Distribution Canal Spill

The Crooked River Distribution Canal spills into McKay Creek at the Reynolds Siphon (RM 3.2) during the irrigation season. Monthly average return flow at the spill during 2006 through 2011 ranged from 0.25 to 45.3 cfs. The maximum daily average spill reported during that period was 54.0 cfs during three days during April 2007, and the minimum daily average was 0.1 cfs during one day each in May and July 2007.

2.7.4. D-8 Drain

The D-8 drain conveys local tailwater to McKay Creek at RM 1.3. Average monthly return flow data for the drain are not available.

2.7.5. Ryegrass Canal Spill

The Ryegrass Canal spills into McKay Creek at the Pine Products Siphon (RM 1.0) during the irrigation season. Monthly average return flow at the spill during 2006 through 2011 ranged from 7 to 11 cfs. The maximum monthly average spill reported during that period was 25 cfs during irrigation start up in April 2007, and the minimum monthly average was 0.3 cfs during August of the same year.

2.8. Lytle Creek

Lytle Creek collects return water at four operational spills and four drains before flowing into the Crooked River at RM 41.0 (see Figure 2-4). The operational spills are at Grimes Flat West Canal (RM 5.7), Ochoco Main Canal (RM 5.0), Crooked River Distribution Canal (RM 3.0), and Ryegrass Canal (RM 1.3). The four drains, located between RM 1.5 and RM 3.2, are known as 823, 825, 827 and D7.

Lytle Creek is generally dry above the OID boundary. Within the district, it flows year round. The majority of flow within district is operational spill and return water during the irrigation season, but a small amount off spring-fed live flow emerges from the D7 drain a short distance above Highway 26 throughout the year. Monthly average flow in Lytle Creek below Ryegrass Canal during the irrigation seasons of 2006 through 2011 ranged from 9.4 to 28.6 cfs. The maximum daily average flow reported during that period was 37.2 cfs, which occurred for one day in June 2006. The minimum daily average was 1.2 cfs during one day in July 2007.

Salmonids likely have physical access to portions of Lytle Creek affected by the covered return flows, although fish use is uncertain. StreamNet (2012) reports man-made blockages to upstream fish passage in Lytle Creek at U.S. Highway 26 (RM 2.7) and Fisher Joe Reservoir (RM 6.4).

3.0 Methods

3.1. Screening Evaluation of Points of Returns

Since water temperature is a physical variable with conservative properties, assessing the thermal condition following complete mixing of two water bodies can occur using a mass-balance approach. For this initial screening assessment, low summer flow and temperature conditions of the receiving water where covered species potentially exist are compared to the volumes and temperatures of covered spills and returns at the points of return.

Receiving water flow conditions are derived from the network of stream gages in the Deschutes River Basin, or from irrigation district flow records where no gages are present. The lowest mean monthly flow on record for the May to September time period is used as a representative low flow condition (Table 3-1). Water temperatures for the receiving waters are generated from longitudinal thermal infrared imaging profiles for the Deschutes and Crooked rivers, and for Ochoco and Tumalo creeks (Watershed Sciences 2006; Watershed Sciences and Max Depth Aquatics 2008) and from regional temperature data collection efforts reported by ODEQ, UDWC, the CRWC, and other data records. Temperature data for other receiving water tributaries are derived from representative peak summer monitoring results at various water temperature stations in the basin (Table 3-1). Where specific temperature data are lacking for a stream segment, the mass-balance equation is used to predict the temperature level needed in either the tributary or return water to trigger a measurable thermal response of greater than ± 0.25°C in the receiving water.

Water temperatures in the Upper Deschutes River basin are generally in excess of biological thermal criteria except where springs or cool reservoir water releases have an influence on downstream water temperature regimes. Such cool water conditions prevail in the following stream reaches:

- Deschutes River downstream of Steelhead Falls between RM 128 and RM 120.0.
- Whychus Creek downstream of Alder Springs between RM 1.6 and RM 0.0
- Crooked River downstream of Bowman Dam between RM 70.5 and RM 57.0
- Crooked River downstream of Hwy 97 between RM 12.0 and RM 0.0

For these cool water situations, inflowing water volumes generally need to be more than 10 percent of the volume of the receiving water to have a material influence on the downstream thermal regime (Brown 1969; Caldwell et al. 1991; Sugden et al. 1998). Where surface waters exceed biological temperature criteria, the ODEQ specifies anti-degradation of current conditions under OAR 340-041-004 and an insignificant temperature increase of less than 0.30°C as a human use allowance under OAR 340-041-0028(11) and (12). Based on the capabilities of most monitoring equipment, the minimum measurable change in water temperature is generally regarded as ± 0.25°C (USEPA 2001). As a result, the municipal discharges and irrigation releases and returns evaluated in this report will be considered as having potential for an adverse effect if: 1) they occur on the order of 10 percent or more of the receiving water volume, or 2) they flow into receiving waters that exceed biological criteria and the worst-case evaluation has the ability to increase ambient receiving water temperatures by 0.25°C or more.

Table 3-1. Representative low flow and high temperature conditions at gages and other locations in receiving waters during the irrigation season.

Gage		Representative Monthly Minimum Flow (cfs)	Representative Maximum Temperature (°C)	Time Period[1/]	Source
Name	Number				
Deschutes River					
Crescent Cr @ Dam	14060000	0	ND	1928 – 1991	USGS (2012)/OWRD (2013)
DR blw Crane Prairie	14054000	14	ND	1922 – 1991	USGS (2012)/OWRD (2013)
DR blw Wickiup	14056500	476	15.5	1942 – 1991	USGS (2012)/OWRD (2013)
DR blw Bend	14070500	19	17.9	1956 – 1991	USGS (2012)/OWRD (2013)
Tumalo Cr nr Bend	14073000	3	17.8	1972 – 1986	USGS (2012)
Tumalo Cr + Col So. Canal	14073001	39	ND	1923 – 1987	USGS (2012)
DR @ Lower Bridge	14074630	34	26.6	1994 – 1997	USGS (2012)
Whychus Cr nr Sisters	14075000	51	14.3	1906 – 1994	USGS (2012)/OWRD (2013)
DR @ Culver	14076500	430	15.2	1952 – 2011 2005 – 2011	USGS (2012)
DR @ Madras	14092500	14092500 3,015	15.8	1924 – 2012	USGS (2012)/ODEQ (2013)
Trout Creek blw Amity Cr	14093600	0	ND	1965 – 1991	Reclamation Hydromet (2013)
Mud Springs Cr nr Gateway	14095250	6	17.5	1999 – 2011	Reclamation Hydromet (2013)
Trout Creek nr Gateway	14095255	7	ND	1999 – 2011	Reclamation Hydromet (2013)
Lower Crooked River					
CR nr Prineville	14080500	67	12.4	1960 – 1991	USGS (2012)
CR nr Prineville	14080500	67	12.4	1991 – to Current	OWRD (2013)/ PNCC (2004)
CR blw Peoples		30	19.0	2005	Watershed Sciences (2006)
CR nr the Gap		60	24.2	2005 – 2007	La Marche (2007)/ODEQ (2012)
CR @ Dry Canyon		60	18.7	2005 - 2010	La Marche (2007)/ODEQ LASAR # 32471
CR @ Lone Pine Cr.		60	22.0	2005	Watershed Sciences (2006)
CR @ Terrebonne /Smith Rocks	14087300	12	22.0	1967 – 1973 1993 - 2011 2006 – 2013	USGS (2012) OWRD (2013) Reclamation Hydromet

Gage		Representative Monthly Minimum Flow (cfs)	Representative Maximum Temperature (°C)	Time Period[1/]	Source
Name	Number				
				2005	(2013) Watershed Sciences (2006)
CR @ Osborne Canyon	14087380	104	19.6	2003 – 2011 2003 - 2006	USGS (2012)
CR blw Opal Springs	14087400	1122	13.8	1961 – 2011 2005 - 2006	USGS (2012)
Cr nr Culver	14087500	970	13.8	1917 – 1963	USGS (2012)
Ochoco Creek					
Ochoco Cr blw Res	14085300	9	16.8	1920 – 2011 2005	OWRD (2013) Reclamation Hydromet (2013) Nielsen-Pincus (2008)
Ochoco Cr @ RM 6.3		6	20.0		ODEQ LASAR # 32568
Crooked River Diversion Canal Spill		10	16.2	2005	ODEQ LASAR # 32495
Ochoco Cr @ RM 5.1		16	17.4	2005	ODEQ LASAR # 32518
McKay Creek					
McKay Cr nr Prineville d/s of Allen Cr.	14086000	0	22.2	1924 – 1932	OWRD (2013) Reclamation Hydromet (2013) ODEQ LASAR # 34180
McKay Cr @ Hwy 26		9	22.8	2005	ODEQ LASAR # 32518 Nielsen-Pincus (2008)

1) Date ranges for flow (top) and temperature (bottom) when multiple ranges are provided
ND = No Data Reviewed

3.2. Cumulative Effects

The scientific literature varies with respect to the extent and magnitude of downstream thermal recovery once streams have been warmed by various land use activities. An understanding of this complex phenomenon is difficult because streams naturally warm in a downstream direction, even in the absence of external heat inputs (Sullivan et al. 1990; Zwieniecki and Newton 1999; Dent et al. 2008). According to the physics of stream heating, water temperatures move toward a fixed equilibrium with the surrounding ambient conditions as a function of stream width and depth, local air temperature (including effects of elevation), riparian canopy levels, and groundwater inflow (Theurer et al. 1984; Adams and Sullivan 1990, Sullivan et al. 1990). Heat inputs result from solar radiation, channel substrate heat loading (conduction), and air temperature that is greater than the water temperature (convection). Heat losses occur from evaporation, air temperature that is less than the water temperature (convection), channel bed conduction if the bed is cooler than the water column, and surface water/groundwater interactions. Over any stream length, heat will be retained as it flows downstream in the water column only if the heat inputs are greater than the heat losses. Water temperatures are in equilibrium when heat input balances heat loss (Theurer et al. 1984).

Any stream section where temperature rises or falls because of environmental disturbance or a change in energy sources can be considered a temperature transition reach where surface water temperatures are out of equilibrium (Zwieniecki and Newton 1999). For example, a warm thermal discharge that adds sufficient volume and heat to the stream is a reach of stream in transition, if a temperature rise is accelerated more than normal. As described above, when the heat loading is reduced, the stream will return to equilibrium shortly downstream.

For large, low elevation streams the thermal increases and decreases in response to changes in heat loading are slow compared to small headwater streams. The rate of change is a function of channel surface area, mean depth, water velocity, and other local hydrological characteristics (Adams and Sullivan 1989; Sullivan et al. 1990; Caldwell et al. 1991).

Important factors found to influence the distance required for downstream thermal recovery include the volume of water and its velocity, which are affected by channel features and slope; and the position of the stream within the channel network. The potential for upstream temperature increases to affect downstream water temperatures is limited by the cooling effects associated with tributaries, hyporheic exchange, heat conduction to the streambed, evaporative cooling, and groundwater exchange (Moore et al. 2005). Large and deep streams take longer to equilibrate with ambient conditions than small streams because of thermal inertia (Adams and Sullivan 1989). Sullivan et al. (1990) calculated that temperature equilibrium following a thermal disturbance was established in 2,000 feet or less for moderately-sized streams (less than 2 feet deep and less than 75 feet wide). In many studies, observed stream temperatures cooled over shorter distances (200 to 2,000 feet) depending on stream size. Larger streams were projected to recover to base temperatures at distances between 5,000 and 6,000 feet (Schloss 1985; La Marche et al. 1997; Sansone and Lettenmaier 2001). The various study results provide a large range of thermal response distances. The variability of the study results is likely due to the various site-specific conditions inherent in each of the studies that influence the ability of streams to come to thermal equilibrium. Based on these studies and the general characteristics of the channel networks within the covered lands, the thermal assessment in this study uses a relatively conservative approach in accordance with large stream sizes and treats any points of return within a mile of each other (5,280 ft) as contributing to the potential for cumulative effects. These returns are assessed jointly rather than individually with the receiving water.

