Evaluation of the Impact of Cumulative Groundwater Withdrawals in the Upper Deschutes Basin on Water Temperatures of the Middle Deschutes River

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Executive Summary

The impact of future groundwater withdrawals in the upper Deschutes basin on mid- to late-summer instream temperatures in the middle Deschutes River is evaluated using the Deschutes HeatSource model.

We estimate that by the year 2025 an additional 100 cubic feet per second (steady state annualized) of groundwater will be pumped in the upper Deschutes basin to meet the water needs of destination resorts, cities, rural development, and other water uses.

Assuming a 90% consumption rate this will result in a 90 cubic feet per second reduction in groundwater discharge to streams, with the bulk of the impact focused on the middle Deschutes River between the Lower Bridge area and Lake Billy Chinook.

Although some loss of spring flow and groundwater discharge will also occur in tributaries of the Deschutes River, we assume for the sake of simplicity that the full reduction would be proportioned amongst the dominant spring complexes of the middle Deschutes River.

We used HeatSource models developed for the Deschutes basin to evaluate two scenarios:

- The first scenario evaluated the impact on stream temperature due to a reduction of 90 cubic feet per second of cold groundwater discharge to the middle Deschutes River.
- The second scenario evaluated the impact on stream temperature due to a reduction of 90 cfs of cold groundwater discharge to the middle Deschutes River, plus a return of 250 cfs of water to the river below Bend by reducing diversions.

Under the first scenario, the middle Deschutes River between miles 14 (near Lower Bridge) and mile 0 (Lake Billy Chinook) is warmed by an average of 1.1 degrees F and in places as much as 1.8 degrees F as a result of reduced groundwater discharge. Under the second scenario the same stretch of the river is warmed by an average of 0.6 degrees F and as much as 1 degree F as a result of reduced groundwater discharge.[1]

The temperature effect of returning substantial amounts of water to the river via reduced agricultural diversions is to substantially cool a roughly 35 mile stretch of river below Bend and above Lower Bridge. However, below Lower Bridge, and even more so below Steelhead Falls (mile 9), which is the stretch of the river dominated by springs, water temperature is warmed significantly. Temperature increases in the lowest 5 miles of the river just above Lake Billy Chinook associated with the reduced diversions approach 2 degrees F. The combined temperature increase resulting from reduced groundwater discharges *and* reduced diversions in places approaches 3 degrees F.

[1] Actual impacts to the middle Deschutes River are likely to be slightly less, as some portion of the 90 cfs reduction will occur in the river's smaller tributaries. However, as growth in Central Oregon is expected to continue well past the year 2025, the impacts to the middle Deschutes River are likely to be substantially greater over time.

Because Steelhead Falls acts as a geological barrier against fish passage upstream, the act of reducing agricultural diversions to improve flows in the middle Deschutes River may lead to a net degradation of water temperature conditions for species like the Steelhead and Chinook which are the focus of reintroduction efforts and numerous related conservation investments.

It is beyond the scope of this analysis to offer a comprehensive assessment of all potential risks and benefits to native fish species from changes in stream flows. However, with respect to water temperatures alone, this work suggests that the loss of spring flows and cold groundwater discharge, combined with the reductions in agricultural diversions, raises serious concerns about the impacts of future growth on native fish.

1.0 Introduction

The objective of the work described in this report was to evaluate the cumulative impact of increased groundwater pumping in the upper Deschutes basin on cold-water reaches of the middle Deschutes River. The reduction of cold groundwater discharges to streams due to cumulative pumping of groundwater is anticipated to result in increases in the temperature of streams. Cold groundwater discharges to streams provide refuge habitat for fish in the summer when stream flows decline and stream temperatures rise. Cold water is one of the primary requirements for maintaining existing populations of native redband trout and bull trout. Cold water is required to assure the successful reestablishment of salmon and steelhead.

The work consisted of two steps. The first step was to quantify the increase in groundwater withdrawals in the upper Deschutes basin from the present to the year 2025. The second step was to model changes in stream temperature in the middle Deschutes River associated with the reductions of cold groundwater discharge to the stream. The middle Deschutes River is defined here as the reach of the Deschutes River between the confluence of Tumalo Creek and the inflow to Lake Billy Chinook.

