Upper Deschutes Watershed Council
Water Quality Monitoring Program
Grant report

Whychus Creek Watershed Project Implementation 2006

Whychus Creek watershed, Deschutes Basin, Oregon

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Abstract

The complex issues in the Whychus Creek watershed are illustrative of watershed restoration challenges across Oregon. In particular, out-of stream water use has resulted in depleted in-stream flows, impaired water quality, and a need for extensive in-stream flow restoration. Water resource decision makers apply limited budgetary resources toward achieving balance between out-of-stream irrigation demands and in-stream ecological needs via in-stream flow restoration targets. The effectiveness of the current in-stream flow restoration targets at improving water quality to meet the needs of trout spawning, rearing, and migration is of interest. To improve in-stream flow restoration effectiveness, implementation of the Whychus Creek Watershed Project under a grant from the Institute of Water and Watersheds was accomplished in 2006. As a result, an approach to evaluating in-stream flow restoration targets based on water quality needs of trout is demonstrated and a graduate thesis concept to establish an annual hydrograph for in-stream flow targets based on water quality needs of trout is proposed.

Study area

Whychus Creek (*Why-choose*) is a federal designated Wild and Scenic River due to its remote nature, steep gradients, hydrology, geology, and cultural uses. Whychus Creek headwater is from seven remnant ice age glaciers within the Three Sisters Wilderness area. The creek is created by glacier melt, is perennial, and has a longitudinal extent of approximately 45 miles with an 8000 foot elevation gradient. Naturally, the creek tends to be flashy with an annual average daily flow of 105 cfs and a maximum of 2000+ cfs. Due to the unique hydrology and geology of the volcanic area, 89% of the water flows as groundwater under the creek to emerge as springs downstream.

Whychus Creek has natural flows in the upper reaches above river mile (RM) 27, depleted flows (irrigation withdraws) in the middle reach between RM 27 and RM 1.5, and replenished flows from groundwater springs below RM 1.5. A major agricultural diversion called the Three Sisters Irrigation District (TSID) canal is located at RM 27 upstream of the City of Sisters city park stream gauging station at RM 24.25. From TSID canal at RM 27 until RM 1.5, Whychus Creek is reduced to approximately 10 cfs (**Map 2**). This section of the creek is state of Oregon Section 303(d) listed for not meeting temperature criteria set to protect the beneficial use of trout spawning, rearing, and migration (**Map 1**). Downstream of RM 1.5, Alder Springs contributes 95 cfs of cold groundwater into Whychus Creek.

Background

Whychus Creek, Oregon exceeds the water temperature standards set forth by the state of Oregon to protect the beneficial use of trout spawning, rearing, and migration in the Deschutes Basin (**Map 1**). The primary driver of this temperature impairment is reduced in-stream flows to meet out-of-stream uses of agriculture (**Map 2**). In order to find a balance between these contrary uses of the water, information is needed regarding the minimal in-stream flow target that is required to keep temperatures below state standard and protect the beneficial use of trout spawning, rearing, and migration. This common watershed challenge of water quality impairment associated with low in-stream flows is indicative of challenges across Oregon and is addressed within the Whychus Creek Watershed Project (WCWP).

In-stream flow restoration for Whychus Creek is a focal objective of the Deschutes River Conservancy (DRC). The DRC has an in-stream flow target set at 20 cfs that was established using the Tennant Method. This method has recently been shown to inaccurately estimate the in-stream flow targets in high gradient watersheds such as Whychus Creek (Mann 2006). In addition, this method is based entirely on physical habitat and does not consider the water quality needs of fish.

The DRC seeks to find balance between in-stream needs of fish and out-of-stream agricultural water uses. The DRC utilizes water transactions and water marketing tools to meet in-stream flow restoration targets. These targets are un-evaluated for their ability to improve water quality, yet they determine how limited restoration budgets are allocated. In order to efficiently apply the DRC economic approaches to restoration, the minimal in-stream flow target able to accord the water quality needed to protect trout is of interest.

To address this informational need, multiple local, state, and federal partners of the Upper Deschutes Watershed Council (UDWC) developed a watershed strategy to be implemented as the WCWP. The long term goal of the WCWP is to understand the spatial and temporal relationships between water quality and in-stream flows. Funding for equipment and materials for the WCWP are provided by the Oregon Department of Environmental Quality (ODEQ) and the Oregon Watershed Enhancement Board (OWEB). The Institute for Water and Watersheds (IWW), Oregon State University (OSU), and the Upper Deschutes Watershed Council (UDWC) partnered to establish a graduate research assistantship to implement the WCWP in 2006.