4.0 Results

4.1. Potential Effects of Releases, Return Flows, and Discharges on Surface Water Temperature

4.1.1. Crescent Creek

4.1.1.1. Crescent Lake Dam

The first point where covered fish species, specifically steelhead trout, are encountered in the Upper Deschutes River lies downstream of Big Falls at RM 132. Crescent Lake Dam is located approximately 147 miles upstream of this point. Stream flow and water temperatures in Crescent Creek have negligible potential to increase water temperatures beyond the threshold of effect for surface waters and covered species downstream of Big Falls.

The influence of storage and release operations on river flows and water temperatures in the upper Deschutes River systems are moderated by spring-fed flows between the Lower Bridge and Culver (RM 133 to RM 122) on the Deschutes River. An example of the overall summer warming trend apparent in longitudinal river temperatures in the Deschutes River between Bend and Big Falls (RM 167 to RM 132) is offset with spring water entering the Deschutes between the Lower Bridge and Steelhead Falls (RM 133 to RM 128) as shown in Figure 4-1 (after Watershed Sciences and MaxDepth Aquatics 2008). The thermal infrared study reports 16 inputs of cold water between Big Falls and the inlet to Lake Billy Chinook (RM 132 – RM 120). Water temperatures near Culver rarely exceed 16°C during peak summer months (Reclamation 2003). As shown in Table 3-1, groundwater infusion adds nearly 400 cfs (92%) of inflow to the river on a worst-case basis, between the flow gages at the Lower Bridge and at Culver. As a result, groundwater inflow regulates the temperature of the Deschutes River upstream of Lake Billy Chinook for 12 miles.

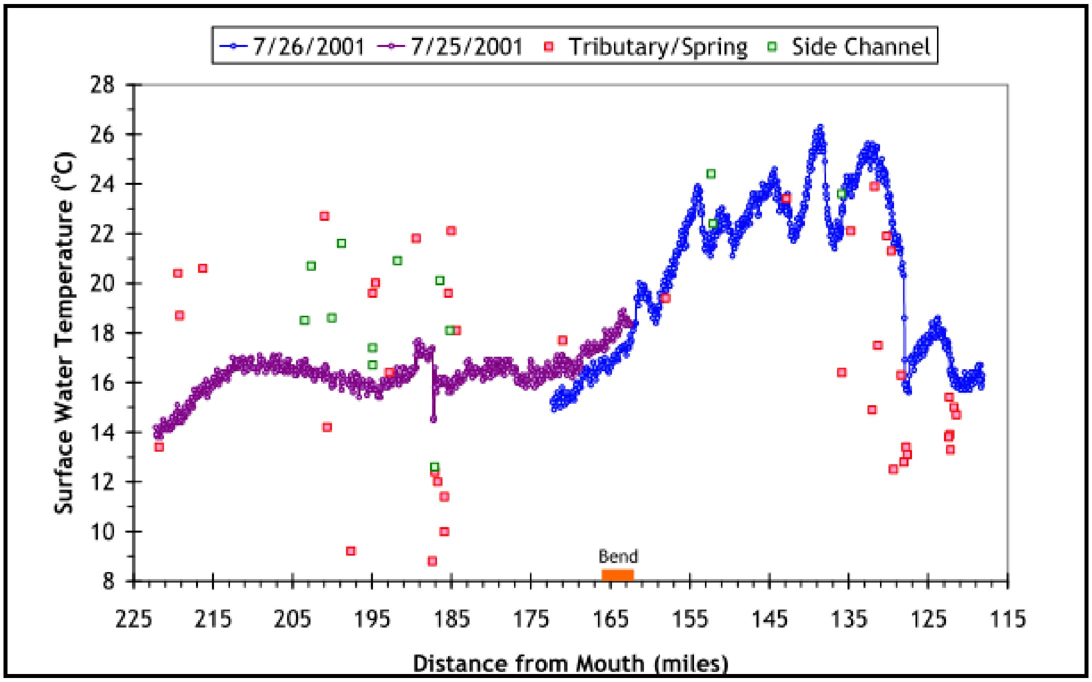

Figure 4-1. Thermal infrared (TIR) temperature profile of the Deschutes River upstream of Lake Billy Chinook.
Source: Watershed Sciences and Max Depth Aquatics (2008).

4.1.2. Deschutes River

4.1.2.1. Crane Prairie Dam

Water leaving Crane Prairie reservoir enters Wickiup Reservoir, about 2 miles downstream. Crane Prairie Dam is approximately 97 miles upstream of Big Falls, the first point at which covered fish species are encountered. Stream flow and water temperatures released at Crane Prairie Dam have negligible potential to increase water temperatures beyond the threshold of effect for surface waters and covered species downstream of Big Falls since groundwater dominates the thermal regime and masks the influence of irrigation storage and release on surface water temperatures downstream of RM 132.

4.1.2.2. Wickiup Dam

As noted above, Wickiup Dam is approximately 95 miles upstream of Big Falls, the first point at which covered fish species are encountered. Stream flow and water temperatures released at Wickiup Dam have negligible potential to increase water temperatures beyond the threshold of effect for surface waters and covered species downstream of Big Falls since groundwater dominates the thermal regime and masks the influence of irrigation storage and release on surface water temperatures downstream of RM 132.

4.1.2.3. Siphon Hydroelectric Project

The Siphon Hydroelectric Project tailrace is approximately 38 miles upstream of Big Falls, the first point at which covered fish species are encountered. Stream flow and water temperatures at the Siphon Hydroelectric Project tailrace have negligible potential to increase water temperatures beyond the threshold of effect for surface waters covered species downstream of Big Falls since groundwater dominates the thermal regime and masks the influence of irrigation storage and release on surface water temperatures downstream of RM 132.

4.1.2.4. North Unit Irrigation District Returns

NUID Lateral 41 and 43 Drains

Both of these drains enter Lake Billy Chinook at RM 112.1, within the distribution range of covered fish species. The maximum return flows are slightly more than 1 cfs each. The combined maximum flow of both drains (2.3 cfs) is only 0.08 percent of the lowest mean monthly summer through-flow at Round Butte Dam (2,750 cfs). This conservative mixing ratio does not account for the total volume of water in Lake Billy Chinook, simply the water flowing past the drains. A return flow of this volume would be insufficient to increase the receiving water in Lake Billy Chinook by 0.25°C.

NUID Lateral 51 Drain and North Unit Main Canal Crossing at Willow Creek

These returns occur into Willow Creek, which subsequently drains into Lake Simtustus at RM 104.6 of the Deschutes River, upstream of the Pelton Hydroelectric Dam. The anadromous fish restoration plan is currently set up to trap upstream migrants at the reregulating dam (RM 100), and to transport and release the migrants upstream of Round Butte Dam (RM 110.6) into Lake Billy Chinook. As a result, only bull trout and juvenile downstream migrants (migratory smolt life stages) of covered fish species released from the fish collection facility in Lake Billy Chinook are present in Lake Simtustus. None of the covered species are anticipated to occur in Willow Creek.

The maximum rate of return flow from the Lateral 51 drain, rated as 1.2 cfs, is only 0.04 percent of the lowest mean monthly summer through-flow at the reservoir of 3,015, as represented at the Deschutes River at Madras gage (USGS gage 14092500 data). As noted for the Lateral 41 and 43 drains, a return flow of this volume is insufficient to increase the temperature of the receiving water in Lake Simtustus by 0.25°C.

Although the maximum potential spill from the Main Canal of 100 cfs at Deschutes RM 104.6 is of considerable volume, the spill generally occurs infrequently (once per year) during irrigation startup in April. This return coincides with the spring smolt outmigration period for covered fish species, but it is unlikely to have the potential to increase the surface water temperatures of the reservoir or the Deschutes River by 0.25°C. Assuming no accretion in river flow between RM 110 and RM 100, the lowest mean monthly flow in this reach of the Deschutes River during April at the Madras gage is 3,602 cfs, with a maximum monthly temperature of 9.7°C (USGS gage 14092500 data). The temperature of the return flow would need to be approximately 19.0°C in April to show a measureable effect on lake or river temperatures, as shown in Equation 1.

Eqn. 1: X°C = [(9.95°C x 3,702 cfs) - (9.70°C x 3,602 cfs)]/100 cfs
X°C = 18.96°C

Where: X°C is the temperature in degrees Celsius of the canal return needed to generate a measureable temperature increase of 0.25°C in water released at Pelton Dam.

Since solar heating is low during the month of April and the main canal is narrow and deep, thermal increases in the canal between the intake and spill into Lake Simtustus are expected to be minimal and not in the range of doubling the ambient water temperature. The return is unlikely to have the potential to increase the surface water temperatures of the reservoir or the Deschutes River by 0.25°C.

NUID Laterals 57/59 Drain

The drain for Laterals 57 and 59, with a maximum rate of return flow of 1.3 cfs, is located in Campbell Creek, which subsequently drains into the Pelton Reregulating Reservoir at RM 101.7 of the Deschutes River. Similar to Lake Simtustus, only outmigrating smolts of covered species are present in the reservoir, and none are anticipated in Campbell Creek.

The lowest mean monthly summer through-flow at the reservoir, as represented at the Deschutes River at Madras gage, is 3,015. The return of 1.3 cfs represents 0.04 percent of the reservoir through-flow and would not have the potential to increase the surface water temperatures of the reservoir or the Deschutes River by 0.25°C.

NUID Lateral 63 and 64 Drains

Lateral drains 63 and 64 occur directly into the Deschutes River at RM 97.8 and RM 94.5, respectively, downstream of the Pelton Round Butte Project. The flow of each return is 1.0 cfs (Table 2-1), or 0.03 percent of the lowest mean monthly flow in the river in this reach of the river during the summer of 3,011 cfs. As noted above, a return flow of this volume is insufficient to increase the temperature of the receiving water by 0.25°C.

North Unit Main Canal Terminus at Frog Springs

The northern terminus of the Main Canal returns excess canal flow to Frog Springs, a natural wetland about 1.5 miles from the Deschutes River at RM 90.1. This reach of the Deschutes River is used by all life history stages of the covered fish species. The wetland has been enlarged by the addition of irrigation water and the typical canal inflow to the wetland during the summer months is estimated to be around 10 cfs with a maximum of 50 cfs (Britton, M. NUID, pers. comm. March 4, 2013). The lowest mean-monthly summer receiving flow at this point in the Deschutes River is 3,015 cfs, USGS gage 14092500 data) and a representative high water temperature is 15.8°C (Lamb, B. ODEQ, pers. comm. Feb, 2013).

Assuming outflow from the Frog Springs wetland to the Deschutes River is commensurate with the main canal inflow, the typical return represents 0.3 percent and the maximum return represents 1.7 percent of low summer flow in this reach of the Deschutes River. The releases do not have the potential to increase the surface water temperatures of the Deschutes River by 0.25°C or more. As shown in Equations 2a and 2b, return temperatures between approximately 31.1°C and 91.4°C would be needed to exhibit a measureable effect on Deschutes River summer temperatures for the maximum and typical main canal returns to Frog Springs, respectively.

