To: Memo to File

From: Michael Kasch, HDR

Project: Surface Water Improvement Project

Date: March 13, 2012

RE: Assessment of the Surface Water Improvement Project on Tumalo Creek Water Temperatures using the Heat Source Model

1 Introduction

Tumalo Creek is the primary water supply source for the City of Bend, Oregon (City). The City has water rights on Tumalo Creek and uses this water as its primary water supply. Additional demand is supplemented with groundwater sources that are more expensive to operate. Tumalo Creek is a high water quality source that has required minimal treatment by the City since its watershed is protected from disturbances under the 1926 Bend Watershed Agreement with the U.S. Forest Service (USFS). Tumalo Creek originates in the Deschutes National Forest in the Cascade Mountains west of the City.

The City has undertaken a Surface Water Improvement Project (SWIP), which includes upgrading the Tumalo Creek intake, conveyance, and treatment facilities. An element of the SWIP includes comparing the water temperature of Tumalo Creek under existing system capacity constraints to proposed system capacity constraints with an increase in water diversions. The comparison refers to these as the “No-Build” and “Build” alternatives. This comparison supports the Environmental Assessment (EA) to comply with the National Environmental Policy Act (NEPA). The alternatives were assessed using a water temperature model, which is the subject of this technical memorandum.

1.1 Background

The SWIP is essential for multiple reasons, including replacing the pipeline from the intake location on Tumalo Creek to the Outback site treatment facility and constructing new water treatment and storage facilities at the Outback site. SWIP objectives include improving reliability by replacing the aging pipeline infrastructure, installing flow control to leave more water instream when not needed or restricted by water rights, meeting mandatory federal treatment rules by 2012, and providing energy production opportunities.

The area of interest includes the confluence of the North Fork Tumalo Creek and Bridge Creek on Tumalo Creek downstream to the Tumalo Feed Canal operated by Tumalo Irrigation District (TID), referred to as Reach A. (Note: Different river miles have been used in published reports.) The reach is divided into two sub-reaches, Reach A1 and Reach A2, with the dividing point at the City’s existing return flow location. Tumalo Creek below the Tumalo Feed Canal to the Deschutes River is referred to as Reach B. Water temperatures in all three reaches (A1, A2, and B) were modeled.

Tumalo Creek flows approximately 18 miles through the 48 square mile Tumalo Creek watershed (Figure 1). Tumalo Creek is a perennial stream located in the glaciated eastern Cascade Mountains. Spring-water and snowmelt are the primary water sources to the creek.

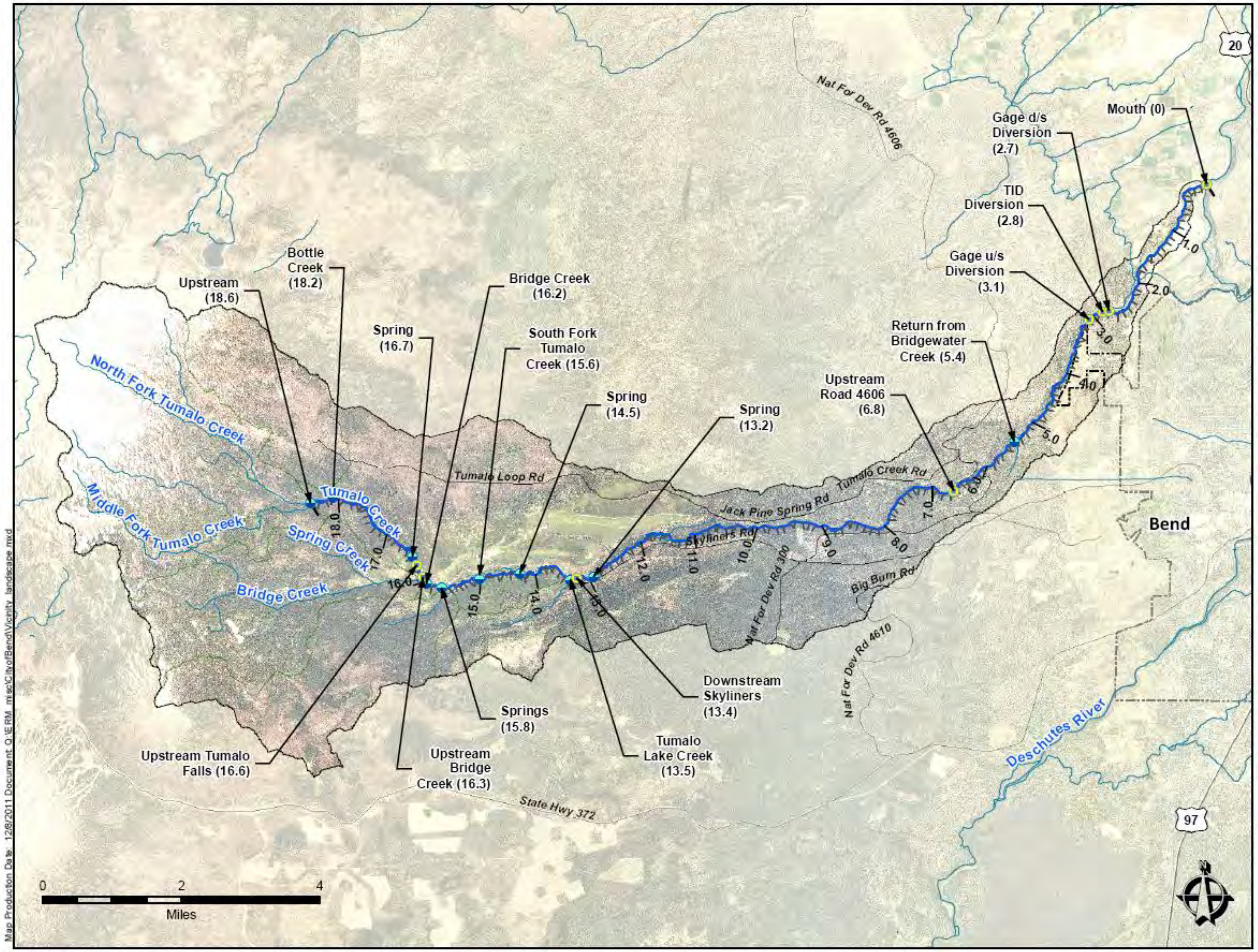

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Figure 1: Tumalo Creek Watershed and Key Points for Water Temperature Assessment

River miles shown are from DEQ's Heat Source model of Tumalo Creek (Boyd and Kasper, 2003; Watershed Sciences, 2008)

The highest mountain peaks include Ball Butte (8,091 feet) and Tumalo Mountain (7,775 feet). Near the headwaters, perennial tributaries to Tumalo Creek include South, Middle, and North Forks of Tumalo Creek, Bridge Creek, and Tumalo Lake Creek. The confluence of Tumalo Creek with the Deschutes River is approximately at 3,200 feet in elevation.

Tumalo Creek flows fluctuate from low winter-time flows of approximately 50 to 100 cubic feet per second (cfs) to high spring-time flows of approximately 300 to 400 cfs. Abundant spring-water in the watershed maintains a relatively high base flow during the winter season and during the late summer through the early fall dry season.

1.2 Purpose

The purpose of this technical memorandum is to support the USFS's development of an Environmental Assessment (EA) of the SWIP by providing the USFS this technical assessment of water temperatures in Tumalo Creek under the No Build and Build alternatives for water supply operations. The analysis focuses on addressing the following question.

- Does the proposed project cause an adverse increase in Tumalo Creek water temperature under foreseeable conditions?

1.3 Definition of Alternatives

The flows for the No-Build and Build alternatives are defined by the existing system and proposed system capacities, the City's water demands, the water rights on Tumalo Creek, and the operation and capabilities of the City's and TID's facilities (HDR, January 24, 2012 – *Draft Technical Memorandum RE: Tumalo Creek Instream Flow Study*). These conditions result in the maximum diversion of 18.2 cfs for the No Build alternative and maximum planned diversion of 21 cfs for the Build alternative. For the purpose of this analysis, the irrigation season is defined as from April 1st through November 1st. Additionally, current TID diversion operations were used in the Flow Study. Future diversion operations may vary and are beyond the control of the City.

1.4 Analysis Approach

The analysis is a comparison of the model predicted water temperatures between the No-Build and Build alternatives. The approach for the analysis was to use a water temperature model to simulate the periods with the most probable impact. These periods are defined as when the system capacity constraints permit the diversion and use maximum for a significant percentage of time while the creek flow is low but generally supportive of high diversion and use flow rates. In other words, the period of interest is when a significant amount of flow is available for consumptive use and when flows are low in Tumalo Creek, but still permit maximum diversion and use for a majority of the days during the period.

1.4.1 Key Understandings

The modeling, analysis and thus conclusions are based on the following key understandings:

- The future flow pattern and magnitudes, water temperatures, climate, and vegetation would be similar to historical.
- Future water rights and TID operations would be the same as existing.
- Future water temperature regulations would not change from existing and would allow for a "de minimis" (or minimal) increase to water temperatures for projects.