WCWP Implementation Goals

The IWW, OSU, and UDWC established an OSU Graduate Research Assistant to implement the WCWP in 2006. The goals of implementation include:

Goal 1: Fabricate and secure continuous multiparameter water quality monitoring stations.

Goal 2: Data collection for temperature, pH, dissolved oxygen, percent saturation, specific conductance and total dissolved solids from:
- ~ Continuous multiparameter water quality monitoring stations,
- ~ Grab sample and continuous temperature water quality monitoring stations, and
- ~ Flow and climate data compilation.

Goal 3: Preliminary analyses

Goal 4: Sharing of information via OSU courses and seminars.

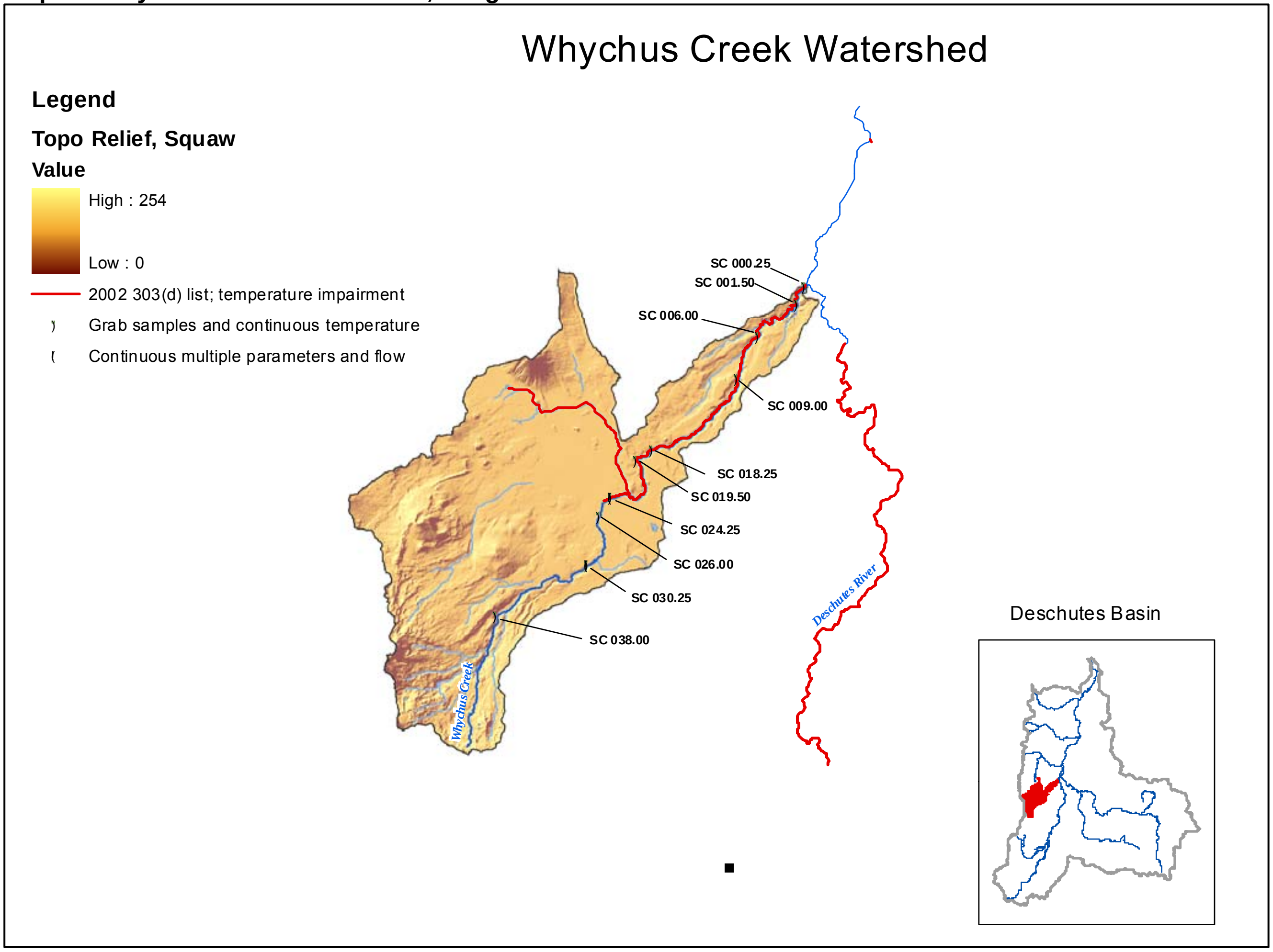
Goal 5: Development of a graduate thesis concept that is applicable to local, state, and federal water resource management in central Oregon.