Eqn. 2a: X°C = (16.05°C x 3,025 cfs) - (15.80°C x 3,015 cfs)/10 cfs
X°C = 91.4°C

Eqn. 2b: X°C = (16.05°C x 3,065 cfs) - (15.80°C x 3,015 cfs)/50 cfs
X°C = 31.1°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

Outflow temperatures from the Frogs Springs wetland between 31.1°C and of 91.4°C are unlikely.

NUID Lateral 58-11 Drain and North Unit Main Canal Terminus at Mud Springs

The Lateral 58-11 drain returns operational spill of approximately 50 cfs once a year to Sagebrush Creek. Sagebrush Creek flows into Mud Springs Creek, which flows into Trout Creek at RM 2.6, which subsequently flows into the Deschutes River at RM 87.2. The terminus of the North Unit Main Canal returns excess canal flow on the order of 5 cfs throughout the irrigation season to a man-made wetland area prior to flowing directly into Mud Springs at RM 0.5.

All life history stages of summer steelhead trout are known to use Trout Creek, where they usually spawn from January through mid-April. The presence of covered fish species in Sagebrush Creek and Mud Springs Creek is unknown, but cannot be dismissed.

Available stream flow and temperature data for Trout Creek are limited. Annual flows in Trout Creek have been monitored by the OWRD at two gage locations, one below Amity Creek near Ashwood, OR, between 1966 and 1991 and one at Clemons Driver near Gateway, OR from 1999 to date. The gage below Amity Creek is located well upstream of the confluence of Trout Creek and Mud Springs Creek, while the one near Gateway is immediately downstream of the Mud Springs Creek inflow.

Seasonal precipitation patterns result in Trout Creek flows at the Gateway gage that peak in late winter and early spring, and rapidly diminish to low flows during the summer months. The minimum monthly flow during the month of April was 39.3 cfs, with a 100.5 cfs average, between 1999 and 2011. The minimum monthly summer low flow was 6.9 cfs, while averaging 39.3 cfs, over the same time period.

Mud Springs Creek exhibits an unusually constant hydrograph compared to most other streams in the drainage. Flows at the OWRD gage in Mud Springs Creek near Gateway generally vary no more than 10 cfs in any season and provide nearly 10 cfs naturally, suggesting that the system is spring-fed. The minimum monthly flow during the month of April was 8.7 cfs, with a 100.5 cfs average, between 1999 and 2011. The minimum monthly summer low flow was 6.4 cfs, while averaging 10.1 cfs, over the same time period. Live flow from Mud Springs Creek combined with seasonal irrigation returns carried by Mud Springs and Sagebrush creeks provides most of the summer/fall flow in lower 2.6 miles of Trout Creek (WPN 2002).

Water temperatures in Trout and Mud Springs creeks during the month of April are typically below 10°C (Hammond et al. 2009). By late May, water temperatures usually exceed biological criteria and can remain high in both creeks through October. The entire length of Trout Creek is listed as water quality limited because of temperature (ODEQ 2010).

A return of 50 cfs from the Lateral 58-11 Drain during the spring exceeds the lowest reported monthly flows in April for both Mud Springs (5.7x) and Trout (1.3x) creeks, and would be sufficient to have a thermal influence on the creeks. Similarly, the addition of 5 cfs from the North Unit Main Canal throughout the irrigation season is sufficient to influence surface water temperatures in Mud Springs Creek (with a lowest monthly flow of 6.4 cfs) and Trout Creek as well (with a lowest monthly flow of 6.9 cfs). Depending on the temperatures of water in the creeks and the canal, the return flow could either increase or decrease surface water temperatures in the receiving water. Since covered fish species have access to Trout Creek and potentially the other tributary streams during the irrigation season, the temperatures of the return water, Sagebrush Creek, Mud Springs Creek, and Trout Creek should be reviewed more completely during the Phase 2 assessment. At least one full irrigation season of data is needed on the rate and temperature of the return flow and the receiving water response.

In contrast, the effect of the 50 cfs return flow on temperature would be immeasurable where Trout Creek enters the Deschutes River. Assuming no accretion in river flow between RM 100 and RM 87.2, the lowest mean monthly flow in this reach of the Deschutes River during April at the Madras gage would be is 3,602 cfs, with a reported maximum monthly temperature during April of 9.7°C since 1978 (USGS gage 14092500 data). The 50 cfs return flow, in combination with a low streamflow of 39.3 cfs in Trout Creek during April, represent only 2.5 percent of the river flow in this case, and would be incapable of increasing river temperatures by 0.25°C as shown under the assumptions included in Equation 3. The resulting temperature in the Deschutes River should remain within the preferred ranges for the covered fish species in the spring (Table 1-1).

Eqn. 3: X°C = (10.0°C x 89.3 cfs) + (9.70°C x 3,602 cfs)/3,691.3 cfs
X°C **=** 9.71°C

Where: X°C is the resulting temperature of two mixed water bodies in degrees Celsius.

The combined temperature of the return flow and Trout Creek would have to be on the order of 20°C in April to record a measureable increase in Deschutes River thermal conditions under this situation as shown in Equation 4.

Eqn. 4: X°C = (9.95°C x 3,692.3 cfs) + (9.70°C x 3,602 cfs)/89.3 cfs
X°C **=** 20.1°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

4.1.3. Tumalo Creek

4.1.3.1. Crater Creek Ditch

Water from the inter-basin transfer via the Crater Creek ditch enters Tumalo Creek at approximately RM 21.7, and is diverted again at the Tumalo Creek Diversion, approximately 31 miles upstream of Big Falls. Stream flow and water temperatures in Tumalo Creek have negligible potential to increase water temperatures beyond the threshold of effect for surface waters and covered species downstream of Big Falls. Groundwater dominates the thermal regime and masks the influence of irrigation storage and release on surface water temperatures downstream of RM 132. Flows from the Crater Creek ditch to Tumalo Creek do not to have the potential for a measurable thermal effect on covered fish species.

4.1.4. Crooked River

4.1.4.1. Bowman Dam

Releases from Bowman Dam (RM 70.5) occur at depth (123 feet; 37.5m below normal pool elevation) in Prineville Reservoir and are relatively cool (Figure 4-2). This release comprises 100 percent of the downstream flow between the dam and the Crooked River Diversion at RM 57. Cold-water reservoir releases influence water temperatures in the Crooked River below Bowman Dam. Summer water temperatures average 8.3°C to 10.0°C with a reported high temperature of 12.4°C (NPCC 2004). The cold-water releases during summer months substantially improve fish habitat in this reach compared to temperatures prior to reservoir construction (Stuart et al. 1996), and have created a coldwater tailrace fishery. The resulting water temperatures are suitable for all life history stages of covered species. Existing flow releases from Bowman Dam do not to have the potential for an adverse thermal effect on covered fish species.

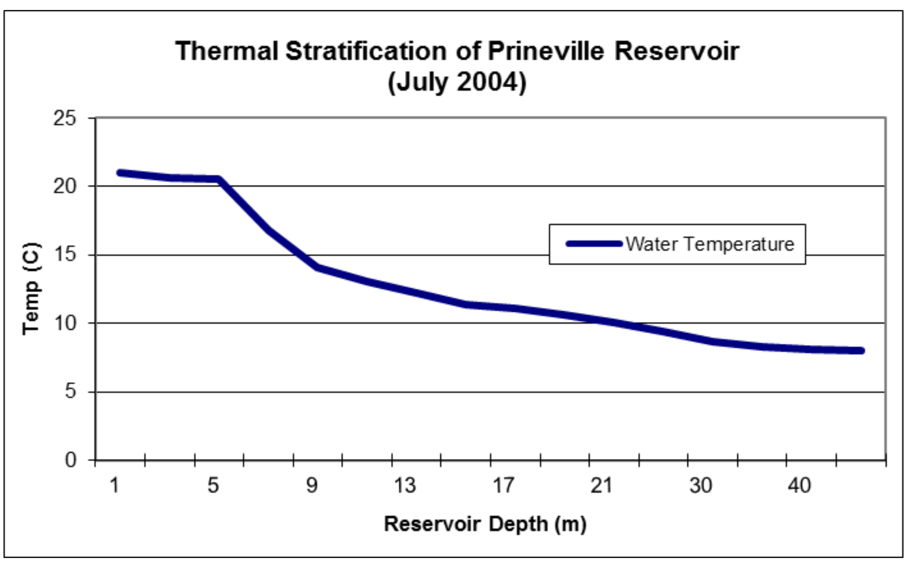

Figure 4-2. Example of Prineville Reservoir thermal stratification– July 2004. **Source: Reclamation WQ data**

4.1.4.2. Ochoco Irrigation District Returns

Juniper Canyon Flood Control Channel

The Juniper Canyon flood control channel flows into the Crooked River at RM 49.4. The daily average flow in the channel is roughly 1 to 2 cfs, and the maximum capacity of OID pumps that contribute to the channel is 8 cfs. The summer water temperature of this return is unknown. The lowest mean monthly summer flow at this point in the Crooked River is 30 cfs. A representative high summer temperature is on the order of 19.0°C (Figure 4-3) (Watershed Sciences 2006). This temperature is above the preferred ranges for the covered fish species. A maximum return of 8 cfs represents 27 percent of low summer flow in the Crooked River, and has the potential to increase the surface water temperatures by 0.25^{o}C or more. As shown in Equation 5a, a return temperature of approximately 20.2°C with a return flow of 8 cfs could exhibit a measureable effect on Crooked River temperatures.

Eqn. 5a: X°C = [(19.25°C x 38 cfs) - (19.00°C x 30 cfs)]/8 cfs
X°C = 20.19°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

If the Juniper Canyon return flow were closer to the average of 2 cfs, a return temperature of 23.0°C could still exhibit a measureable effect on Crooked River temperatures, as shown in Equation 5b.

Eqn. 5b: X°C = [(19.25°C x 32 cfs) - (19.00°C x 30 cfs)]/2 cfs
X°C = 23.00°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

The probability of the return water exceeding 23°C is unknown, but within the realm of possibility. According to OID, Juniper Canyon may have groundwater contribution that could minimize any thermal influence of the return water. Since, the typical return from Juniper Canyon to the Crooked River has an unknown potential and the maximum return capacity has a likely potential for a thermal effect on covered fish species, water temperatures and return flows for the Juniper Canyon return and the Crooked River at RM 49.4 should be reviewed more completely during the Phase 2 assessment. At least one full irrigation season of data is needed on the rate and temperature of the return flow and the receiving water response.

Ochoco, McKay, and Lytle Creeks

OID returns to Crooked River tributaries consisting of Ochoco, McKay, and Lytle creeks are described and evaluated below in Sections 4.1.5, 4.1.6, and 4.1.7, respectively.