- The analysis is based on a comparison of the No Build to Build alternatives.
- The analysis is based on a combination of conditions with the most probable maximum impact to water temperatures. Based on the historical record, typical hydrologic, tributary water temperatures, and climatic conditions would result in a lower impact to water temperatures under the proposed operations of the Build alternative than predicted by the model simulations. If the maximum conditions occur, the improved flow control of the Build alternative will allow for operational changes to reduce the impact to water temperature.
- The Heat Source model predicts hourly water temperatures and provides the maximum water temperature and associated metrics which are appropriate for assessing potential impacts of the SWIP to Tumalo Creek water temperatures.
- Operations controlling the flows diverted are defined by the existing system and proposed system capacities, the City's water demands, the water rights on Tumalo Creek, and the operation and capabilities of the City's and TID's facilities.

The hydrology for the Tumalo Creek watershed was developed on a daily time step, in other words everyday has a unique flow. The hydrology includes an accounting of flow time series from tributaries, springs, and diversions by the City and TID to match the flows recorded at the downstream gage. The system capacity constraints were then imposed on the hydrologic dataset. Alternative diversion and use maximum flow rates were then added into the dataset. Each day was checked to determine if the flow in Tumalo Creek was above the system capacity constraints and if the additional flow met the maximum flow demand. This resulted in new hydrologic time series which were then simulated in the water temperature model. The water temperature model predicted hourly water temperatures for the simulation period along with providing maximum values.

Predicting the potential impact of the SWIP on water temperatures in Reach B includes some unknown variability as the hydrology of Reach B is dominated by TID operations. TID withdraws water from either or both of its two sources, Tumalo Creek or the Deschutes River provided from Crescent Lake storage. TID's operational decision on the amount of water to divert from Tumalo Creek is based on many factors including: irrigation water demand, Tumalo Creek flow, water rights, instream water rights and objectives in Reach B, water leases, storage in Crescent Lake, calls for water from Crescent Lake, projected future weather patterns and Crescent inflows, and Deschutes River water conveyance capacity. This is a real time operational decision and could not be integrated into the hydrology for the water temperature modeling. Additionally, the City cannot control and has little influence on TID operations. Under typical summer streamflow conditions, TID water diversions from Tumalo Creek may be four times the amount of the City's diversion, resulting a much greater impact to water temperatures in Reach B.

2 Model Selection and Review

The Oregon Department of Environmental Quality (DEQ) Heat Source model of Tumalo Creek was selected for the water temperature modeling (Boyd and Kasper, 2003; Watershed Sciences, 2008). The Heat Source model was selected because DEQ has used it previously to complete a temperature study of Tumalo Creek, and the City utilized the model for a previous planning study to develop the City's Water Supply Alternative Project in 2009. The Heat Source model of

Tumalo Creek was anticipated to be useful in the development of recommendations for the Environmental Assessment of the SWIP.

Heat Source is an analytical method for calculating dynamic open channel heat and mass transfer (Boyd and Kasper, 2003). This flow and water temperature model was developed in 1996 as a Masters Thesis at Oregon State University in the Departments of Bioresource Engineering and Civil Engineering. The Heat Source model was peer reviewed by EPA and professors at Oregon State University and Dartmouth College and found appropriate for water temperature modeling. Oregon DEQ currently maintains the Heat Source methodology and computer programming (DEQ, 2011a).

Oregon DEQ applied the Heat Source model to Tumalo Creek from July 19, 2001 through August 7, 2001 (Watershed Sciences, 2008). The development of the Heat Source model and application of the Heat Source model to Tumalo Creek was not completed as part of the SWIP. The Heat Source model (Boyd and Kasper, 2003) and the application to Tumalo Creek (Watershed Sciences, 2008, DEQ, 2011b) was reviewed for use to evaluate the No Build and Build alternatives of the SWIP. The review included: the Tumalo Creek model setup, model performance and results, identification of model limitations and accuracy of the model representation. The review concluded with a determination that the model was appropriate for the project evaluation.

The Heat Source model of Tumalo Creek is applicable for the evaluation of the impacts of the SWIP as part of an EA. The evaluation included the simulation of various flow regimes and shade, vegetation, and channel restoration scenarios. The ability to compare alternative scenarios is a benefit of using a model like Heat Source; however, every model has limitations. Potential concerns and limitations of the Heat Source model and its application to Tumalo Creek were identified (Table 1). Additionally, potential implications that these limitations have on the conclusions from the water temperature simulations for the SWIP were identified (Table 1).

Table 1: Findings from Model Review and on Influence on Results

Potential Concerns and Limitations	Potential Implications
Stream temperature data at the mouth of Tumalo Creek did not pass quality assurance protocols and were not used for model validation.	Model performance at the mouth of Tumalo Creek is downstream of the study area of focus and the effects of the SWIP are anticipated to have dissipated upstream.
No data were presented for "Continuous Data" tab for Continuous Data Node 3 (Downstream Skyliner) Stream Temperature (DEQ 2011b).	Incomplete model setup documentation does not affect comparison of model results.
Minor inflows and outflows from Tumalo Creek were indirectly accounted for in the model. These flows were not explicitly identified; however, the flows are included in the total accounting of flows as recorded at the gage.	Model results are compared between No Build and Build alternatives without the unaccounted flows.
The model did not simulate a two-day period of cooler temperatures, perhaps due to localized weather (i.e. showers) that were not captured in the weather input data used from the nearby Redmond Airport. Meteorological data collected in the Tumalo Creek watershed would be more representative.	Model results are compared between No Build and Build alternatives using the same meteorological conditions and the two-day period is part of a longer simulation period.
Many reaches of Tumalo Creek were either too narrow or too vegetated to digitize the channel edges using digital ortho-photographs; in such cases channel widths were estimated based on field data or upstream and downstream comparison.	Model results are compared between No Build and Build alternatives using the same channel representation.
The calibrated Heat Source model is accurate to approximately plus/minus 1.0°C.	Accuracy is a measurement of closeness between actual and predicted values. This study is focuses on the difference between two predicted values. Variability of model results is considered in the evaluation.
The Heat Source author's opinion is that most forms of model inaccuracy result from poor data input quality/quantity, rather than model algorithm error (Boyd and Kasper, 2003). Model system error is estimated as less than 0.01°C (EPA, 2001).	Model algorithm error is not anticipated to significantly affect model results or interpretation of those results.
The model is intended to be applied over large scales with the intent of capturing cumulative effects.	The model was applied to Tumalo Creek and the results are evaluated at locations along the stream reach.
The Heat Source model of Tumalo Creek is not applicable outside of the calibration conditions without modification.	Model inputs were modified for simulations outside of the original simulation period.
The complexity of the model allows it to be applied to many different physical situations, and to be able to alter many different physical parameters without unique solutions.	Model results are compared between No Build and Build alternatives using the same model parameters except those assessed.
The complexity of the input data, especially the vegetation data, is challenging for modeling different seasons or years.	While flow, water temperature, meteorological data, and vegetation were used for simulations outside of the original simulation period, the inputs were the same for comparing the No Build and Build alternatives
The Heat Source model is 1-dimensional, with mass balance flow routing.	The model methodology is sufficient for assessing stream water temperatures

The Heat Source model framework is a complex representation of the heat balance in surface water bodies. As such, it requires detailed information for many processes that impact the temperature balance. These include factors that affect channel morphology, near stream vegetation and hydrology. In addition, many of these factors are interrelated. Data requirements, both spatially and temporally, are extensive and it is not realistic to assume all the required data will be available; therefore uncertainties may persist where data are unavailable.

Data deficiencies are common to any mathematical model that attempts to simulate natural environmental conditions. Generally, the viability of a model is directly correlated to the experience of the user. In order for the model to be viable for evaluating various engineering alternatives, the user must have modeling experience. The user also has the responsibility to consult with others who are familiar with the area of concern.

In this case, DEQ contracted with Watershed Sciences in 2008 to calibrate a Tumalo Creek temperature model using the Heat Source model. The model assumptions were reviewed and appear to have been based on sound engineering judgment and resulted in an appropriate water temperature representation. Given the documentation of calibration notes and assumptions provided by Watershed Sciences, modeling projects should consider additional monitoring that can address some of the model assumptions. Although additional data collection may address some of the model assumptions, the model, as currently configured, is comprehensive and is an appropriate tool to evaluate temperature impacts in Tumalo Creek due to the SWIP.

3 Water Temperature Standards

The SWIP may be evaluated by the State of Oregon to determine if the project meets State water quality standards. Every water body in the State has at least one applicable temperature criterion. Many water bodies are subject to multiple criteria, which could include both numeric criteria and narrative criteria (DEQ, 2008).

Since the fish and aquatic life uses are the most sensitive to temperature, these criteria are the most restrictive and are the focus of this section. The designated fish and aquatic life beneficial uses of Tumalo Creek are (OAR 340-41-0130 Figure 130A and 130B):

- Upper Tumalo Creek (approximately at the confluence with Tumalo Lake Creek)
  - " Bull trout spawning and juvenile rearing" (Figure 130A)
- Lower Tumalo Creek (approximately at the confluence with Tumalo Lake Creek)
  - "Salmon and trout rearing and migration" (Figure 130B)

The water temperature criteria for the designated beneficial uses are shown in Table 2. (Note: This study uses different river miles than have been used by DEQ.)