Mark Yinger was responsible for the quantifying the increase in withdrawals. Ed Salminen was responsible for modeling changes in stream temperature. Mark Yinger has managed hydrogeologic and groundwater flow modeling projects in the upper Deschutes basin. These projects were focused on investigating the impact of destination resort development on groundwater and streams. Ed Salminen is a surface water hydrologist who has undertaken stream temperature modeling projects across the range of conditions found in the Pacific Northwest. Ed has evaluated land management impacts on stream temperature using a variety of analytical tools.

2.0 Increase in Groundwater Withdrawals

The water needs for growth in the upper Deschutes basin will rely on increased pumping of groundwater. As groundwater withdrawals increase, discharges of cold groundwater to streams will be reduced. It is reasonable to assume that most of this impact will be to the middle Deschutes River. The projected increases in groundwater withdrawals by 2025 are summarized in the following table. The sources for values in the table are explained in the footnotes of the table.

Table 1. Projected increases in groundwater withdrawals through 2025

Destination Resorts proposed or in development

	Annual withdrawal in acre feet (af)	Steady state annualized pumping rate in cubic feet/second (cfs)
Green Ridge (Colson)[1]	2422	3.35
Metolian (Dutch Pacific)[1]	262	0.36
Aspen Lakes[2]	1420	1.96
Skyline Forest[3]	1500	1.66
Thornburgh[2]	2129	2.94
Thornburgh II[3]	2129	2.94
Tetherow[2]	2852	3.94
Remington Ranch[4]	1578	2.18
Brasada[4]	1578	2.18
Crossing Trails[4]	1578	2.18
Pronghorn[5]	1378	2.18
Caldera Springs[3]	1200	1.66
Crescent Creek[1]	4032	5.57
Totals	23958	33.09

Combined Within Urban Growth Boundaries[6]

Bend, Redmond, Prineville, Sisters, Culver, Madras and Metolius	17600	24.31
Totals	17600	24.31

Outside Urban Growth Boundaries[6]

Irrigation	3299	4.56
Industrial	811	1.12
Group Domestic	90	0.12
Pond Maintenance	22	0.03
Quasi-Municipal	13844	19.12
Totals	18066	24.95

Exempt Wells[6]

Exempt domestic wells	13444	18.57
Totals	13444	18.57

Grand Total	73068	100.93

Footnotes:

1. Based on water right application (OWRD, 2008).
2. Based on water right permit (OWRD, 2008). In the case of Aspen Lakes some portion is already being pumped.
3. Estimated based on development or similar nearby development.
4. These resorts are supplied by Avion from a combination of 12 wells in the Bend area. We used the Deschutes Water Alliance (DWA) report, "Future Ground Water Demand in the Deschutes Basin" 2006 estimate for a destination resort (Newton, 2006).
5. Pronghorn Resort groundwater is estimated. The resort uses waste water from the City of Bend for a portion of its irrigation needs.
6. These estimates are based on data in contained the Deschutes Water Alliance (DWA) report, "Future Ground Water Demand in the Deschutes Basin" (Newton, 2006).

3.0 Stream Temperature Modeling and Calculation

Approach

The Oregon Department of Environmental Quality (ODEQ) has contracted with Watershed Sciences to develop stream temperature models for the Deschutes River upstream of Lake Billy Chinook, Tumalo Creek, and Whychus Creek (Watershed Sciences, 2008). These models were developed using the HeatSource modeling methodology developed by ODEQ[2]. Copies of these models were made available for this assessment by ODEQ[3].

We used the Deschutes HeatSource models to evaluate two scenarios:

- The first scenario evaluated the impact on stream temperature due to a reduction of 90 cubic feet per second (cfs) of cold groundwater discharge to the middle Deschutes River.
- The second scenario evaluated the impact on stream temperature due to a reduction of 90 cfs of cold groundwater discharge to the middle Deschutes River, plus a return of 250 cfs of water to the river below Bend by reducing diversions.

Results from the current conditions model developed for the Deschutes River were used as the baseline condition for evaluating changes in temperature associated with each scenario. The current conditions are representative of late summer stream flows prior to the recent return of modest amounts of water to the river via reduced diversions.

In the first scenario, the Deschutes model was used to assess the impacts of a 100 cfs increase in groundwater withdrawals resulting in a 90 cfs reduction of cold groundwater discharge to the middle Deschutes River (assuming that 90% is consumed). The 90 cfs reduction was proportioned based on the estimated magnitudes at groundwater inflow locations identified by Watershed Sciences (Table 2). This approach assumes that the impacts are evenly distributed throughout the reach, and are experienced at each spring complex proportional to the observed flow volumes.