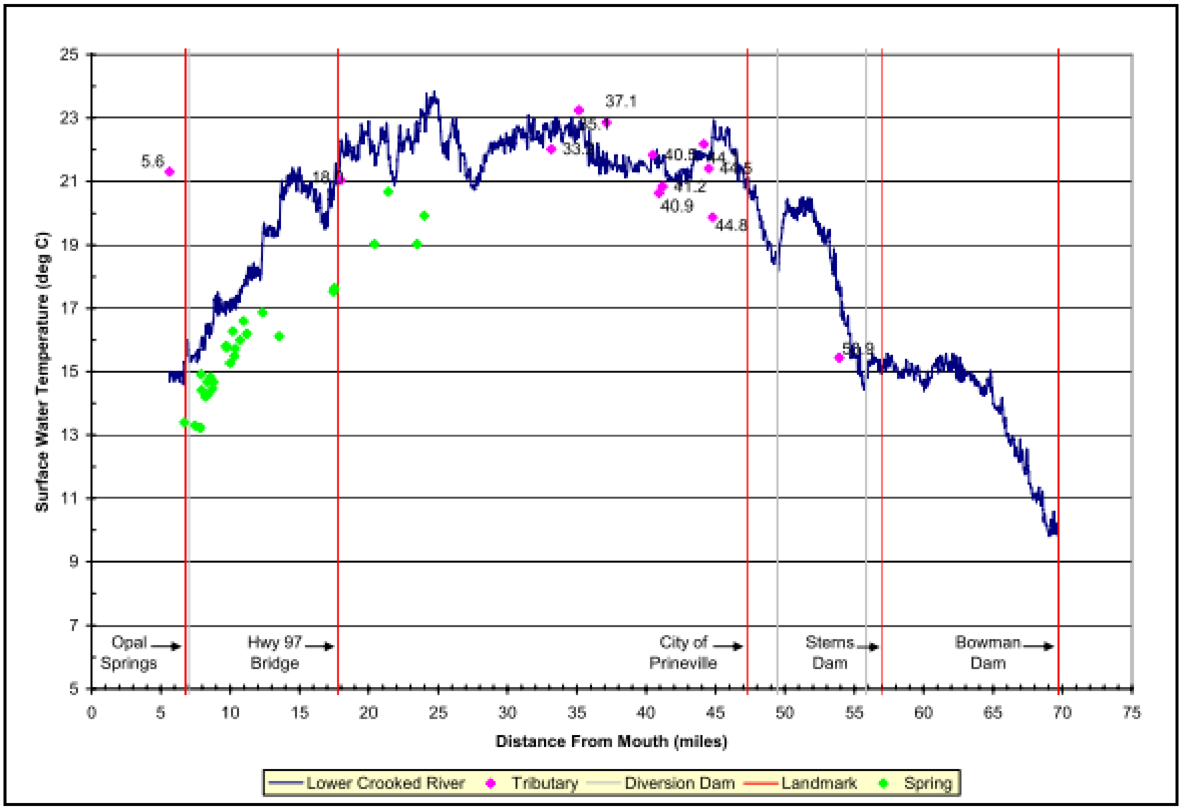

Figure 4-3. Thermal infrared (TIR) temperature profile of the Crooked River upstream of Lake Billy Chinook. Source: **Watershed Sciences (2006).**

The Gap

OID's primary direct return to the Crooked River at RM 39.6 is called The Gap. This return is the terminus of the Ochoco Main Canal, where water is spilled throughout the irrigation season to manage flows within the canal. Monthly average spill during 2006 through 2011 during the irrigation season ranged from 3.0 to 8.2 cfs. The maximum daily average spill reported during that period was 18.5 cfs during early May. Water temperatures for this return are unknown, but the canal is known to pick up groundwater seepage as it traverses the hill slope.

The typical low mean monthly summer flow at this point in the Crooked River is on the order of 60 cfs after picking up various tributary and groundwater inflows (La Marche 2007). The 7-day maximum temperature during the summer of 2005 was 24.2°C (ODEQ 2005), which is above the preferred temperature ranges for the covered fish species. The maximum daily return flow at the Gap represents 31 percent of low summer flow in this reach of the Crooked River and has the potential to increase the surface water temperatures by 0.25^{o}C or more. As shown in Equation 6, a return temperature of approximately 25.3°C during the maximum daily average spill could exhibit a measureable effect on Crooked River summer temperatures.

Eqn. 6: X°C = [(24.45°C x 78.5 cfs) - (24.20°C x 60 cfs)]/18.5 cfs
X°C = 25.26°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

The probability of the return water exceeding 25.3°C is unknown, but within the realm of possibility. It is also possible groundwater contribution could minimize the thermal influence of the return water. The maximum daily average return flow from the Gap to the Crooked River has the potential for a thermal effect on covered fish species. Water temperatures and return flows for the Gap and the Crooked River at RM 39.6 should be reviewed more completely during the Phase 2 assessment. At least one full irrigation season of data is needed on the rate and temperature of the return flow and the receiving water response.

4.1.4.3. North Unit Irrigation District Returns

North Unit Main Canal Crossing

Upward of 200 cfs of water spills from the North Unit Main Canal at RM 27.5 on the Crooked River for one day each year during annual startup. The average monthly flow rate of the Crooked River at Terrebonne (USGS gage No. 14087300) during the month of April is approximately 750 cfs, although the lowest mean monthly flow on record was 75 cfs. The water temperatures of the spill and the receiving water in April are unknown, but are generally similar in nature. A one-day return flow of the same magnitude or more than the receiving water during the month of April could influence water temperature, depending on the relative temperatures of the two waters. However, the return would be unlikely to have an adverse thermal influence on spawning or rearing life stages of covered species present during that time. Unless considerable thermal shock occurs or temperatures are lethal (> 21°C for steelhead trout spawning, Table 1-1), exposure of a one-day duration event is likely not significant to the productivity of the covered species. Water temperatures and return flows for the Main Canal Crossing of the Crooked River at RM 27.5 should be reviewed during the Phase 2 assessment. A measurement of the water temperature and volume at the diversion, at the spill location, and in the Crooked River upstream of the annual spill would be sufficient to evaluate the receiving water response.

NUID Laterals 31 and 34 Drains

The drains for Laterals 31 and 34 convey ongoing operational spills throughout the irrigation season of 1.0 cfs each to the Crooked River at RM 19.6 and RM 18.4, respectively. The lowest mean monthly flow for this reach of the Crooked Rivers is 12 cfs at the Terrebonne/Smith Rocks gage (USGS gage #14087300). The summer water temperatures of these returns are unknown. The maximum summer receiving water temperature at this point in the Crooked River is in the neighborhood of 22.0°C (Watershed Sciences 2006).

The maximum daily spills each represent 8 percent of low summer flow in the Crooked River, and have a slight potential to increase the surface water temperatures by 0.25°C. As shown in Equation 7, a temperature for each spill of approximately 25.3°C would be needed to exhibit a measureable effect on Crooked River summer temperatures.

Eqn. 7: X°C = [(22.25°C x 13 cfs) - (22.0°C x 12 cfs)]/1 cfs
X°C = 25.3°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

The probability of the return water exceeding 25.3°C is unknown, but within the realm of possibility. It is also possible groundwater contribution could minimize the thermal influence of the return water. Water temperatures and return flows for the Lateral 31 and 34 Drains should be reviewed during the irrigation season under the Phase 2 assessment. At least one full irrigation season of data is needed on the rate and temperature of each return flow and the receiving water response.

North Unit Main Canal Return at Mile Post 37

Upward to 100 cfs of water spills from the North Unit Main Canal at Mile Post 37 into the Crooked River at RM 11.9 for one day each year during annual startup. The average monthly flow of the Crooked River at Osborne Canyon (USGS gage No. 14087380) during the month of April is approximately 1,160 cfs, although the lowest mean flow recorded for a single month was 421 cfs. The water temperatures of the spill and the receiving water in April are unknown. A one-day return representing 9 to 24 percent of the receiving water volume during the month of April could influence water temperature, depending on the relative temperatures of the two waters, but the return would be unlikely to have an adverse influence on spawning or rearing life stages of covered species present during that time. Unless temperature differentials offer considerable thermal shock or they are lethal (> 21°C for steelhead trout spawning, Table 1-1), exposure of a one-day event is likely not significant to the ultimate abundance or productivity of the covered species.

NUID Lateral 37 Drain

This drain enters Lake Billy Chinook at RM 2.7 of the Crooked River. The maximum return flow is 1 cfs, or 0.04 percent of the lowest average monthly through-flow of the reservoir during the summer (2,750 cfs). As noted for other returns that flow into Pelton Round Butte reservoirs, a return flow of this volume is insufficient to increase the temperature of the receiving water by 0.25^{o}C.

4.1.4.4. Central Oregon Irrigation District Returns

Dry Canyon Return

Water reaching the end of COID's Central Oregon Canal is spilled near the top of Dry Canyon, where it continues as surface and shallow subsurface return flow to the Crooked River at about RM 34.1, approximately 13 miles downstream of Prineville. COID has monitored flow and water temperatures at the point of return to the Crooked River with continuous recorders. The maximum summer monthly flow rate peaked at 64 cfs, while the maximum weekly maximum temperatures (MWMT°C) of continuous gages were 26.3°C and 32.2°C during the 2005 and 2006 irrigation seasons, respectively (Figures 4-4 and 4-5). ODEQ's LASAR database includes three summer recordings from the mouth of Dry Canyon (Station #32471) ranging between 16.3 °C and 18.7°C (ODEQ 2012).

The lowest mean monthly summer flow at this point in the Crooked River is 60 cfs, and the maximum summer temperature of 22.5°C (Watershed Sciences 2006). With reported return flow volumes and water temperatures potentially higher than the receiving water conditions, the Dry Canyon return has the potential for a thermal effect on covered fish species. Receiving water temperature conditions in the immediate vicinity of Dry Canyon during the summer low flow period should be reviewed more completely during the Phase 2 Assessment.

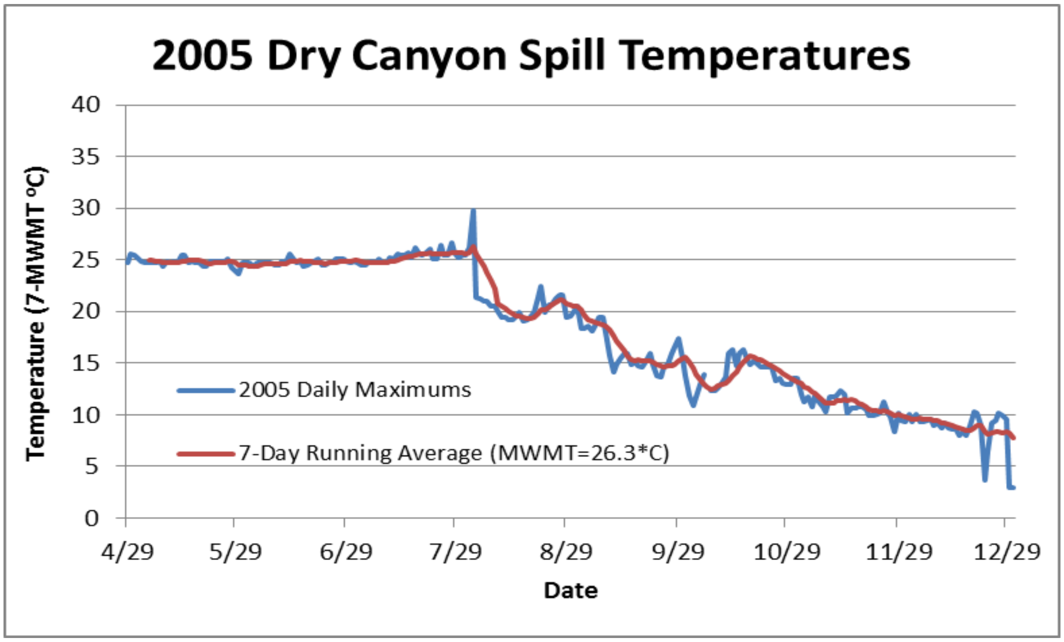

Figure 4-4. Recorded daily maximum and 7-Day running average of the maximum values (MWMT°C) for irrigation returns at Dry Canyon – 2005.