Table 2: Water Temperature Criteria by Designated Beneficial Use

Beneficial Use	Applicable Criteria	OAR 340-041-0028	When Criterion Applies
Bull trout spawning and juvenile rearing	12°C 7-day average maximum Spawning narrative Cold water protection, summer	(4)(f) (4)(f) (11)(a)&(c)	Year round Aug 15 to May 15 Summer (Jun 1 to Sept 30)
Salmon and trout rearing and migration	18°C 7-day average maximum Cold water protection, summer	(4)(c) (11)(a)&(c)	Year round Summer (Jun 1 to Sept 30)

The metric for the numeric criteria is the 7-day average of the daily maximum stream temperature, or the "7-day average maximum" (7dAM). DEQ, indicates that "while the narrative criteria do not specify, the same metric will generally be used" for assessment (DEQ, 2008).

DEQ's description of how to calculate the 7dAM includes the following. "The 7dAM stream temperature is calculated by averaging the daily maximum instream water temperatures for 7 consecutive days. Because the criteria apply to every 7 day period, it is referred to as the rolling 7dAM. For the second 7-day period, the first day is dropped and another day is added to the end date. For example, one 7-day period is August 4 to 10, the next 7-day period is August 5 to 11, and so on" (DEQ, 2008).

4 SWIP Water Temperature Assessment

The SWIP water temperature assessment was completed by first using the Heat Source model of Tumalo Creek for 2001. Additional assessment of available data and model simulations were then performed to assess water temperatures due to the SWIP.

4.1 Tumalo Creek 2001 Model Simulation

The Heat Source model of Tumalo Creek as provided by DEQ was used. (DEQ provided multiple simulations and the "validated CCC" model file was used. The files provided also included the model output.) The provided results were compared to results from a re-simulation of the model. The datasets were compared at the output locations and were found to be the same. This demonstrated that the simulation results could be replicated.

The Tumalo Creek 2001 Model simulated a period when there was little additional water available for consumptive use and insufficient water to divert the No Build and Build alternatives at maximum diversions during the irrigation season. The annual flow in Tumalo Creek for 2001 was in the lowest 10th percentile for the period of record, approximately 1923 through 2010, with data gaps. The annual median flow in 2001 was approximately 56 cfs. The monthly flow for July 2001 was also in the lowest 10th percentile at approximately 59 cfs. The monthly flow for August 2001 was slightly higher, ranked in the lowest 15th percentile at approximately 51 cfs.

Tumalo Creek flow was gaged from October 1923 through September 1987 and records are available on a daily time step. The gage records are the sum of Tumalo Creek flow downstream of the City's return flow from Outback site (but upstream of the existing TID diversion) and the diversions at the historic Columbia Southern Canal diversion location that occurred upstream from the City's return flow but is now abandoned. The historical gage record does not reflect natural conditions since the City was diverting water from the Creek upstream during this time. To "naturalize" the gage record, the City's estimated use was added to the gage record to develop a "native" flow record. The native flow record is representative of the conditions just upstream of the existing TID diversion.

The summer 2001 period insufficiently represents the range of flow conditions to be assessed for the EA. The flows did not permit maximum diversion at minimum Creek flow for the most probable impact. Since this period is insufficient to meet the modeling objectives, available data were reviewed to select additional periods for assessment.

4.2 Flow, Water Temperature, and Meteorological Data

Flow, water temperature, and meteorological data were reviewed to modify the existing Heat Source model of Tumalo Creek. A frequency analysis based on the available hydrologic data for the annual average flow, and flows for the periods May through July and July through August is shown in Figure 2. July and August are climatologically the warmest months of the year in the area.

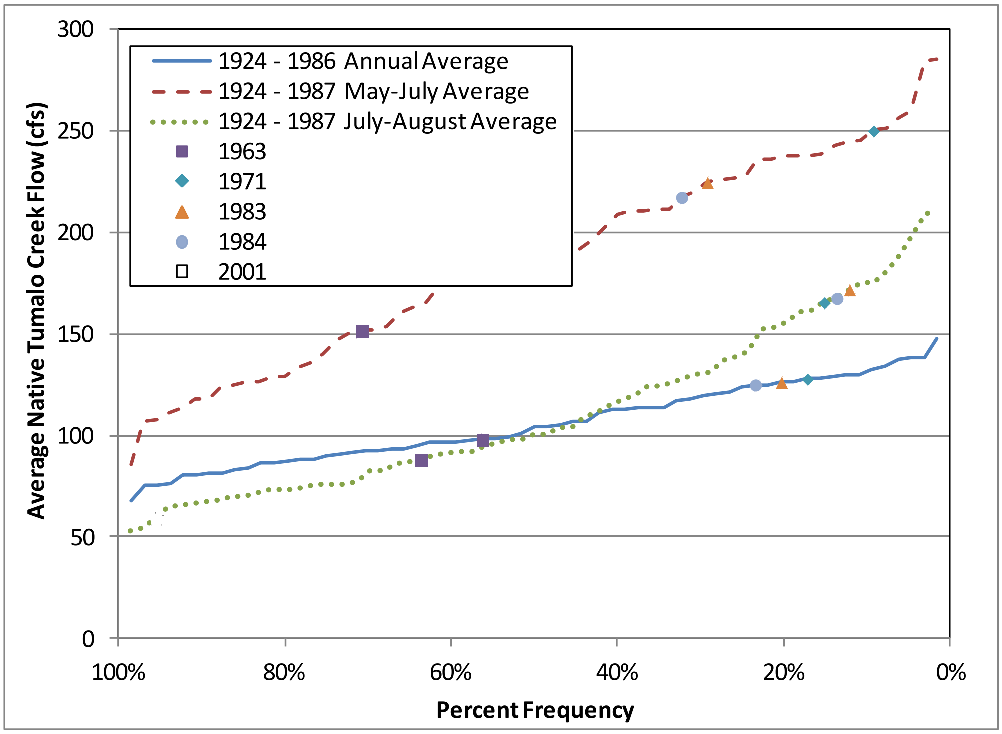


Figure 2: Tumalo Creek Native Flow Frequency

(Lines are frequency curves based on the data for the period shown in the legend, symbols show where individual years are within the frequency curves.)

The water temperature in Tumalo Creek for July and August 2001 was warmer than the median water temperature for the period of record from approximately 1994 through 2009 (Figure 3). The daily maximum water temperature was determined from the 40-minute data recorded at the four locations. Statistics on the July and August daily maximum values are shown in Table 3. Water temperature data from Tumalo Creek have been greater than 12°C in the upper reach and greater than 18°C in the lower reach during the summer as shown in the monitoring data (Figure 3).

Table 3: Statistics for July and August Daily Maximum Water Temperatures

Location	Median	Maximum	Minimum	July and August Years
Downstream of Skyliner Bridge	12.1	13.9	6.7	2001
	12.6	16.7	5.4	1995, 1997-2000, 2002-2009
Upstream of Forest Road 4606 Bridge	14.8	16.9	10.9	2001
	14.0	18.3	6.5	1999-2001, 2003, 2005, 2007, 2009
Downstream of TID Diversion at Gage	16.5	18.8	12.0	2001
	15.1	21.6	7.5	1999-2006, 2008
Mouth of Tumalo Creek	19.9	23.1	13.9	2001
	18.8	24.0	11.5	2001-2005, 2007, 2009