A second scenario was modeled incorporating the ODFW instream water rights target and modeling the same reduction in cold water discharge. The instream water rights target for the Deschutes River from North Canal Dam to Lake Billy Chinook is 250 cfs.

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[2] http://www.deq.state.or.us/wq/TMDLs/tools.htm
[3] Bonnie Lamb, ODEQ Eastern Region TMDL Basin Coordinator (541) 388-6146 x239

Table 2. Groundwater inflow locations in the middle Deschutes identified by Watershed Sciences (2008), inflow magnitudes, and flow modifications.

Stream mile (kilometer)	Locational Information	Inflow in units of cfs (cms)	Proportional reduction in inflow	Reduction in inflow in cfs (cms)	Revised inflow in units of cfs (cms)
14.42 (23.20)	Spring	4.52 (0.1280)	0.0133	1.20 (0.0339)	3.32 (0.0941)
13.86 (22.30)	Unnamed Trib	8.79 (0.2490)	0.0259	2.33 (0.0659)	6.47 (0.1831)
12.74 (20.50)	Spring	4.63 (0.1310)	0.0136	1.22 (0.0347)	3.40 (0.0963)
12.18 (19.60)	Spring	8.40 (0.2380)	0.0247	2.22 (0.0630)	6.18 (0.1750)
11.84 (19.05)	Mackenzie Canyon	9.75 (0.2760)	0.0287	2.58 (0.0730)	7.17 (0.2030)
10.91 (17.55)	Spring	9.36 (0.2650)	0.0275	2.48 (0.0701)	6.88 (0.1949)
10.56 (17.00)	Spring	73.63 (2.0850)	0.2165	19.49 (0.5518)	54.15 (1.5332)
10.22 (16.45)	Spring	61.98 (1.7550)	0.1822	16.40 (0.4644)	45.58 (1.2906)
4.78 (7.70)	Spring (combination of several points)	159.02 (4.5030)	0.4676	42.08 (1.1917)	116.94 (3.3113)
	Totals	**340.08 (9.6300)**	**1.0000**	**90.00 (2.5485)**	**250.08 (7.0815)**

Results

The Deschutes HeatSource models apply to the length of the Deschutes River from Wickiup Lake to Lake Billy Chinook. No changes were made to the original model parameters other than those shown in Table 2 above. Consequently results are only reported here for the portion of the Deschutes River from Tumalo Creek to Lake Billy Chinook.

The HeatSource model uses actual climate and stream flow data to drive the model. Consequently, results are applicable to a certain day or series of days, and must be interpreted in the context of how that particular modeling period fits in relation to the range of conditions experienced in that particular stream. The models that were developed for the middle Deschutes River covered the time period from 7/19/2001 to 8/7/2001. Peak 7-Day average maximum water temperatures occurred on 7/25/2001. The flow profiles along the middle Deschutes River on 7/25/2001 are shown in Figure 1. Also shown are the 20%, 50% (i.e., median) and 80% exceedance flows for 7/25 at the USGS stream gages located within the reach. The 20% and 80% exceedance flows are a measure of high and low values for that day in the period of record at these gages. The period of record available for gage #14076500, Deschutes River near Culver, is from 1953 to 2007, while the period of record available for gage #14070500, Deschutes River below Bend, is only from 1957 to 1991. These values indicate that, for current conditions, the 7/25/2001 discharge is slightly lower than the median value at the Culver gage, and slightly above the median value at the gage below Bend. This discrepancy may be due to the truncated record available for the Bend gage if the more recent flows are higher than they have been historically. However, the more important point is that the range between high and low values is very narrow, suggesting that the time period used in the HeatSource current conditions[4] model may be fairly representative of the range of conditions experienced at the site over the past ~50 years.

Model results are given in Figures 2 and 3. Impacts associated with both scenarios occur in the downstream 14-mile section of the Deschutes River below Lower Bridge. Modeled water temperatures for the first scenario increase in this reach by as much as 1.8 degrees F (1.0 degrees C), with an average increase of 1.1 degrees F (0.62 degrees C) for this 14-mile portion of the reach (Figure 3). Increases are less under the second scenario, given the buffering effect of the greater overall stream volume (addition of 250 cfs); however, increases are as great as 1 degree F (0.6 degrees C), with an average increase of 0.6 degrees F (0.36 degrees C) for this 14-mile portion of the reach (Figure 3). Also shown in Figure 2 is the 64.4 degree F (18 degree C) rearing and migration water quality standard for temperature during critical summertime periods set to protect salmonid rearing and migration[5].