Source: COID temperature monitoring data

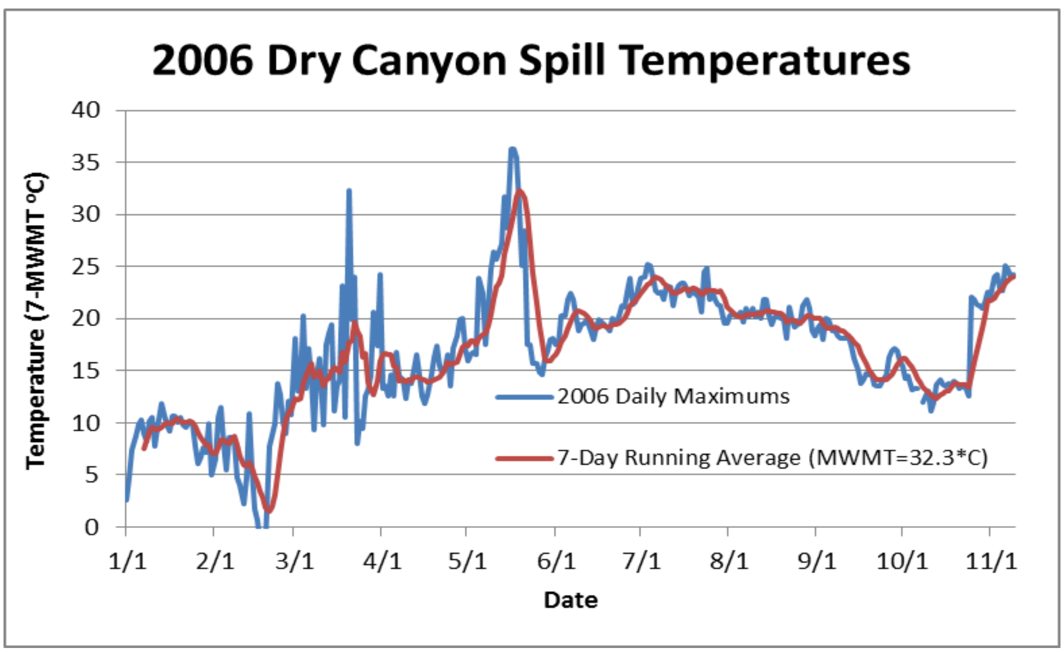

Figure 4-5. Recorded daily maximum and 7-Day running average of the maximum values (MWMT°C) for irrigation returns at Dry Canyon – 2006.

Source: COID temperature monitoring data

Lone Pine Delivery Spill

Between 1 and 10 cfs are spilled from the Pilot Butte Canal to the Crooked River at RM 27.7 throughout the irrigation season to regulate the delivery of water to the Lone Pine Canal. The lowest mean monthly flow for this reach of the Crooked Rivers is 12 cfs at the Terrebonne/Smith Rocks gage (USGS gage #14087300). The water temperatures of this return are unknown. A representative high summer receiving water temperature at this point in the Crooked River is on the order of 22.0°C (Watershed Sciences 2006).

The maximum daily spill of 10 cfs represents 21 percent of low summer flow in the Crooked River, and thus has the potential to increase the surface water temperatures by more than 0.25^{o}C. As shown in Equation 8, a spill temperature of approximately 22.6°C would be needed to exhibit a measureable effect on Crooked River summer temperatures.

Eqn. 8: X°C **=** [(22.25°C x 22 cfs) - (22.0°C x 12 cfs)]/10 cfs
X°C **=** 22.55°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

Return water exceeding 22.6°C some time during the irrigation season is possible. This return should be reviewed more completely before a determination of effect on covered species is made. At least one full irrigation season of data is needed on the rate and temperature of the return flow and the receiving water response.

Pilot Butte Canal J Waste

An estimated 1 cfs or less spills from the J-22 Lateral of the Pilot Butte Canal to the Crooked River at RM 25.0 when flow in the canal is reduced for operational or emergency purposes. This spill occurs less than once per year and lasts 1 day or less. The lowest mean monthly flow for this reach of the Crooked Rivers is 12 cfs in July at the Terrebonne/Smith Rocks gage (USGS gage #14087300). The water temperature of this return is unknown. A representative high summer receiving water temperature at this point in the Crooked River is on the order of 22.0°C (Watershed Sciences 2006).

The maximum daily spill of 1 cfs represents 2 percent of low summer flow in the Crooked River, and has little potential to increase the surface water temperatures by 0.25^{o}C. As shown in Equation 9, a spill temperature of approximately 25.3°C would be needed to exhibit a measureable effect on Crooked River summer temperatures.

Eqn. 9: X°C **=** [(22.25°C x 13 cfs) - (22.0°C x 12 cfs)]/1 cfs
X°C **=** 25.25°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

The probability of the return water exceeding 25.3°C is unknown, but within the realm of possibility. However, the return would be unlikely to have an adverse influence on spawning or rearing life stages or the ultimate abundance or productivity of covered species because of its short duration (1 day or less).

Pilot Butte Canal H-17 Return

Up to 3 cfs spills from the H-17 Lateral of the Pilot Butte Canal to the Crooked River at RM 18.0 when flow in the canal is reduced for operational or emergency purposes. This spill occurs for 1 day or less each year. The lowest mean monthly flow for this reach of the Crooked Rivers is 12 cfs at the Terrebonne/Smith Rocks gage (USGS gage #14087300). The summer water temperature of this return is unknown. A representative high summer receiving water temperature at this point in the Crooked River is on the order of 22.0°C (Watershed Sciences 2006).

The maximum daily spill of 3 cfs represents 6 percent of low summer flow in the Crooked River. As shown in Equation 10, a spill temperature of approximately 23.3°C would produce a measureable effect on Crooked River summer temperatures.

Eqn. 10: X°C **=** [(22.25°C x 15 cfs) - (22.0°C x 12 cfs)]/3 cfs
X°C **=** 23.25°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

A return water of 23.3°C is possible during mid-summer. If such warm waters occurred, the return could contribute to river water temperatures approaching lethal conditions for some life history stages of various species (Table 1). However, the short duration of spill limits the potential effect. A 1-day return flow of 3 cfs occurring earlier in the irrigation season, when both the receiving water and the return water temperatures are lower, would be unlikely to have a an adverse influence on spawning or rearing life stages of covered species. The timing, frequency, and water temperature of this return should be evaluated further before a determination of effect on covered species is made.

4.1.4.5. City of Prineville Sewage Treatment Plant Effluent

In accordance with their NPDES permit, the City of Prineville can only discharge up to 1.5 cfs from its wastewater treatment plant to the Crooked River at RM 46.8, but only at a ratio of 15:1 [river to effluent] (ODEQ 2003). The discharge amounts to 6.7 percent of the receiving water flow when the river exceeds 15 cfs during the months of November through April. Since (1) the discharge does not occur during the warm summer months, (2) the reported river temperatures downstream following effluent discharge are slightly cooler than upstream river temperatures (City of Prineville discharge monitoring reports 2007, 2008), and (3) the water temperatures are cooler than the biological criteria for the life stages potentially present during the discharge period, this seasonal discharge does not offer the potential for an adverse thermal effect on covered fish species.

4.1.4.6. Lone Pine Irrigation District Canal Return

Tailwater from the LPID canal flows into the Crooked River at RM 30.2. The maximum summer tailwater flow is on the order of 6 cfs (Fitzpatrick 2005). The high summer water temperatures of this return are unknown, but a one-time measurement at Station No. 32521 of 21.8°C was recorded in the morning hours of August 9, 2005 (ODEQ LASAR database). The summer receiving water condition at this point in the Crooked River indicates a minimum mean monthly flow of 60 cfs (La Marche 2007, Main 2012) and a representative high temperature of approximately 22.0°C (Watershed Sciences 2006). A fully-mixed water body of these two sources is estimated in the mass balance equation below:

Eqn. 11: $X°C = (21.8°C \times 6\ cfs) + (22.0°C \times 60\ cfs)/66\ cfs$
$X°C = 21.98°C$

Where: X°C is the resulting temperature of two mixed water bodies in degrees Celsius.

The anticipated change in temperature under this situation is immeasurable. A temperature for the tailwater return of approximately 24.8°C would be needed to exhibit a measureable effect on Crooked River summer temperatures. Since the available information is limited, and this threshold value of 24.8°C seems possible, the tailwater return from the Lone Pine Canal to the Crooked River should be reviewed more completely before a determination of effect on covered species is made. At least one full irrigation season of data is needed on the rate and temperature of the return flow and the receiving water response.

4.1.5. Ochoco Creek

4.1.5.1. Ochoco Dam

Releases from Ochoco Dam (RM 11.1) occur at depth within Ochoco Reservoir and are relatively cool. The intake tower lies 35 feet above the reservoir bottom, and summer thermal stratification in the reservoir indicates water less than 14°C is usually withdrawn (Figure 4-6). Water leaving the reservoir flows into the Ochoco Main Canal, were approximately 15 cfs are spilled back into Ochoco Creek for instream conveyance. The spill makes up nearly all the stream flow in Ochoco Creek between the reservoir and Red Granary diversion at RM 10.4, with the exception of approximately 2 cfs of dam seepage that is captured and piped to the creek. ODEQ's LASAR water temperature data at Station No. 32404 downstream from Ochoco Dam record summer temperatures ranging between 10.9°C and 13.3°C. There is some evidence as the reservoir is drawn down in late summer, the release to the creek may warm slightly. The CRWC's Lower Crooked River Watershed Assessment (Nielsen-Pincus 2008) report temperature data from OID's canal flow into Ochoco Creek slightly exceeding 16°C during late August 2005. According to Nielsen-Pincus (2008), the peak temperatures of the Ochoco Dam release to the creek in 2005 occurred in early September, approximately 1.5 months later than peak temperatures elsewhere in Ochoco Creek. This thermal signature might suggest the cool bottom water diminishes late in the irrigation season. The seasonal water temperatures of the release to the creek are suitable for all life history stages of covered species. Flow releases from Ochoco Dam do not have the potential for an adverse thermal effect on covered fish species.

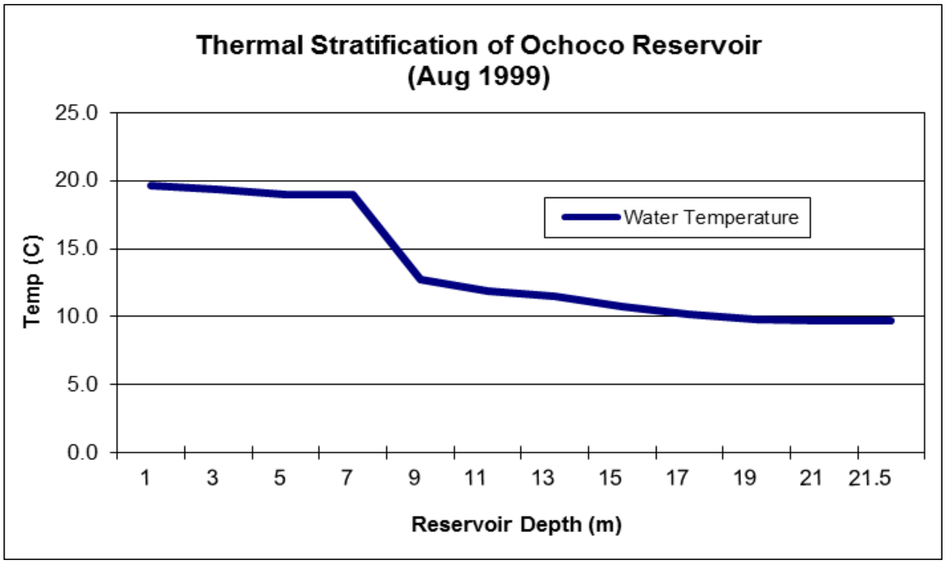

Figure 4-6. Example of Ochoco Reservoir thermal stratification– 1999.
Source: USBR WQ data

4.1.5.2. Ochoco Irrigation District Returns

D-2 Drain

The D-2 drain conveys local tailwater to Ochoco Creek at RM 6.3. Typical maximum flows from the drain are in the neighborhood of 2 cfs. Water temperatures of this drain are unknown. The lowest mean monthly summer flow at this point in Ochoco Creek is 6 cfs, following irrigation diversions between RM 11.1 and RM 6.3. A representative high summer temperature is on the order of 22.7°C (CRWC 2005, Watershed Sciences 2006). Water temperature in the creek generally increases with downstream distance between Ochoco Dam and the Crooked River Diversion Canal spill at RM 5.1 (Figure 4-7). The entire lower portion of Ochoco Creek is on the state's 303(d) list for temperature-impaired water bodies (ODEQ 2010).