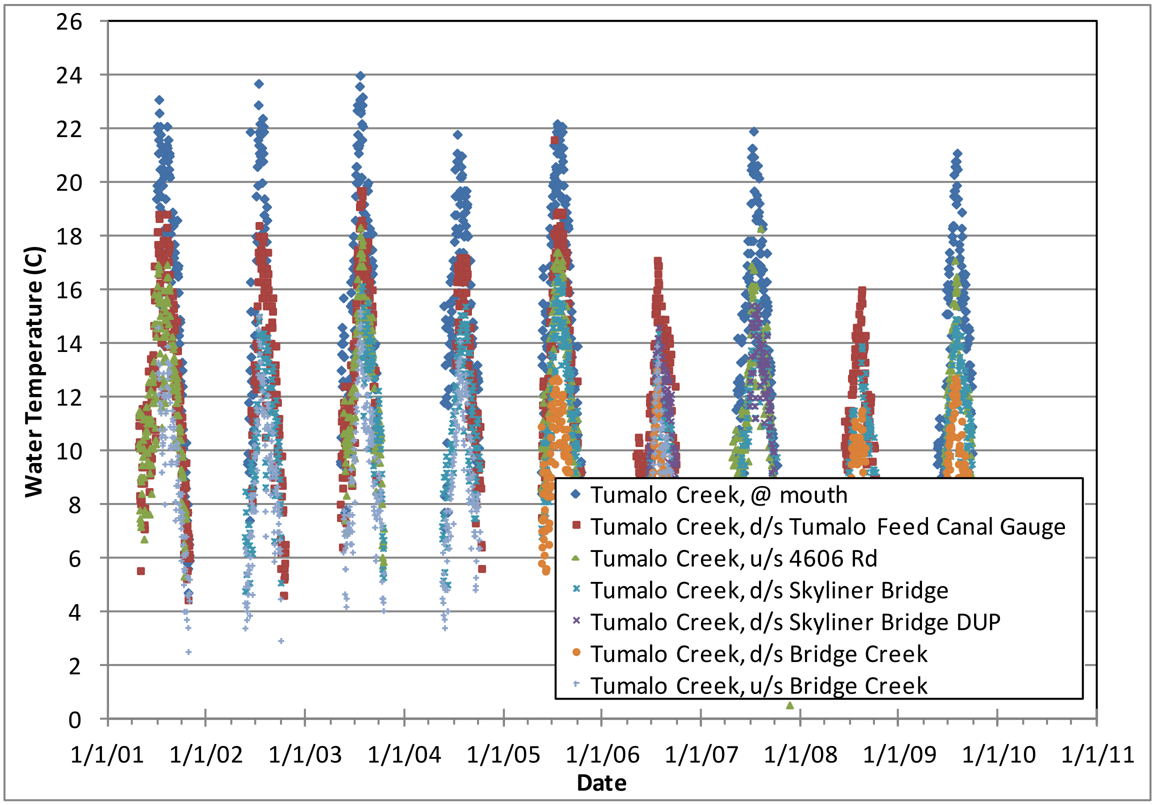


Figure 3: Tumalo Creek Water Temperatures

The data were examined to select additional periods for model simulations. When Tumalo Creek is at its lowest flows, it is subjected to the greatest thermal loading and potential increase in water temperatures. However, when Tumalo Creek is at its lowest flows, there is little or no additional water available for consumptive use by the City. Thus, a comparison of model simulations between No Build and Build alternatives would show little or no differences in water temperatures because there would be little or no difference in the quantity of flow consumed.

When Tumalo Creek is at its highest flows, the greatest amount of water is available for consumptive use. However, the quantity of additional flow consumed is small relative to the flow in Tumalo Creek and thus any potential impacts to water temperatures are anticipated to be small. The flow data were examined to identify years when a combination of low flows and sufficient water for maximum consumptive use occurred.

- The period of interest is a combination of when a significant amount of flow is available for consumptive use and when flows are low in Tumalo Creek.

Selection of the period of interest and determination of the model inputs required the development of a water balance of Tumalo Creek. The measured Tumalo Creek flows at the gage (near the TID diversion) were used as the starting point for the water balance. Other known items were the flow capacity of the water supply pipeline from Bridge Creek, 9.1 cfs from 1930 through 1955 and 18.2 cfs from 1955 to current, along with the historic City of Bend surface water usage. There are few data available for flows from the springs in the upper watershed and along Tumalo Creek. Based on the capacity of the diversion canal, the flow from

Spring Creek to Bridge Creek (Springs Diversion) was set at a constant 18.4 cfs. Other spring flows were set at constant values based on the spring flows in the Tumalo Creek 2001 Model.

Flows in the tributaries were estimated based on apportioning Tumalo Creek flows (native flows excluding any diversions and less the spring flows) by the drainage area and mean annual precipitation. The mean annual precipitation was used due to the variation in precipitation and runoff across the topography of the watershed. The mean annual precipitation used PRISM (Parameter-elevation Regressions on Independent Slopes Model), which incorporates 30 years of data (1971 through 2000) into a Geographic Information Systems (GIS) grid (OCS, 2011). The subbasins within the Tumalo Creek watershed were delineated using the USGS StreamStats application (USGS, 2011). The subbasins were overlaid onto the mean annual precipitation (Figure 4). The results are summarized in Table 4.

Table 4: Summary of Watershed Subbasins Compared to Mean Annual Precipitation to Flow

Subbasin	Area (square miles)	Mean Annual Precipitation (inches)	Runoff Rate (cfs)	Percentage
Upstream confluence of Middle Fork and North Fork Tumalo Creek	10.3	59	45	46
Bottle Creek	3.3	52	13	13
Bridge Creek	5.4	48	19	20
South Fork Tumalo Creek	4.8	44	15	16
Tumalo Lake Creek	1.7	38	5	5

The Tumalo Creek native flow, Reach A1, A2, and B were then calculated. Flows were also calculated for City of Bend diversion, TID diversion, and instream water rights based on the Tumalo Creek native flow. TID's diversion was also limited by the standard operating water requirements.

The water balance was then modified to two scenarios: the No Build alternative with maximum consumptive use of 18.2 cfs with no return flow from Bridge Creek and the Build alternative with maximum planned consumptive use of 21 cfs. The available consumptive use is determined by the availability of upstream flows, by the downstream TID standard operating water requirements, and water rights for TID and instream flow.

The period of interest is when a significant amount of flow is available for consumptive use and flows are low in Tumalo Creek. This was examined by contrasting the number of days when maximum diversion was available for consumptive use to the native flow in Tumalo Creek (Figure 5). This situation occurs during the spring runoff (receding portion of the hydrograph), which typically occurs from May through July with additional flow potentially available from August through October. The six month period of May through October was selected for the model simulations. Four years with periods of interest were identified as having sufficient data for modeling (Figure 5, points circled in red). Figure 5 demonstrates that for the Build alternative 21 cfs would not have been available throughout the year for most of the hydrologic record. The flows for these four years are shown in Figures 6 and 7. These four periods are:

- May 1 through October 15, 1963
- May 1 through October 15, 1971
- May 1 through October 15, 1983
- May 1 through October 15, 1984

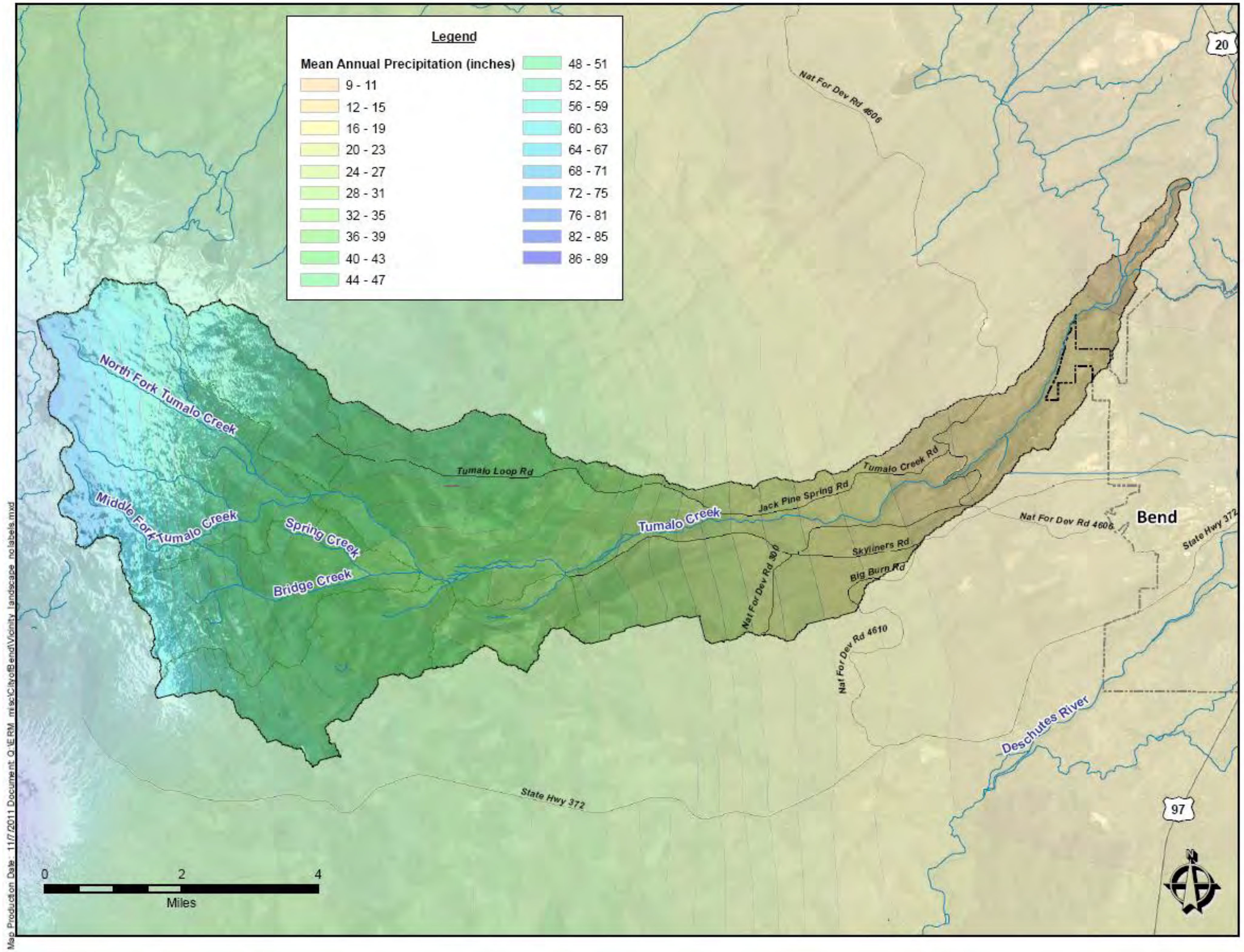
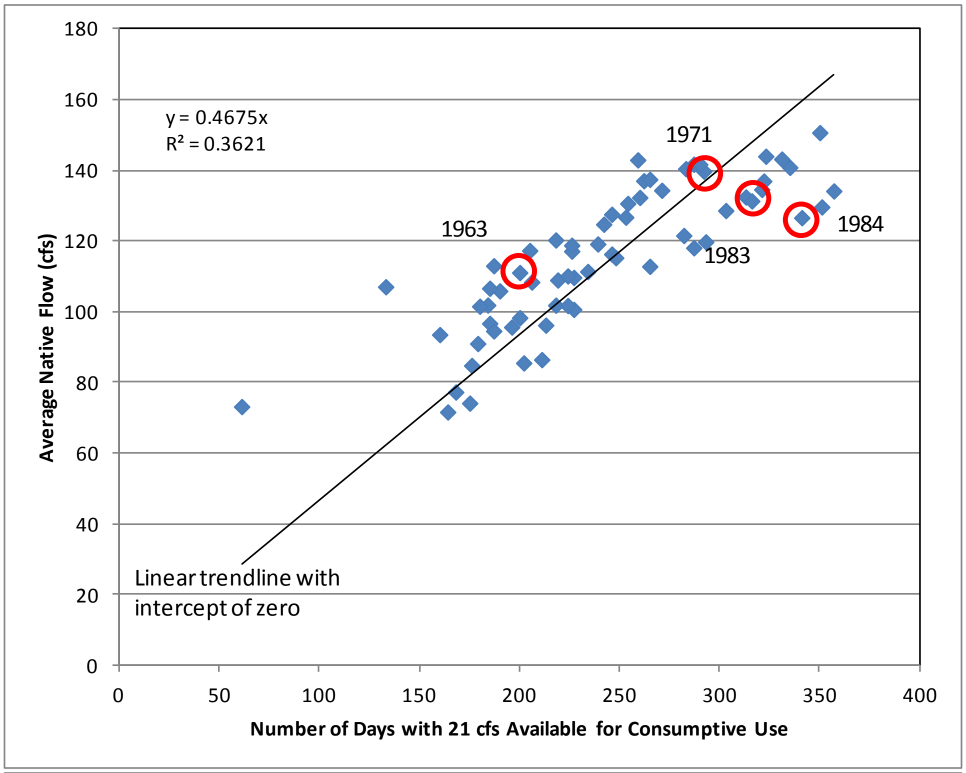