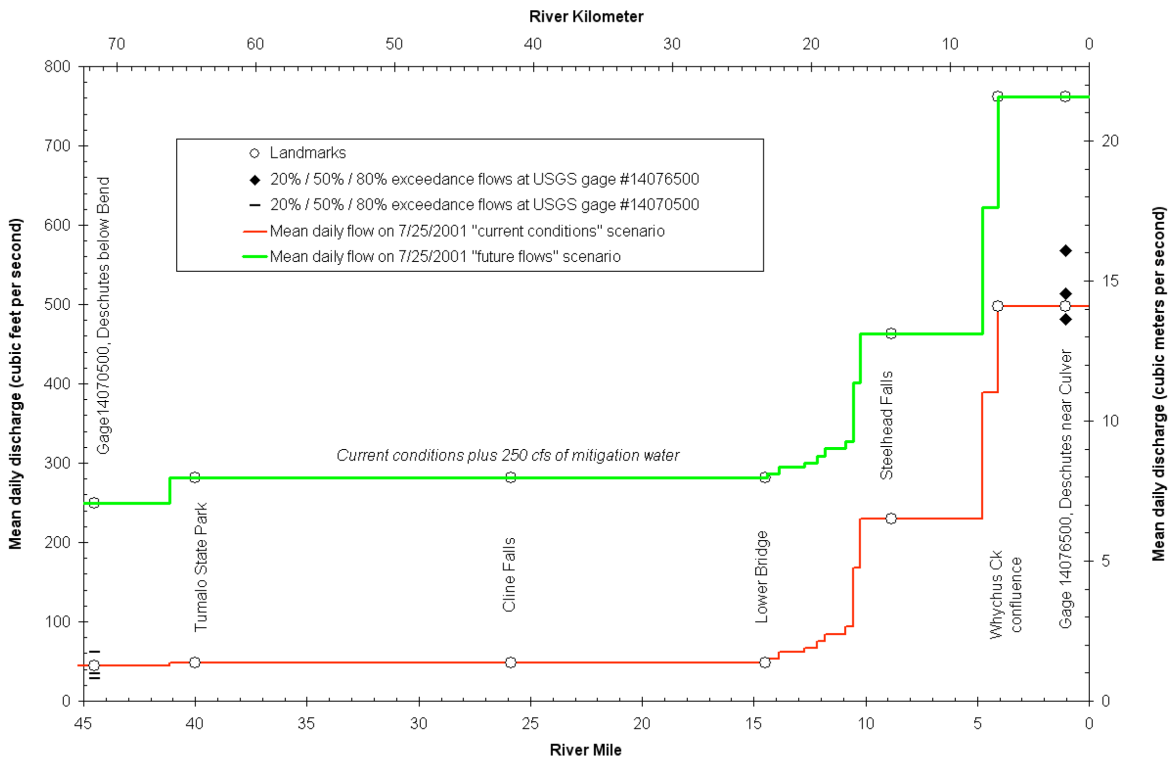

Figure 1. Mean daily flow profile on 7/25/2001 along the Middle Deschutes reach from the HeatSource current conditions and future flows models. Also shown are 20%, 50% and 80% exceedance flows for 7/25 observed at the stream gages located on the Deschutes River downstream of Bend, and near Culver.

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[4] Note that recent in-stream water leases have returned modest amounts of water to this section of the river, consequently, the current conditions model is likely to be representative of the range of conditions experienced for several decades before the in stream leases came into being.

[5] OAR 340-041-0001.