The maximum daily return flow represents 33 percent of low summer flow in this reach of Ochoco Creek, and has the potential to increase the surface water temperatures by more than 0.25^{o}C. As shown in Equation 12, a temperature for the drain of approximately 23.7°C would exhibit a measureable effect on Ochoco Creek summer temperatures.

Eqn. 12: X°C = [(22.95°C x 8 cfs) - (22.7°C x 6 cfs)]/2 cfs
X°C = 23.70°C

Where: X°C is the temperature in degrees Celsius of the return needed to generate a measureable temperature increase of 0.25°C in the receiving water.

The probability of the return water exceeding 23.7°C is unknown, but within the realm of possibility. Based on the low volume of water in Ochoco Creek at this point, the tailwater return from the D-2 Drain to Ochoco Creek has the potential for an adverse thermal effect on covered fish species and should be reviewed more completely before a determination of effect on covered species is made. At least one full irrigation season of data is needed on the rate and temperature of the return flow and the receiving water response.

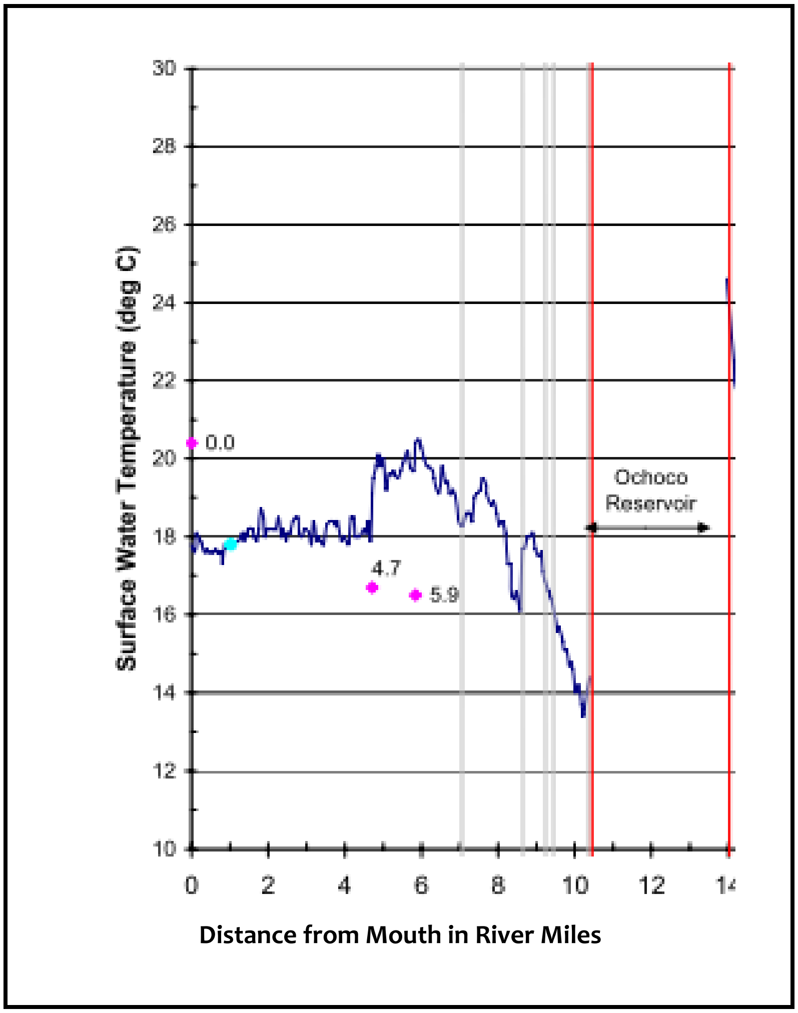

Figure 4-7. Longitudinal water temperature profile for Ochoco Creek from its mouth at the Crooked River to Ochoco Reservoir-July 2005.

Source: Watershed Sciences (2006); pink diamonds represent the RM locations and temperatures of significant inflows to the creek.

Crooked River Diversion Canal Spill

Water is spilled from the Crooked River Diversion Canal where it crosses Ochoco Creek at RM 5.1 throughout the irrigation season to manage flows within the canal. Monthly average spill during the 2006 through 2011 irrigation seasons ranged from 10 to 34 cfs. The maximum daily average spill reported during that period was 75.0 cfs. This spill increases the overall flow in Ochoco Creek downstream of RM 5.1, roughly mid-way between Ochoco Dam and the confluence with the Crooked River. The spill is routinely larger than the creek flow at this point, and appears to be beneficial for covered fish species. A full season of summer water temperature collection at the spill has not been completed, but temperatures are likely cool.

Since the water originates from the Crooked River at RM 57, water temperatures should be approximately 15°C plus any small increase due to heating in the diversion canal. ODEQ report an early August 2005 7-day maximum temperature of this spill of 16.2°C (LASAR database Station No. 32495). Surface water temperatures in Ochoco Creek between June and August reported from ODEQ LASAR data at Station No. 32518, downstream of Combs Flat Road (RM 5.1), ranged between 10.5 °C and 17.4°C, while averaging 14.3°C during 2005 and 2006. These temperatures are lower than the water temperatures recorded upstream where Ochoco Creek temperatures were generally above 20°C much of the time from mid-June to mid-August and the 7-day maximum temperature was 22.7°C in mid-July 2005 (Nielsen-Pincus 2008). As shown in Figure 4-8, the thermal infrared (TIR) imaging study performed by Watershed Sciences during a 4-day period in August, 2005 demonstrated the cooling trend offered by the diversion canal spill (Watershed Sciences 2006). Based on available information, it appears the spills from the Crooked River Diversion Canal cool Ochoco Creek water and should be a benefit to covered species. Flow returns from the spill do not appear to have the potential for an adverse thermal effect on covered fish species.

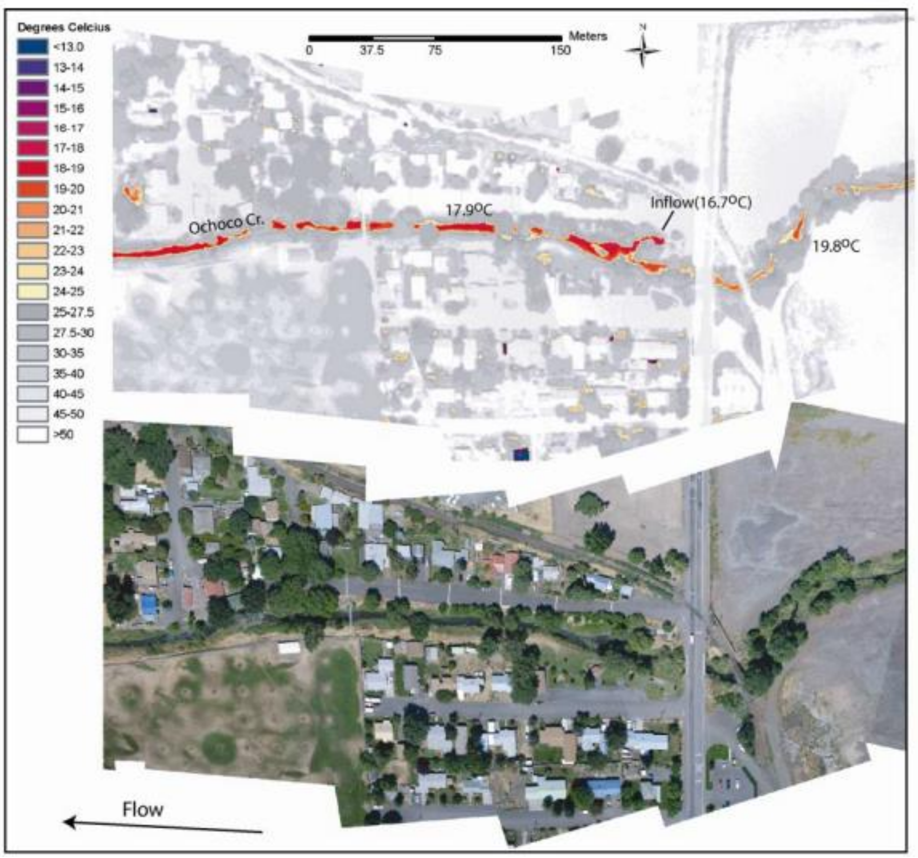

Figure 4-8. A thermal infrared image (top) and true color image (bottom) showing Ochoco Creek near Combs Flat Road and the Crooked River Diversion Canal Spill, August 2005.
Source: Watershed Sciences 2006

4.1.6. McKay Creek

McKay Creek receives return water at five locations within Ochoco Irrigation District (Table 2-1), including four operational spills and one drain (see Figure 2-7). The entire lower portion of McKay Creek within the OID boundary is on the state's 303(d) list for temperature-impaired water bodies (ODEQ 2010). McKay Creek is also used as one of the juvenile fish release points for re-initiating anadromous fish runs in the Upper Deschutes River basin, and will likely offer spawning, rearing and migratory habitats for covered fish species.

4.1.6.1. Ochoco Main Canal Spill

The Ochoco Main Canal spills into McKay Creek at Jones Dam (RM 5.8) throughout the irrigation season. Data on flows and water temperatures are not available for this spill. The surface waters of McKay Creek upstream of the OID boundary can run dry during summer months, depending on seasonal weather conditions and annual snow pack. The recorded mean monthly summer flow in McKay Creek upstream of the OID boundary is approximately 6 cfs, but the monthly minimum is 0 cfs (OWRD gage McKay Creek nr Prineville, OR #14086000) located downstream of Allen Creek (RM 8.0). This reach of the creek is typically dry by July. Based on limited temperature data, summer temperatures in McKay Creek at RM 8.0 appear to range between 14.7°C and 22.0°C (ODEQ LASAR Database Station No. 34180).

On occasion, the water provided by the spill could represent 100 percent of the flowing water in McKay Creek. Since this water originates from near the bottom of Ochoco Reservoir, it should range between approximately 12°C and 16°C plus a small amount of heating in the canal. It is likely this spill could cool live flow in McKay Creek, or conversely it could provide 100 percent of the streamflow. Unless temperatures are lethal to rearing life stages, the spill is expected to provide a benefit to covered fish species.

4.1.6.2. Dry Creek Live Flow and Spill

Dry Creek carries live flow and irrigation spills into McKay Creek at RM 3.9**.** Live flow occurs occasionally during the winter months. Flow and water temperature data are not available for the spill into 'Old' Dry Creek. As the creek name implies, live flows during summer months are often non-existent and the spill represents 100 percent of the Dry Creek flow into McKay Creek. Given the lack of site-specific data, it would be prudent to evaluate this spill more completely before a determination of effect on covered species is made. At least one full irrigation season of data is needed on the rate and temperature of the spill and any live flow.