Figure 4: Tumalo Creek Watershed and Subbasin Mean Annual Precipitation



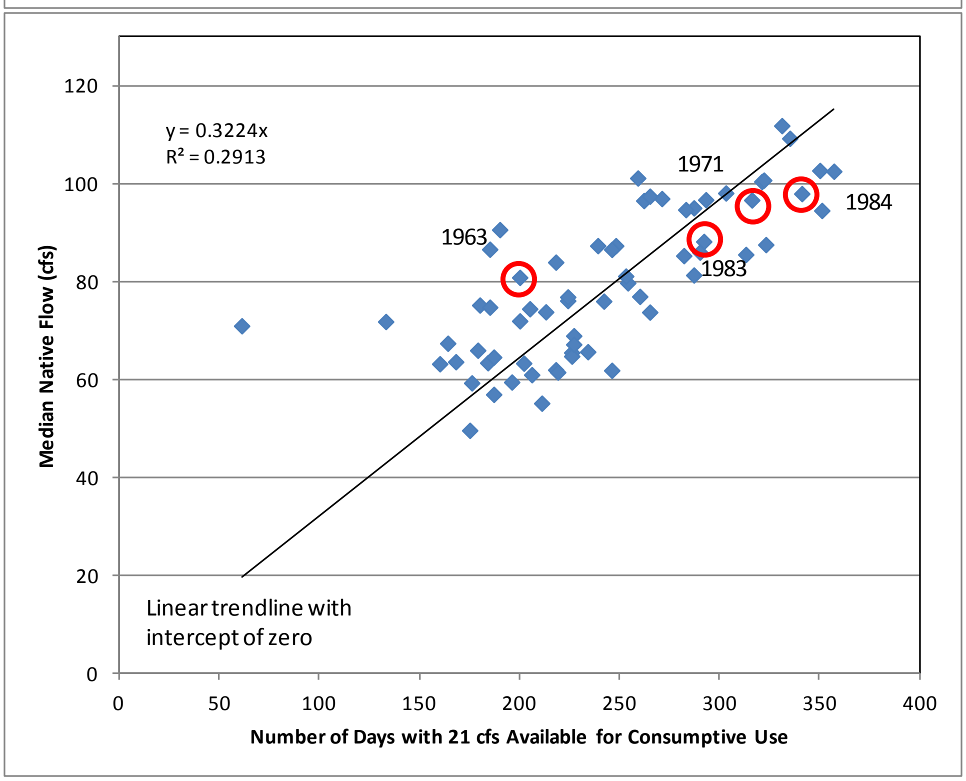


Figure 5: Consumptive Use at 18.2 cfs versus Native Tumalo Creek Flows

(Diagonal lines were used to parse data points and select years to model. The red circles are data points for the four years with periods of interest and the years labeled near the red circles.)