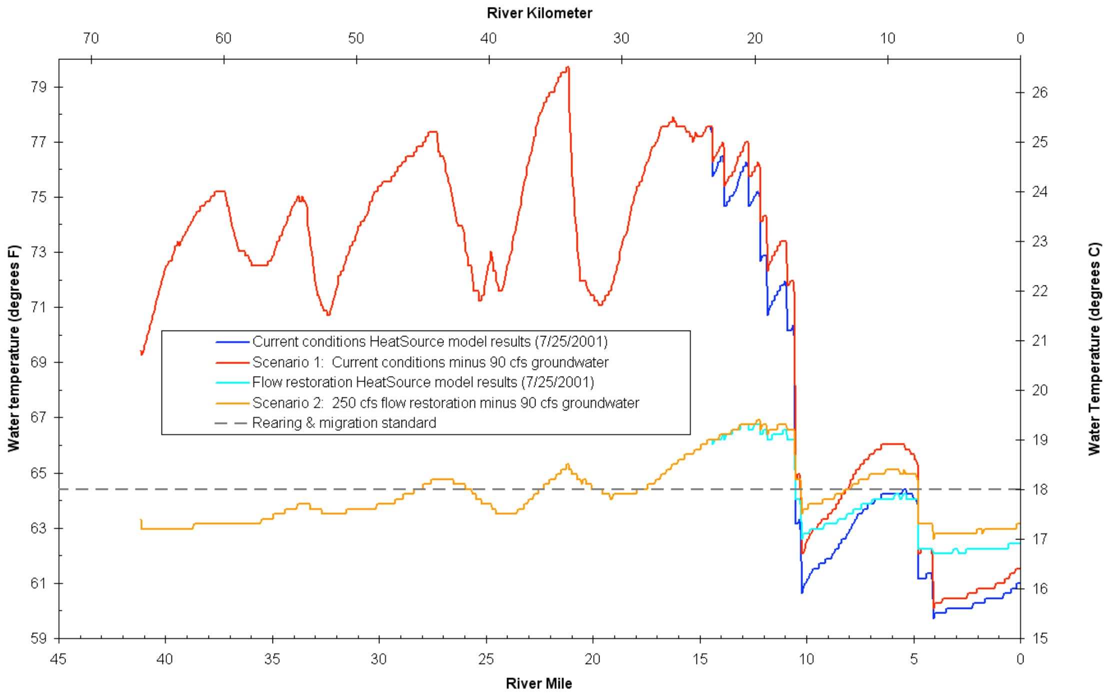

Figure 2. Modeled maximum water temperatures on 7/25/2001 for current conditions, with 250 cfs flow restoration, and for the two modeling scenarios

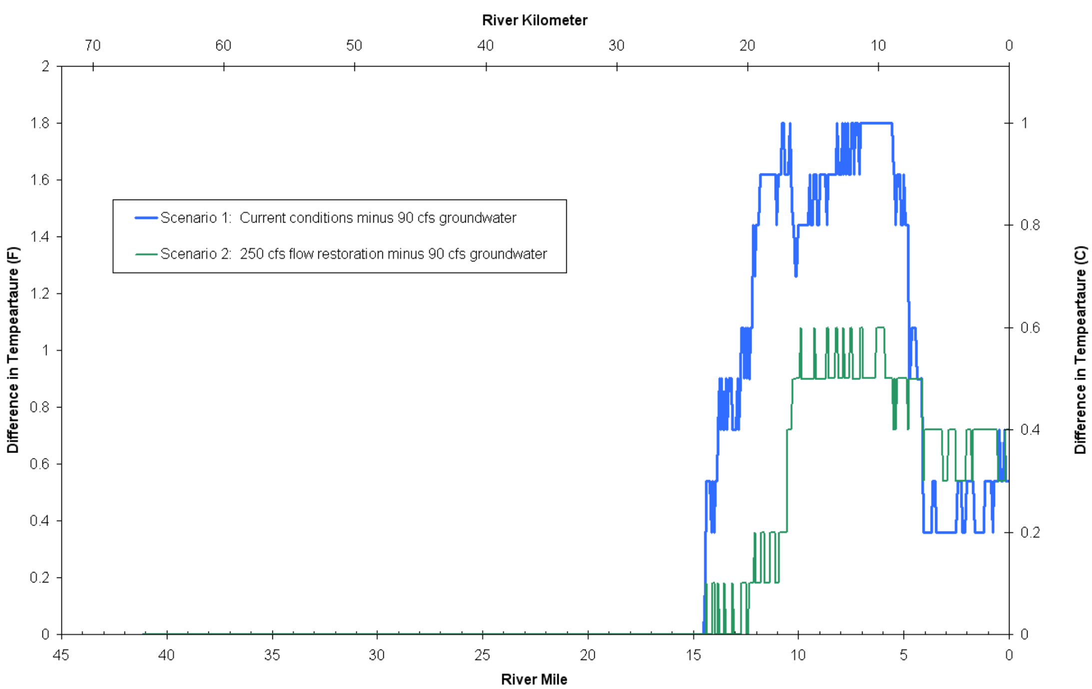

Figure 3. Difference in temperature for the two model scenarios.

Discussion

Since salmonids are ectothermic (cold-blooded), water temperature plays a vital role in feeding behavior, growth, resistance to disease, competitive ability and predator avoidance. Cool water temperature is recognized as a critical factor in the reintroduction of steelhead trout and Chinook salmon to the upper Deschutes basin.