4.1.6.3. Crooked River Distribution Canal Spill

The Crooked River Distribution Canal spills into McKay Creek at the Reynolds Siphon (RM 3.2) throughout the irrigation season. Monthly average flow at the spill during 2006 through 2011 ranged from 0.25 to 45 cfs. The maximum daily average spill reported during the 6-year period was 54 cfs (OID 2012). The temperature of the water returned at this point is unknown. The source water originates from the Crooked River at RM 57. ODEQ report an early August 2005 7-day maximum temperature of the Crooked River Distribution Canal spill of 16.2°C at Ochoco Creek (LASAR database Station No. 32495). Given a small amount of heating in the diversion canal between the two release sites, the spill to McKay Creek is likely slightly warmer but it is expected to be within the same order of magnitude as the spill to Ochoco Creek. The maximum

7-day average of peak daily water temperatures in McKay Creek upstream of the spill at RM 3.5 was 23.5°C during continuous temperature recordings from June through October, 2006 (LASAR database Station ID No. 34180). Based on limited information, it appears the spill from the Crooked River Diversion Canal has the ability to cool McKay Creek water and should offer a benefit to covered species. The spill does not appear to have the potential for an adverse thermal effect on covered fish species.

4.1.6.4. D-8 Drain

The D-8 drain conveys local tailwater to McKay Creek at RM 1.3. Flows and water temperatures in the drain are not recorded. Given the lack of site-specific data, it would be prudent to evaluate this spill more completely before a determination of effect on covered species is made. At least one full irrigation season of data is needed on the rate and temperature of the tailwater and receiving water.

4.1.6.5. Ryegrass Canal Spill

The Ryegrass Canal spills into McKay Creek at the Pine Products Siphon (RM 1.0) throughout the irrigation season. Monthly average return flow at the spill during 2006 through 2011 ranged from 7 to 11 cfs. The maximum monthly average spill reported during that period was 25 cfs during irrigation start up in April. The temperature of the water returned at this point during the summer season is unknown. The source of water for the Ryegrass Canal comes from the lowermost section of Ochoco Creek (RM 4.7). Summer temperatures of the source water are in the range of 18°C (Watershed Sciences 2006). Water temperatures may warm up slightly during transit in the canal and within the lower mile of McKay Creek, since Watershed Sciences measured 22.2°C at the mouth of McKay Creek during July 2005, ODEQ reports a temperature of 20.4°C at Highway 26 (Station No. 32518) during an afternoon in August 2005, and CRWC report a 7-day maximum value of 22.8°C during mid-July 2005 at Highway 26 (Nielsen-Pincus 2008). Given the lack of site-specific data and the general warm condition of McKay Creek in the vicinity of this return, it would be prudent to evaluate the spill more completely before a determination of effect on covered species is made. At least one full irrigation season of data is needed on the flow and temperature of the spill and receiving water.

4.1.7. Lytle Creek

Covered fish species presence in Lytle Creek is currently unknown. However, migratory fish have physical access to portions of Lytle Creek affected by the points of irrigation returns. StreamNet (2012) reports man-made blockages to upstream fish passage in Lytle Creek at U.S. Hwy 26 (RM 2.7) and Fisher Joe Reservoir (RM 6.4). OID personnel believe the box culvert at U.S. Hwy 26 is currently passable (Rhoden, pers. comm. 2012).

Lytle Creek collects return water at four operational spills and four drains before flowing into the Crooked River at RM 41.0, including spills at: 1) Grimes Flat West Canal at RM 5.7; 2) Ochoco Main Canal at RM 5.0; 3) Crooked River Distribution Canal at RM 3.0; 4) Ryegrass Canal at RM 1.3; and four drains known as 823, 825, 827 and D-7 occurring between RM 1.5 and RM 3.2 (see Figure 2-4).

Lytle Creek is naturally dry upstream of the OID boundary. Within the district, the creek flows year round. The majority of flow within district is operational spill and return water during the irrigation season, but a small amount of spring-fed live flow emerges from the D7 drain a short distance above Highway 26 throughout the year. On occasion, Lytle Creek is comprised of only irrigation water during the summer irrigation season. Monthly average flow in Lytle Creek below Ryegrass Canal during the irrigation seasons of 2006 through 2011 ranged from 9 to 29 cfs. The maximum daily average flow reported during that period was 37 cfs (OID 2012).

Estimates of flow and water temperature are not available for the spills or drains returning to Lytle Creek. Similarly, there are no known regionally operated flow gages or water quality monitoring sites on Lytle Creek. Watershed Sciences (2006) measured temperatures at the mouth of Lytle Creek during their July 2005 TIR study of the Crooked River. The median temperature value In Lytle Creek was 21.8°C, which at the time was comparable to the thermal regime in the mainstem Crooked River. Given the lack of site-specific data and the general warm condition of Lytle Creek, it would be prudent to evaluate all spills and drains in greater detail.

5.0 Conclusions and Recommendations

This initial screening-level assessment of irrigation releases, return flows, and discharges was conservative in its assumptions regarding the representative high surface water temperatures and low flows during the irrigation season. Since in many cases the assessment relies on assumptions, the results do not necessarily provide an accurate representation of on-site conditions. The objective of the approach was to identify where additional information is needed to improve the evaluation for a short-list of releases, return flows, and discharges while eliminating those with a reasonably low likelihood of a measureable influence on water temperatures. As described in Section 5.2, only 23 of 44 points-of-return warrant further detailed assessment to determine if they could have adverse thermal influences on covered species.

5.1. Recommendations on Techniques for Documenting Changes in the Thermal Regimes of Affected Surface Waters from DBHCP Conservation Measures

Site-specific assessments such as those presented in Section 4 *Results* are sufficient for evaluating thermal effects associated with return flows. A system-wide assessment using advanced modeling techniques is not warranted given the localized effects of the returns and the influence of groundwater springs in both the Deschutes and Crooked River basins. These springs dominate the thermal regimes of some downstream waters, making integrated studies of longitudinal modifications in water temperatures from cumulative irrigation returns unnecessary. Additionally, very few of the points of return met the distance criteria for joint inclusion in an assessment of cumulative effects. As such, any thermal disturbances brought about by the returns would be local in nature and persistently brought into temperature equilibrium by the receiving body.

Although indefinitely on hold, ODEQ is planning to perform HeatSource temperature modeling of the lower Crooked River to complete mandated TMDL studies (Lamb, pers. comm. September 11, 2012). Such an effort would cover nearly 90 percent of the irrigation returns identified in this report as needing further evaluation. Draft HeatSource models have been developed. Although the output would be useable for evaluation of DBHCP conservation measures, the results are not essential as described below.

With site-specific monitoring to fill missing data points, as described in Section 5.2 *Assessment of the Need for Additional Monitoring* below, a mass balance approach of local site conditions, as used in this screening-level assessment, will provide an adequate evaluation of the temperature changes anticipated for irrigation releases and returns under current conditions and for conservation planning within the DBHCP.

5.2. Assessment of the Need for Additional Monitoring

Based on the current assessment, specific water temperature and/or stream flow information is needed at the following irrigation returns. Other reaches that need additional water temperature or stream flow information may be identified during Phase 2 of this study:

- Deschutes River
  - Lateral 58-11 Drain
  - North Unit Main Canal Terminus at Mud Springs
- Crooked River
  - Juniper Canyon Flood Control Channel
  - Spill at the Gap
  - North Unit Main Canal Crossing
  - North Unit Laterals 31 and 34
  - Dry Canyon Return
  - Lone Pine Delivery Spill
  - Pilot Butte Canal H-17 return
  - Lone Pine Canal Return
- Ochoco Creek
  - D2 – Drain
- McKay Creek
  - Dry Creek Live Flow and Spill
  - D-8 Drain
  - Ryegrass Canal Spill
- Lytle Creek
  - All four spills and four drains

5.2.1. Water Temperature

For routine releases, spills and returns occurring throughout the irrigation season, continuous temperature monitors, deployed at the return points and immediately upstream in the receiving waters, would provide essential data for determining the thermal contributions of covered returns at the locations noted above. Monitoring should consist of deploying continuous monitoring thermographs (data loggers like Optic StowAway, or similar, with an accuracy of ± 0.25°C) set to record temperature information at hourly time intervals. For one-time spills during annual startup, a measurement of the water temperature and volume at the diversion, at the spill location, and in the Crooked River upstream of the annual spill would be sufficient to evaluate the receiving water response. A properly calibrated mercury thermometer in the neighborhood of 0-30°C range would be preferred. Calibration, deployment, and data retrieval protocols for the temperature monitoring should be consistent with local watershed council and ODEQ procedures.

5.2.2. Stream Flow

Flow measurements of irrigation returns and receiving water are needed to determine the relative contribution of each source to downstream water temperature regimes. Most of the aforementioned points-of-return have either measurement weirs or electronic equipment for determining flow rates. Some of the monitoring performed by the member irrigation districts is infrequent (non-routine) or conversely the information is not easily retrievable for assessment.

Effort should be extended to summarize available information where it exists or, conversely, to install monitoring equipment at these returns. Assumptions related to the frequency, duration, and magnitude of flow returns can be used in lieu of equipment, but such an assessment would provide at a lower level of confidence than monitoring data.

6.0 References

Adams, T.A. and K. Sullivan. 1990. The physics of forest stream heating: a simple model. Washington Department of Natural Resources Timber/Fish Wildlife Report TFW-WQ3-90-007.

Batt, P.E. 1996. Governor Phillip E. Batt's State of Idaho Bull Trout Conservation Plan. Boise, Idaho. 20p.

Bell, M.C. 1991. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Biosystems, Water Work Consulting, Coos Watershed Association, Alsea Geospatial, Inc., and Karen Bahus Technical Writing. 2003. Elliott State Forest Watershed Analysis. Final Report to Oregon Department of Forestry. Salem, OR.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. J. Fish. Res. Board Can. 9(6):265-323.

Brett, J.R. 1964. The respiratory metabolism and swimming performance of young sockeye salmon. J. Fish. Res. Board Can. 21:1183-1226.

Brett, J.R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Oncorhynchus nerka*). Am. Zoo1.11(1):99-113.

Brett, J.R., J.E. Shelbourn, and C.T. Shoop. 1969. Growth rate and body composition of fingerling sockeye salmon, *Oncorhynchus nerka*, in relation to temperature and ration size. J. Fish. Res. Board Can. 26(9):2363-2394.

Brown, L.G. 1992. On the zoogeography and life history of Washington's native charr; Dolly Varden, *Salvelinus malma* (Walbaum) and bull trout, *Salvelinus confluentus* (Suckley). Appendix A. Bull trout/Dolly Varden management and recovery plan. Olympia, WA: Washington Department of Wildlife.

Brun, C.V. and R.D. Dodson. 2000. Bull trout distribution and abundance in the waters on and bordering the Warm Springs Reservation, 2000 Annual Report. Bonneville Power Administration, Portland, Oregon.

Buchanan, D.V., M.L. Hanson, and R.M. Hooten. 1997. Status of Oregon's bull trout. Oregon Department of Fish and Wildlife, Portland, Oregon.

Caldwell, J.E., K. Doughty, and K. Sullivan. 1991. Evaluation of downstream temperature effects of type 4/5 waters. Timber/Fish/Wildlife Rep. No. TFW-WQ5-91-004. Washington Dept. Nat. Resources, Forest Practices Division, Olympia, WA. 71 p.

California Department of Water Resources (CDWR). 1988. Water temperature effects on Chinook salmon (*Oncorhynchus tshawytscha*) with emphasis on the Sacramento River: A literature review. Northern District Office Report, Red Bluff, CA. 42 pp.

Central Oregon Irrigation District (COID). 2012. Temperature monitoring data for the main canal return at Dry Canyon. Email transmission of data August 2012.

City of Prineville, OR. 2007. Monthly Discharge Monitoring Reports (DMRs) for the municipal wastewater treatment plant; 2007.

City of Prineville, OR. 2008. Monthly Discharge Monitoring Reports (DMRs) for the municipal wastewater treatment plant; 2008.