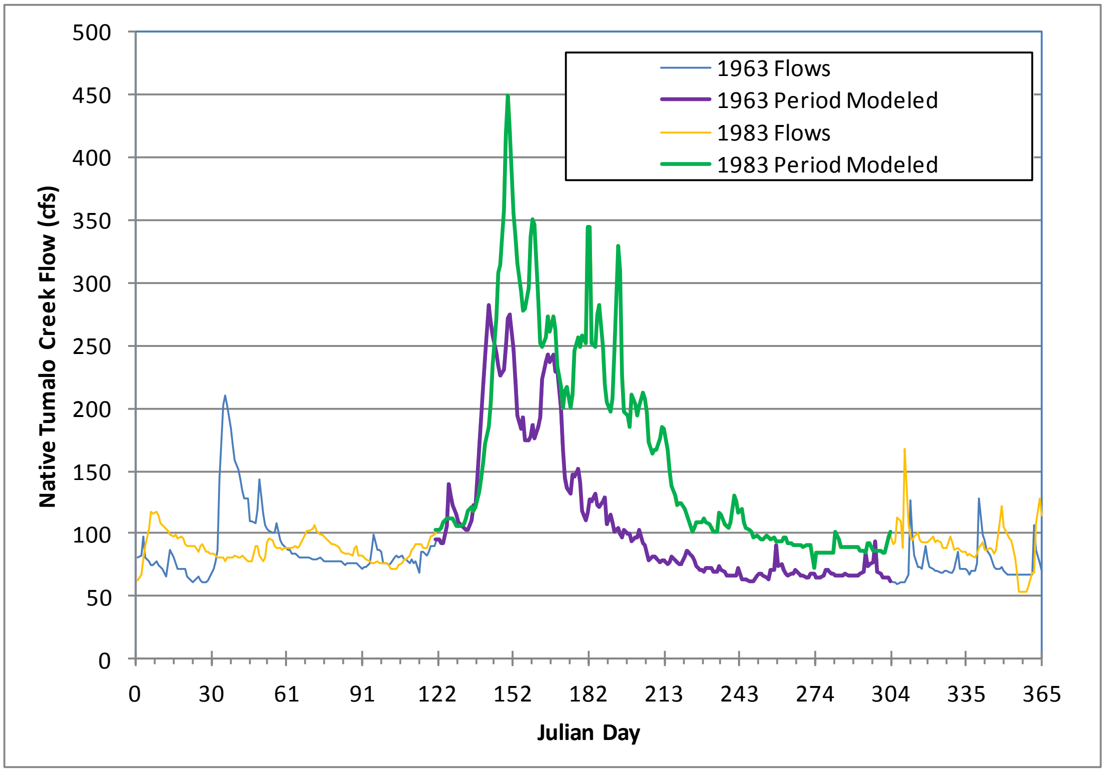


Figure 6: Native Tumalo Creek Flows for 1963 and 1983

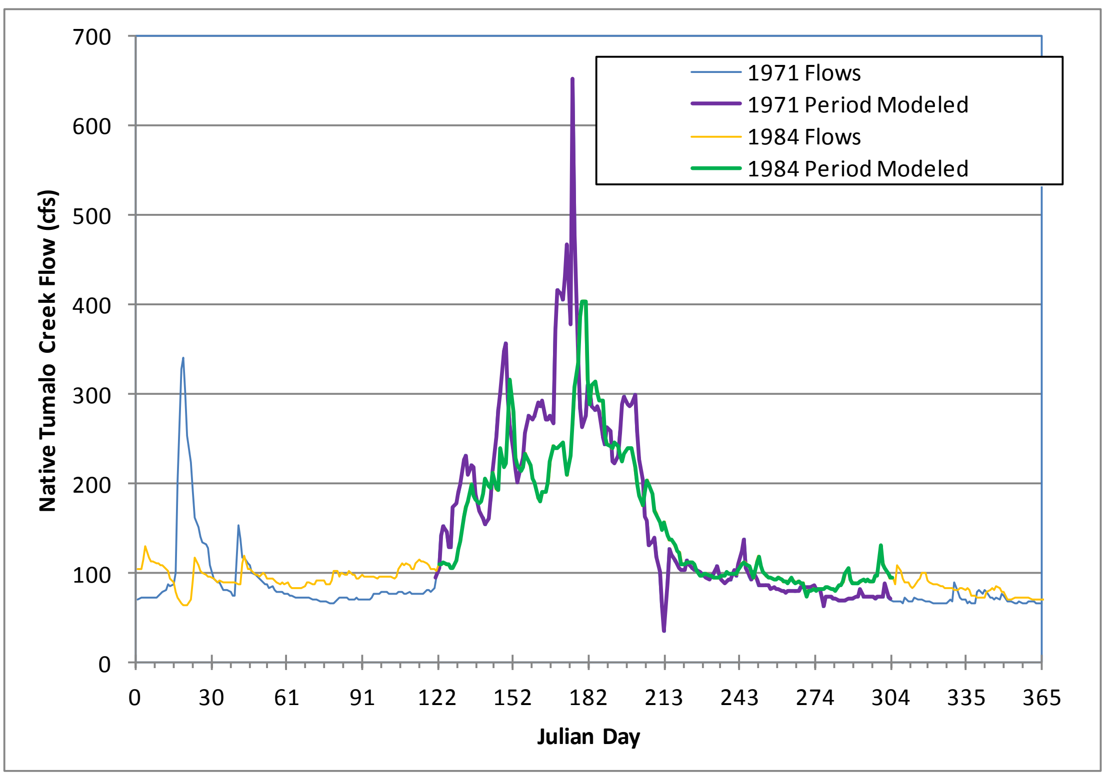


Figure 7: Native Tumalo Creek Flows for 1971 and 1984

4.3 Tumalo Creek SWIP Model Simulations

The results of the model simulations were compared at four locations along Tumalo Creek. These locations were included as part of the Tumalo Creek 2001 Model. The locations (Figure 1) are:

- Downstream of Skyliner Bridge, approximately river mile 13.4
- Upstream of Forest Road 4606 Bridge, approximately river mile 6.8
- Downstream of TID Diversion at Gage, approximately river mile 2.7
- Mouth of Tumalo Creek, approximately river mile 0

As identified in the standards, the metric of the 7-day average of the daily maximum stream temperature was used to evaluate the model results. The 7-day average maximum water temperature is calculated by averaging the daily maximum water temperatures for 7 consecutive days. The Heat Source model includes these calculated values within the model output.

The maximum 7-day average maximum water temperature for the four model simulations at the four locations are shown for the Build alternative in Table 5. The maximum increase of the 7-day average maximums between the No Build and Build alternatives model simulations at the four locations are shown in Table 6.

Table 5: Build Alternative Maximum Predicted 7-Day Average Maximum Water Temperature

Period	Diversion and Use for 6-months[1], Percent Use to Maximum, Percent Build[2] Flow, Days at Maximum[3]	Tumalo Creek Location (Water Temperature, C)			
		Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
May 1 through October 15, 1963	84%, 5%, 46	12.5	13.0	14.4	15.3
May 1 through October 15, 1971	97%, 13%, 139	12.7	13.5	14.8	15.3
May 1 through October 15, 1983	98%, 14%, 148	11.7	11.9	12.2	12.8
May 1 through October 15, 1984	99%, 14%, 157	11.6	11.9	12.6	13.4

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

[3]The maximum diversion and use was not available everyday due to the restrictions (Table 7). The percent use to maximum is the sum of the available use divided by the sum of the maximum diversion and use or the percentage of water used to the maximum water sought. The percent build flow is the difference of the sum of the available use divided by the sum of the available use for the No Build alternative, or the percentage of additional water diverted and used. The maximum percentage is 15% or 2.8 divided by 18.2 cfs. The days at maximum is the number of days the maximum diversion and use was available. The maximum is 168 days for the period.

Table 6: No Build v. Build Alternative Maximum Predicted Increase in 7-Day Average Maximum Water Temperature

Period No Build v. Build[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
May 1 through October 15, 1963	0.04	0.06	0.07	0.21
May 1 through October 15, 1971	0.10	0.10	0.24	0.36
May 1 through October 15, 1983	0.06	0.09	0.13	0.24
May 1 through October 15, 1984	0.10	0.10	0.14	0.39

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

4.4 Model Simulation Sensitivity Analyses

Based on the results of the four periods modeled, the conditions for 1971 generally have the greatest overall impact. The 1971 model was used to perform sensitivity analyses on four model inputs that influence water temperatures. The results were compared for the No Build and Build alternatives using the 7-day average maximum of the results. The four inputs assessed are:

- Flows – Diversion Rates
- Vegetation, Shade, and Channel Characteristics
- Meteorological Conditions
- Water Temperature Boundary Conditions

4.4.1 Intake and Flow Regimes

Alternative diversion and use maximums were simulated for the Build alternative and compared to the No Build alternative. The diversion and use rates vary daily in the water balance, as determined by the availability, water right, and need. The maximum value is diverted and used unless otherwise restricted by the system capacity constraints. These flow conditions for maximum diversion are summarized in Table 7.

The maximum 7-day average maximum water temperature for the model simulations at the four locations are shown for the Build alternative in Table 8. The maximum increase of the 7-day average maximums between the No Build and Build alternatives model simulations at the four locations are shown in Table 9.

Table 7: Flow Scenario Conditions for Maximum Diversion used in Model Simulations

Condition	Description	Diversion Table	
		Only When Creek Flow Exceeds (cfs)	Maximum Diversion (cfs)
1	Available Flow in Tumalo Creek	50	21
2	Water Rights / TID Operation	80	24
3	System Capability	160	27
4	Demand by City	200	33
5	Diversion Table	260	36

Table 8: Build Alternative Maximum Predicted 7-Day Average Maximum Water Temperature at Various Diversion Rates

Period May 1 through October 15, 1971 Diversion and Use Maximum (cfs)[1,2]	Diversion and Use during Maximum 7dAM, Percent Use to Maximum, Percent Build Flow, Days at Maximum[3]	Tumalo Creek Location (Water Temperature, C)			
		Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
19.2	87%, 3%, 3	12.7	13.5	14.8	15.3
21	83%, 7%, 3	12.7	13.5	14.8	15.3
24	78%, 15%, 3	12.8	13.6	14.9	15.4
27	70%, 15%, 3	12.8	13.6	14.9	15.4
33	70%, 15%, 3	12.8	13.6	14.9	15.4
36	70%, 15%, 3	12.8	13.6	14.9	15.4

[1]Flow rate under diversion and use maximum was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

[3]For the 7 days resulting in the maximum predicted 7-day average maximum, the maximum diversion and use was not available everyday due to the restrictions (Table 7). The percent use to maximum is the sum of the 7-day available use divided by the sum of the 7-day maximum diversion and use or the percentage of water used to the maximum water sought. The percent build flow is the difference of the sum of the 7-day available use divided by the sum of the 7-day available use for the No Build alternative, or the percentage of additional water diverted and used. The days at maximum is the number of days the maximum diversion and use was available for the 7 days.

Table 9: No Build v. Build Alternative Maximum Predicted Increase in 7-Day Average Maximum Water Temperature at Various Diversion Rates

Period May 1 through October 15, 1971 Diversion and Use Maximum (cfs)[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
19.2	0.04	0.04	0.12	0.14
21	0.10	0.10	0.24	0.36
24	0.19	0.20	0.36	0.70
27	0.19	0.20	0.36	0.70
33	0.19	0.20	0.36	0.70
36	0.19	0.20	0.36	0.70

[1]Flow rate under diversion and use maximum was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

4.4.2 Vegetation and Channel Regimes

Due to fire and restoration activities in Reach A1, vegetation and channel regimes representing increases in vegetation and reduction in channel width were estimated to represent periods for 5-, 20- and 50-years into the future. The bank full width and the land cover vegetation data were changed to represent these conditions. The changes were to 3.1 miles of the restoration reach. The bank full width was reduced by 5- and 20-percent. The land cover was increased by 2-meters for the small (< 4 meter height) and medium (<6 meter height) vegetation or to 5-, 12- and 18.3-meters for all vegetation. These heights are values used for vegetation in other reaches.

The maximum 7-day average maximum water temperatures for the model simulation at the four locations are shown for the Build alternative in Table 10. The maximum increase of the 7-day average maximums between the No Build and Build alternatives model simulations at the four locations are shown in Table 11.