The Oregon Water Quality Standards recognize the importance of controlling temperature increases by specifying that point and nonpoint sources may not increase water temperature greater than 0.5 degrees Fahrenheit 0.3 degrees C) above the applicable criteria after complete mixing[6]. The modeled temperature increase for the Deschutes River exceeds this benchmark and therefore should not be dismissed as inconsequential.

Attainment of the ODFW flow restoration targets (i.e., restoration of 250 cfs of summertime flow downstream of Bend; Figure 1) will likely result in a significant improvement of water temperatures in the portion of the reach that does not receive significant groundwater inputs (i.e., upstream of Lower Bridge; Figure 2). However, Steelhead Falls will continue to pose a natural barrier to upstream migration of salmonid species, even after passage is restored above Pelton Dam. Consequently, despite the positive benefits associated with the flow restoration in the upper portion of the reach, the combination of "warm" mitigation water and reduced spring flows will likely degrade conditions in the portion of the middle Deschutes most critical to anadromous species (Figure 4). This area is currently the best functioning with respect to temperature, and provides critical habitat for cold-water species.

[6] Oregon Administrative Rules 340-041-0028

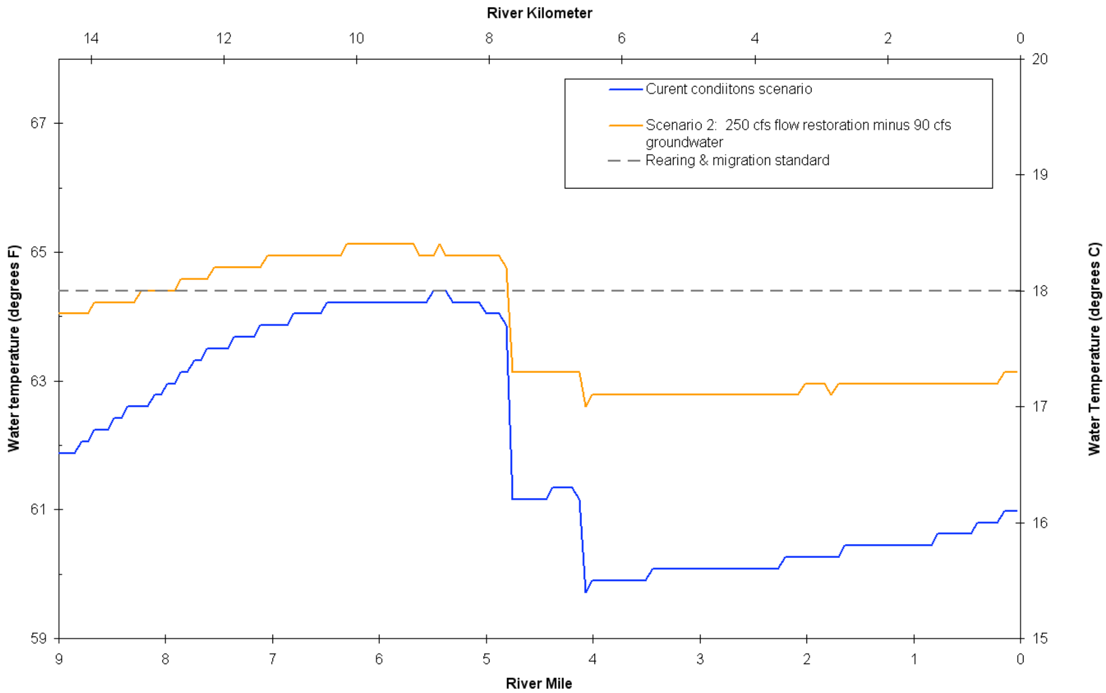

Figure 4. Modeled maximum water temperatures on 7/25/2001 downstream of Steelhead Falls (~RM 9) under a) current conditions and b) with 250 cfs of instream flow restoration and a 90 cfs reduction in groundwater discharge.

References:

Newton, David; Perle, Mathias and Polvi, Jake. 2006. Future ground water demand in the Deschutes basin. Prepared for the Deschutes Water Alliance. 39p.

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Watershed Sciences. May 8, 2008. Deschutes River, Whychus Creek, and Tumalo Creek Temperature Modeling. Prepared for Oregon Department of Environmental Quality. Prepared by Watershed Sciences Inc., Corvallis, OR, and MaxDepth Aquatics Inc., Bend, OR. 85p.