Dent, L, V. Danielle, K. Abraham, S. Schoenhotlz, and S. Johnson. 2008. Summer temperature patterns in headwater streams of the Oregon Coast Range. Journal of the American Water Resources Association 44(4). August 2008.

Donaldson, L.R., and E.J. Foster. 1941. Experimental study of the effect of various water temperatures on the growth, food utilization and mortality rates of fingerling sockeye salmon. Trans. Am. Fish. Soc. 70:339-346.

Dunham, J., B. Rieman, and G. Chandler. 2003. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23:894–904.

Essig, D.A., C.A. Mebane, and T.W. Hillman. 2003. Update of bull trout temperature requirements. Idaho Department of Environmental Quality, Boise, ID. Final Report April 30, 2003. 48p.

Fies, T., B. Lewis, M. Manion, and S. Marx. 1998. Upper Deschutes River Subbasin Fish Management Plan. Oregon Department of Fish and Wildlife, Portland, Oregon.

Fitzpatrick, K. 2005. Excel spreadsheets of flow measurement data and analysis for Lone Pine Irrigation District returns. May 2005.

Foerster, R.E. 1968. The sockeye salmon, *Oncorhynchus nerka*. Bulletin of Fisheries Research Board of Canada. 162. 422 pp.

Fraley J. and B. Shepard. 1989. Life history, ecology, and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. Northwest Science 63:133-143.

Goetz, F. 1989. Biology of the bull trout*, Salvelinus confluentus*, a literature review. U.S. Forest Service, Willamette National Forest, Eugene, OR. 53 p.

Hammond, E., J. Roofener, and others. 2009. Monitoring agricultural runoff. PowerPoint Presentation, Prepared by the Oregon Department of Agriculture and Jefferson County. 45p.

Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada. Bulletin 180. 665 pp.

Kraemer C. 1994. Some observations on the life history and behavior of the native char, Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) of the North Puget Sound region. Washington Department of Fish and Wildlife, Mill Creek, Washington.

La Marche, J. 2007. Results from 2007 Crooked River seepage run. State of Oregon Water Resources Department. Technical Memorandum dated January 2, 200(8). 10 p.

La Marche, J., T. Dubin and D.P. Lettenmaier. 1997. A 2-layer energy balance model for the prediction of stream temperature. American Geophysical Union Fall Meeting. Poster Presentation.

Lindsay R.B., B.C. Jonasson, R.K. Schroeder, and B.C. Cates. 1989. Spring Chinook salmon in the Deschutes River, Oregon. Information Reports No. 89-4. Oregon Department of Fish and Wildlife. 92 p.

Main, B. 2012. Personal Communication between Bob Main, Ochoco Irrigation District and Ron Campbell, R2 Resource Consultants, Inc. at a meeting regarding hydrologic model runs in the Crooked River, September 20, 2012.

Martin, S.W., M.A. Schuck, K. Underwood, and A.T. Scholz. 1992. Investigations of bulltrout (*Salvelinus confluentus*), steelhead trout (*Oncorhynchus mykiss*), and spring Chinook salmon (*O. tshawytscha*) interactions in southeastern Washington streams. Annual Report for the Bonneville Power Administration, Project No. 90-53, Contract No. DE-B179-91BP17758, Portland, OR.

McCullough, D., S. Spalding, D. Sturdevant, M. Hicks. 2001. Issue Paper 5. Summary of technical literature examining the physiological effects of temperature on salmonids. Prepared as part of U.S. EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. EPA-910-D-01-005. Available at: http://yosemite.epa.gov/R10/WATER.NSF/1507773cf7ca99a7882569ed007349b5/ce95a3704aeb5715882568c400784499?OpenDocument.

McMahon, T., A. Zale, J. Selong, and R. Barrows. 1998. Growth and survival temperature criteria for bull trout: annual report 1998 (year one). Montana State University and the U.S. Fish and Wildlife Service, Bozeman Fish Technology Center, Bozeman, MT.

McMahon, T., A. Zale, J. Selong, and R. Barrows. 1999. Growth and survival temperature criteria for bull trout: annual report 1999 (year two). Montana State University and the U.S. Fish and Wildlife Service, Bozeman Fish Technology Center, Bozeman, MT.

McMahon, T., A. Zale, J. Selong, and R. Barrows. 2000. Growth and survival temperature criteria for bull trout: annual report 2000 (year three). Montana State University and the U.S. Fish and Wildlife Service, Bozeman Fish Technology Center, Bozeman, MT.

McPhail, J.D., and C.B. Murray. 1979. The early life-history and ecology of Dolly Varden (*Salvelinus malma*) in the Upper Arrow Lakes. University of British Columbia, Department of Zoology and Institute of Animal Resources. Vancouver, BC. 113p.

Moore, R.D., D.L. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: A review. Journal of the American Water Resources Association (JAWRA) 41(4):813-834. August 2005.

Myrick, C.A. 2002. Bull trout temperature thresholds peer review summary. Report prepared by Colorado State University for the USFWS, Lacey, WA. September 19, 2002. 13p.

National Marine Fisheries Service (NMFS). 2008. Proposed Middle Columbia River Steelhead Recovery Plan. Federal Register 73(186):55045.

Nielsen-Pincus, M. (ed). 2008. Lower Crooked River Watershed Assessment. Crooked River Watershed Council. February, 2008, 249p.

Northwest Power and Conservation Council (NPCC). 2004. Deschutes Subbasin Plan [Assessment, inventory, and Management Plan]. May 28, 2004. 333p. + app.

Ochoco Irrigation District (OID). 2012. Flow monitoring data for District returns. Email transmission of data July 2012.

Oregon Department of Environmental Quality (ODEQ). 2001. State of Oregon antidegradation policy

Oregon Department of Environmental Quality (ODEQ). 2003. City of Prineville NPDES Waste Discharge Permit No. 101433. Permit issued by ODEQ, Eastern Region, Bend Office, Bend OR. 22p. Permit available online at: http://www.deq.state.or.us/wqpr/1012_A0906151142117858241.PDF Last accessed September 12, 2012.

Oregon Department of Environmental Quality (ODEQ). 2010. State of Oregon 303(d) list for water quality limited streams. Online @ http://www.deq.state.or.us/wq/assessment/rpt0406/search.asp#db

Oregon Department of Environmental Quality (ODEQ). 2012. LASAR database retrieval. Information available at: http://deq12.deq.state.or.us/lasar2/SearchLasar.aspx?page=1&dt=0. Last accessed September 12, 2012.

Oregon Department of Environmental Quality (ODEQ). 2013. Personal communication. Email forwarded by Bonnie Lamb, ODEQ to Biota Pacific re: comments on DBHCP Draft Study 2, February 14, 2013.

Oregon Water Resources Department (OWRD). 2013. Historic streamflow data online retrieval at http://apps.wrd.state.or.us/apps/sw/hydro_report/default.aspx. Last accessed March 2013.

Pauley, G.B., R. Risher, and G.L. Thomas. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--sockeye salmon. USFWS Biol. Rep. 82 (11.116). U.S. Army Corps of Engineers, TR EL-82-4. 22 pp.

Portland General Electric (PGE). 2012. Fish counts at Pelton Dam; online at http://www.portlandgeneral.com/community/environment/initiatives/protecting_fish/deschutes_river. Last accessed August, 2012.

Reiser, D.W., and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. USFS, Pacific Northwest For. Range Exp. Station. Gen. Tech. Rep. PNW-96. 54 pp.

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U.S. Forest Service (USFS) Intermountain Research Station General Technical Report INT-302, September 1993

Rhoden, R. 2012. Personal communication of Russ Rhoden, Ochoco Irrigation District with Ron Campbell, R2 Resource Consultants, Inc. Email memorandum dated November 7, 2012.

Sansone, A.L. and D.P. Lettenmaier. 2001. A GIS-based temperature model for the prediction of maximum stream temperatures in the Cascade Mountain Region. Water Resources Series Technical Report 168 December 2001. 87p.

Schloss, A.J. 1985. A predictive model for estimating maximum summer stream temperatures in western Oregon. Technical Note 370, Denver, CO: Bureau of Land Management Service Center, U.S. Department of Interior; BLM/4A/PT/85-006-4341; 8 p.

StreamNet. 2012. Fish distribution for the Deschutes Basin, accessed 21 March 2012. Available online at http://www.streamnet.org/index.html

Stuart, A.M., S.T. Thiesfeld, T.K. Nelson, and T.M. Schrader. 1996. Crooked River Basin Plan, Ochoco Fish District. Oregon Department of Fish and Wildlife. Portland, Oregon.

Sullivan, K. and T.A. Adams. 1990. The physics of stream heating: Part 2, An analysis of temperature patterns in stream environments based on physical principles and field data. Weyerhaeuser Tech. Rep. 044-5002/89/2. Tacoma, WA. 54p.

Sullivan, K., J. Tooley, K. Doughty, J. E. Caldwell and P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Rep. No. TFW-WQ3-90-006. Washington Department of Natural Resources, Olympia, WA.

Theurer, F.D., K.A. Yoos and W.1. Miller. 1984. Instream water temperature model. Instream Flow Info. Paper No. 16. U.S.D.I. Fish and Wildlife Service FWS/OBS-84/15.

U.S. Bureau of Reclamation (Reclamation). 2003. Biological Assessment (BA) on continued operation and maintenance of the Deschutes River Basin Projects and effects on essential fish habitat under the Magnuson-Stevens Act - Deschutes, Crooked River, and Wapinitia Projects. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Lower Columbia Area Office, Portland, Oregon. September 2003.

U.S. Bureau of Reclamation (Reclamation). 2013. Hydromet online data retrieval at http://www.usbr.gov/pn/hydromet/dfcgi.html. January 2013.

U.S. Environmental Protection Agency (USEPA). 2001. Technical synthesis; scientific issues relating to temperature criteria for salmon, trout, and char native to the Pacific Northwest. A summary report submitted to the Policy Workgroup of the EPA Region 10 Water Temperature Criteria Guidance Project. United States EPA 910-R-01-007. August, 2001.

U.S. Fish and Wildlife Service (USFWS). 2010. Revised designation of critical habitat for bull trout (Salvelinus confluentus) in the coterminous United States; Final Rule. Federal Register 75 (200):63898.

U.S. Fish and Wildlife Service (USFWS). 2012. Species Fact Sheet – Bull Trout (*Salvelinus confluentus*). Located at: http://www.fws.gov/oregonfwo/Species/Data/BullTrout/ Last accessed September 6, 2012.

U.S. Geological Survey (USGS). 2012. USGS Surface-Water Daily Data for Oregon online data retrieval at http://nwis.waterdata.usgs.gov/or/nwis. Last Accessed December 2012.

Watershed Professionals Network (WPN). 2002. Trout Creek Watershed Assessment. Prepared for Bonneville Power Administration and Trout Creek Watershed Council. Corvallis, Oregon.

Watershed Sciences, Inc. 2006. Airborne thermal infrared remote sensing, Crooked River, OR. Prepared for Oregon Department of Environmental Quality, Portland, OR.

Watershed Sciences and MaxDepth Aquatics. 2008. Deschutes River, Wychus Creek, and Tumalo Creek Temperature Modeling. Report prepared by Watershed Sciences and MaxDepth Aquatics, Inc. of Bend, OR for the State of Oregon Department of Environmental Quality.

Weaver T.M., and R.G. White. 1985. Coal Creek fisheries monitoring study No. III. Quarterly Progress Report. Montana State Cooperative Fisheries Research Unit, Bozeman.

Wydoski, R.S., and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle. 168pp.

Zwieniecki, M. A. and M. Newton. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of western Oregon. Western Journal of Applied Forestry. Volume 14(2): 106-113.