The absolute water temperatures are reduced with the reduction in channel width and increase in vegetation and shade. The differences between the No Build and Build alternatives are similar.

Table 10: Build Alternative Maximum Predicted 7-Day Average Maximum Water Temperature with Restoration Reach Vegetation and Channel Improvements

Period May 1 through October 15, 1971 Restoration Reach Improvements[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
Build Alternative	12.7	13.5	14.8	15.3
Channel Width Reduced 5% Vegetation < 4-meter +2 meters	12.7	13.5	14.8	15.3
Channel Width Reduced 20% Vegetation < 6-meters +2 meters	12.7	13.5	14.8	15.3
Channel Width Reduced 20% Vegetation 5-meters	12.6	13.5	14.7	15.3

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

Table 11: No Build v. Build Alternative Maximum Predicted Increase in 7-Day Average Maximum Water Temperature with Restoration Reach Vegetation and Channel Improvements

Period May 1 through October 15, 1971 Restoration Reach Improvements[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
No Build v. Build Alternatives	0.10	0.10	0.24	0.36
Channel Width Reduced 5% Vegetation < 4-meter +2 meters	0.09	0.09	0.24	0.36
Channel Width Reduced 20% Vegetation < 6-meters +2 meters	0.10	0.10	0.24	0.36
Channel Width Reduced 20% Vegetation 5-meters	0.10	0.09	0.24	0.33

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

4.4.3 Seasonal Meteorological Conditions

A simulation using the 1971 model when water temperatures are likely to be the greatest and warm at the greatest rate, as represented by the warmest May through October period in the 29-year, 1961 through 1990 meteorological record, was performed. The 1971 meteorological data had a 6-month average air temperature of 13.6^{o}C for the period May 1st through October 31st. The 1967 meteorological data had a 6-month average air temperature of 16.7^{o}C for the period May 1st through October 31st. These air temperatures are shown in Figure 8.

The maximum 7-day average maximum water temperatures for the model simulation at the four locations are shown for the Build alternative in Table 12. The maximum increase of the 7-

day average maximums between the No Build and Build alternatives model simulations at the four locations are shown in Table 13.

This simulation provides information about the potential impacts on water temperature if this combination of events were to occur. The results in Table 12 and Table 13 may appear counter intuitive as the warmer 1967 air temperatures resulted in colder 7-day average maximum water temperatures at three locations. However, the air temperatures are a 6-month average, while the water temperatures are a 7-day average maximum. While 1967 had the warmest air temperatures for the 6-months, during the week of the warmest water temperatures in early August, air temperatures from 1971 were greater than from 1967, resulting in greater 7-day average maximum water temperatures. The average for the 6-months of 7-day average maximum water temperature was warmer with the 1967 than 1971 air temperatures by approximately 0.1^{o}C indicating the results are a consequence of the averaging periods and the timing of higher air temperatures within the 6-month period.

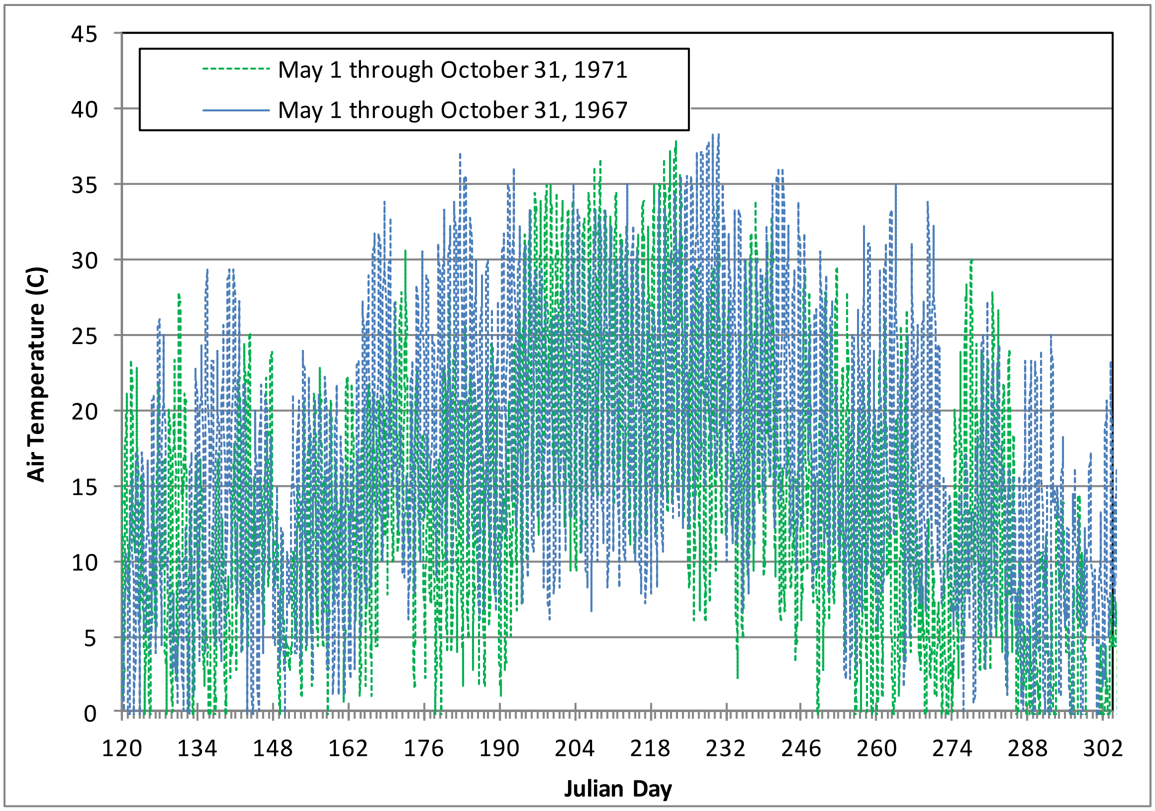


Figure 8: Air Temperature

Table 12: Build Alterative Maximum Predicted 7-Day Average Maximum Water Temperature using Warmest May through October Air Temperatures from 1961 through 1990

Period May 1 through October 15, 1971 Meteorological Condition[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
Build Alternative	12.7	13.5	14.8	15.3
Warmest May-October (1967)	12.5	13.2	14.4	16.0

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

Table 13: No Build v. Build Alternative Maximum Predicted Increase in 7-Day Average Maximum Water Temperature using Warmest May through October Air Temperatures from 1961 through 1990

Period May 1 through October 15, 1971 Meteorological Condition[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
No Build v. Build Alternatives	0.10	0.10	0.24	0.36
Warmest May-October (1967)	0.11	0.13	0.20	0.47

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

4.4.4 Water Temperature Boundary Conditions

Simulations using the 1971 model with increases in the tributary water temperatures of 1 and 2°C were performed. This simulation is a sensitivity analysis of the results to these boundary conditions.

The maximum 7-day average maximum water temperatures for the two model simulation at the four locations are shown for the Build alternative in Table 14. The maximum increase of the 7-day average maximums between the No Build and Build alternatives model simulations at the four locations are shown in Table 15.

The absolute water temperatures are greater with the simulated increases in tributary water temperatures but still below the water temperature standards for Tumalo Creek. The differences between the No Build and Build alternatives are similar suggesting using the comparison is not sensitive to the water temperature boundary condition.

Table 14: Build Alternative Maximum Predicted 7-Day Average Maximum Water Temperature at Greater Tributary Water Temperatures

Period May 1 through October 15, 1971 Tributary Water Temperature[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
Build Alternative	12.7	13.5	14.8	15.3
1°C Increase	13.4	14.1	15.3	15.7
2°C Increase	14.1	14.8	15.9	16.1

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

Table 15: No Build v. Build Alternative Maximum Predicted Increase in 7-Day Average Maximum Water Temperature at Greater Tributary Water Temperatures

Period May 1 through October 15, 1971 Tributary Water Temperature[1,2]	Tumalo Creek Location (Water Temperature, C)			
	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
No Build v. Build Alternative	0.10	0.10	0.24	0.36
1°C Increase	0.10	0.10	0.23	0.30
2°C Increase	0.09	0.09	0.21	0.27

[1]Maximum flow rate for diversion and use was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

5 Summary and Conclusions

The Heat Source model of Tumalo Creek was evaluated and determined to be appropriate for use to simulate the No Build and Build alternatives for the SWIP. The model time period was extended to evaluate a range of conditions. Of particular interest were hydrologic periods that represent a combination of when the greatest amount of flow is available for consumptive use and when flows are low in Tumalo Creek. August through early September was the critical period with the greatest maximum 7-dAM water temperatures and increases in 7-dAM water temperature between the No Build and Build alternatives. The May through October period was simulated to encompass this critical period with hydrologic data from four years. One of the four years was selected to use for sensitivity analyses which included evaluating a range of flows.

The results of the sensitivity analyses did not change the conclusions. Restoration activities that reduce channel width and increase vegetation and shading would reduce water temperatures. The model is sensitive to changes in meteorological and water temperature boundary conditions. The boundary conditions are representative of the most probable conditions and are conservative relative to predicting the impacts of the SWIP.