All goals are completed and the methodology, analyses, and results are provided in this report. Goal 2 is ongoing under a multi-year collaborative agreement between the UDWC and OSU to offer an undergraduate internship within the natural resources program at the Cascades Campus. Under Goal 4, seminars were held at the following OSU – Cascades Campus courses:

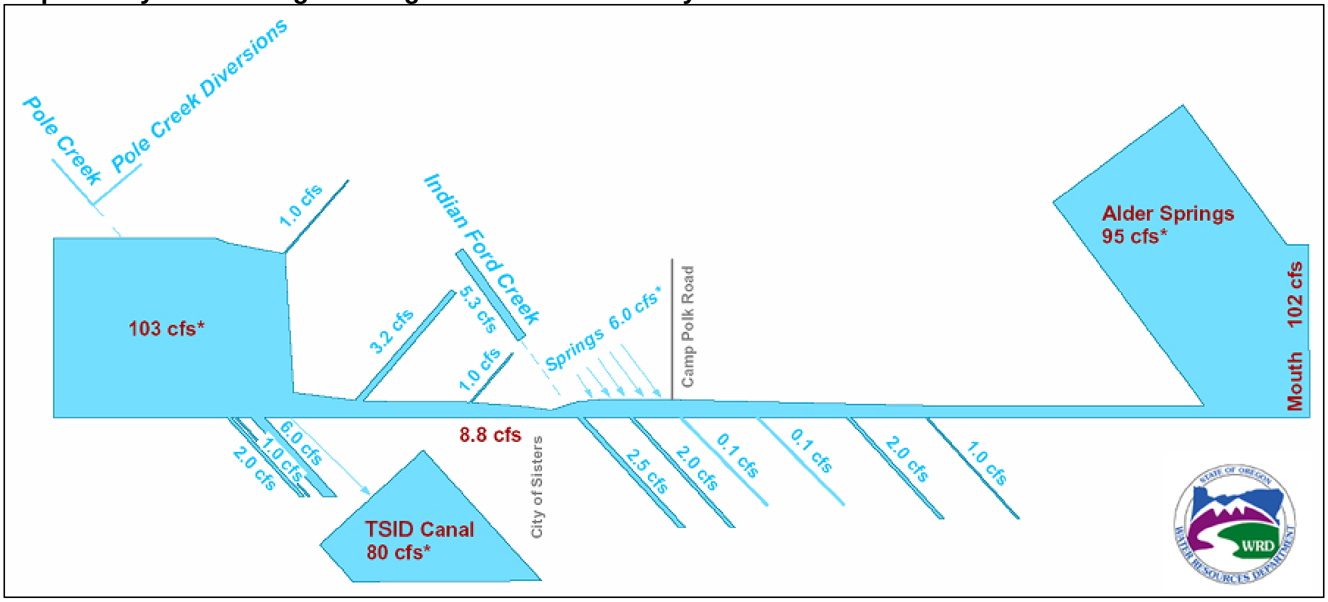
- ~ NR 455 Natural Resource Decision Making
- ~ FOR 365 Issues in Natural Resources Conservation

In addition, an oral presentation of the WCWP is accepted at the International Symposium on In-stream Flows 2007, Australia.

Map 1. Whychus Creek Watershed, Oregon



Map 2. July flows along the longitudinal extent of Whychus Creek



Methods

Stations and parameters

There are nine monitoring stations that are implemented under the WCWP displayed on **Map 1** and within **Table 1**. There are two continuous multiparameter monitoring stations and nine grab sample / continuous temperature stations. Measured water quality parameters include those that expect to change seasonally and with varied flows:

- ~ Temperature
- ~ Dissolved oxygen and percent saturation
- ~ Specific conductance and total dissolved solids