The modeled simulations provide predictions of water temperatures for a range of conditions for the No Build and Build alternatives. This information should be useful for evaluating if the proposed project could cause an adverse increase in Tumalo Creek water temperature under foreseeable conditions. The model results indicate a difference of 1°C or less between No Build and Build alternatives and operations can be managed with the new flow control at the intake diversion, a conclusion of an adverse increase is not anticipated. The average 7-dAM water temperature change in Tumalo Creek with the SWIP is less than 0.05°C with a potential maximum 7-dAM change of less than 0.4°C.

6 References

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SUPPLEMENT A

"Current Conditions" Scenario Water Temperature Model Simulation and Results at Additional Locations

The results of the model simulations were compared at four locations along Tumalo Creek. Two additional locations are shown in this Supplement. These six locations (Figure 1) are:

- Above South Fork Tumalo Creek, approximately river mile 15.7 (Added for Supplement A)
- Downstream of Skyliner Bridge, approximately river mile 13.4
- Upstream of Forest Road 4606 Bridge, approximately river mile 6.8
- Above TID Diversion, approximately river mile 4.0 (Added for Supplement A)
- Downstream of TID Diversion at Gage, approximately river mile 2.7
- Mouth of Tumalo Creek, approximately river mile 0

For the assessment of water temperature, the comparisons were between a No Build alternative with a maximum use of 18.2 cfs and various alternative scenarios. A scenario with "current conditions" was completed. The flows are average City use for the month in year 2011 and represent "current conditions" (Table A-1). Both scenarios are with the No Build alternative, so 18.2 cfs is diverted at intake and the return flow is the difference between 18.2 cfs and City use with "current conditions".

The use values in Table A-1 are different than those shown in HDR, January 24, 2012 – *Draft Technical Memorandum RE: Tumalo Creek Instream Flow Study.* The monthly average use in Table A-1 was calculated with zero flow when the system was bypassing turbidity flows through the return flow for 11 days in June 2011. The monthly average use in the *Instream Flow Study* was calculated without the 11 days of bypass to represent a typical monthly average when the system is operational.

Table A-1: Current Conditions based on 2011 City Use Data

Month	Use
May	13.8
June	7.8[1]
July	16.3
August	16.5
September	16.8
October	12.3

[1]June monthly average use is low because the 11 days for bypassing turbidity flows was included in the average as zero flow. The maximum 7dAM did not occur in June.

The maximum use of 18.2 cfs was replaced with these monthly use values to update the hydrology. The updated hydrology was entered into the Heat Source model to simulate water temperatures. The results were compared similarly as done for the other intake and flow regime scenarios as shown in the technical memorandum *Assessment of the Surface Water Improvement Project on Tumalo Creek Water Temperatures using the Heat Source Model – Draft*, dated January 27, 2012.

The maximum 7-day average maximum water temperature for the model simulations at six locations are shown in Table A-2, which includes scenarios presented in Tables 5 and 8. The maximum increase of the 7-day average maximum water temperatures between the simulations at the locations is shown in Table A-3, which includes scenarios presented in Tables 6 and 9.

Since the comparison is between the No Build alternative with a maximum use of 18.2 cfs and the scenario, in Table A-3 the line for 18.2 cfs No Build is shown as 'n/a'. In Table A-3, the difference is zero at the first three locations because the 18.2 cfs is diverted down the existing pipeline and return flows are downstream of these locations, therefore there is zero difference. In Table A-3, the difference is shown as negative at the last three locations because the difference between the No Build alternative with a maximum use of 18.2 cfs and the scenario using Table A-1 with less consumptive use, so more water is returned to Tumalo Creek and water temperatures are lower.

The difference in the location of the flow control between the No Build and Build alternatives results in some interesting phenomena. For the No Build alternatives a constant 18.2 cfs is diverted with some return flow downstream as determined by the diversion rates (Table 5) while for the Build alternative the diverted flow is determined by the diversion rates (Table 5) with zero return flow.

At the location above South Fork Tumalo Creek, the maximum predicted 7-day average maximum water temperature is greater for the No Build alternatives than for the Build alternatives (Table A-2). This result occurs because the maximum diversion is restricted by water rights in the period of the 7-day average maximum so more flow passes this location in the Build alternatives than in the No Build alternatives and water temperatures are colder. Likewise, the predicted increase in 7-day average maximum water temperature is negative.

This same pattern continues at the Downstream Skyliner Bridge and Upstream Road 4606 Bridge locations. The maximum increase in 7-day average maximum water temperatures occur later than the maximum predicted 7-day average maximum water temperature.

The pattern shifts below the return flow. At the location above TID Diversion, the opposite effect occurs. Here the maximum predicted 7-day average maximum water temperature is greater for the Build alternatives than for the Build alternatives (Table A-2). The larger maximum increase in 7-day average maximum water temperatures is due to the influence of colder return flows in the No Build alternative than zero return flows for the Build alternative (Table A-3). The return flows remain at a similar water temperature in the diversion pipe while the water temperatures downstream have increased. The maximum increase in 7-day average maximum water temperatures also occurs a few days later than occurred at the location above S. Fork Tumalo Creek.

The locations Gage downstream of TID Diversion and Mouth of Tumalo Creek exhibit more of the anticipated and classical trends of increasing water temperatures moving downstream and greater water temperatures with less instream flow. There is TID diversion of flow at the head of this reach and the increase in water temperatures is due to less flow but there are no significant tributary or return flows to confound the resulting predicted water temperatures.

Table A-2: Alternative Maximum Predicted 7-Day Average Maximum Water Temperature at Various Diversion Rates

Period May 1 through October 15, 1971 Diversion and Use Maximum (cfs)[1]	Diversion and Use during Maximum 7dAM, Percent Use to Maximum, Percent Build Flow, Days at Maximum[3]	Tumalo Creek Location (Water Temperature, C)					
		Above S. Fork Tumalo	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Above TID Diversion	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
Table 1[1] No Build[2]	92%, -8%, 5	11.3	12.9	13.8	14.0	14.5	15.0
18.2 cfs[1] No Build[2]	90%, 0%, 4	11.3	12.9	13.8	14.0	14.6	15.2
19.2 cfs[1] Build[2]	87%, 3%, 3	11.0[4]	12.7[4]	13.5[4]	14.3	14.8	15.3
21 cfs[1] Build[2]	83%, 7%, 3	11.0[4]	12.7[4]	13.5[4]	14.3	14.8	15.3
24 cfs[1] Build[2]	78%, 15%, 3	11.0[4]	12.8[4]	13.6[4]	14.4	14.9	15.4
27 cfs[1] Build[2]	70%, 15%, 3	11.1[4]	12.8[4]	13.6[4]	14.4	14.9	15.4

[1]Flow rate under diversion and use maximum was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.

[3]For the 7 days resulting in the maximum predicted 7-day average maximum, the maximum diversion and use was not available everyday due to the restrictions (Table 7). The percent use to maximum is the sum of the 7-day available use divided by the sum of the 7-day maximum diversion and use or the percentage of water used to the maximum water sought. The percent build flow is the difference of the sum of the 7-day available use divided by the sum of the 7-day available use for the No Build alternative, or the percentage of additional water diverted and used. The days at maximum is the number of days the maximum diversion and use was available for the 7 days.

[4]Water temperatures are lower for the Build alternative than the No Build alternative due to the change in flow control location and the maximum diversion and use available during the 7-days resulting in the maximum predicted 7-day average maximum.

Table A-3: No Build v. Scenario Maximum Predicted Increase in 7-Day Average Maximum Water Temperature at Various Diversion Rates

Period May 1 through October 15, 1971 Diversion and Use Maximum (cfs)[1]	Tumalo Creek Location (Water Temperature, C)					
	Above S. Fork Tumalo	Downstream Skyliner Bridge	Upstream Road 4606 Bridge	Above TID Diversion	Gage downstream of TID Diversion	Mouth of Tumalo Creek upstream Deschutes River
Table 1[1] No Build[2]	0.00	0.00	0.00	-0.17	-0.20	-0.41
18.2 cfs[1] No Build[2]	n/a	n/a	n/a	n/a	n/a	n/a
19.2 cfs[1] Build[2]	-0.36	0.04	0.04	0.29	0.12	0.14
21 cfs[1] Build[2]	-0.34	0.10	0.10	0.30	0.24	0.36
24 cfs[1] Build[2]	-0.31	0.19	0.20	0.39	0.36	0.70
27 cfs[1] Build[2]	-0.27	0.19	0.20	0.49	0.36	0.70

[1]Flow rate under diversion and use maximum was only on days when available and not restricted (Table 7), not everyday during six month model simulation.

[2]No Build alternative includes 18.2 cfs diverted in existing pipeline to the Outback site treatment facility and the return flow equaling 18.2 cfs less the flow used because flow control is at the Outback site. Build alternative uses diversion flow equal to use flow because flow control is at intake diversion.