Table 1. Whychus Creek monitoring stations

Station ID	System	Location	CMP and Flow	G/CT
SC 000.25	Whychus Creek	Mouth		X
SC 006.00	Whychus Creek	u/s Rd 6360		X
SC 009.00	Whychus Creek	Rim Rock Ranch		X
SC 018.25	Whychus Creek	d/s end DBLT property		X
SC 019.50	Whychus Creek	d/s Camp Polk Bridge on DBLT property		X
SC 024.25	Whychus Creek	City Park gauge	X	X
SC 026.00	Whychus Creek	4606 Rd, footbridge		X
SC 030.25	Whychus Creek	OWRD gauge at USFS boundary	X	X
SC 038.00	Whychus Creek	Rd 1514		X

CMP and Flow = continuous multiparameter and continuous flow
G/CT = grab samples and continuous temperature

Continuous multiparameter water quality monitoring occurs April – October. Grab samples are collected monthly April – October with a YSI 556 MPS from nine stations that have continuous temperature loggers. Data collected by the OSU Graduate Research Assistant is downloaded and graded for quality according to standards set forth by ODEQ. This data will be available online at www.restorethedeschtues.org in summer 2007.

Secure water quality monitoring stations

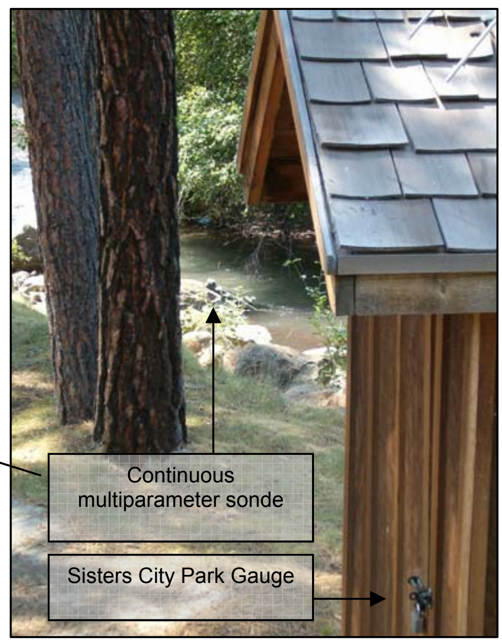
Continuous multiparameter water quality monitoring stations were installed at two flow gauging locations in Whychus Creek. The water quality monitoring stations include two components: a deployment setup and one YSI 6920 multiparameter sonde. The deployment setup is fabricated from stainless steel as to not interfere with water quality measurements, is vandal resistant, and is durable against natural events. It is designed to be mounted to natural or manmade features within the river. It can be adjusted to changing flow regimes and removed or relocated easily by the technician. The setups are installed near flow gauges to collect continuous multiparameter water quality data that can be related to in-stream flows.

Photo 1 depicts the process of installing a deployment setup at the Oregon Water Resources Department flow gauge located within the US Forest Service Three Sisters Wilderness Area. Small holes are drilled into rock or other structures by using a chainsaw motor and drill in order to install deployment setups. **Photo 2** depicts the installed deployment setup. **Photo 3** and **Photo 4** show the OSU graduate research assistant checking on equipment during its deployment at the water quality monitoring station adjacent to the City of Sisters city park flow gauge.

Implementation of the WCWP resulted in the installation of equipment and provided for data collection and data management for one year. The equipment will continue to operate through 2009 due to the initial support from IWW and OSU and continued funding from ODEQ and OWEB.

Photo 1. and Photo 2. Water quality monitoring station on Whychus Creek within Three Sisters Wilderness

Photo 3 and Photo 4 Water Quality Monitoring Station on Whychus Creek at the City of Sisters city park gauge.



Preliminary analyses

A long term goal of the WCWP is to understand the spatial and temporal relationship between water quality and in-stream flow. The preliminary analyses provided under the implementation of the WCWP aims to support the long term goal by:

~ Establishing a statistical model that relates water quality to in-stream flow within a degree of confidence,

~ Quantifying preliminary in-stream flow restoration targets based on water quality, and

~ Comparing results to current in-stream flow restoration targets.

Parameters to be evaluated in the preliminary analyses include average daily flows (QD) in cubic feet per second (cfs) and seven day maximum moving average temperatures (7DMAX) degree C. The following is the source of QD:

Oregon Water Resource Department (OWRD) flow gauge
#14076050 Whychus Creek at Sisters Oregon
http://www1.wrd.state.or.us/cgi-bin/choose_gage.pl?huc=17070301

To establish a statistical model that relates water quality to in-stream flow, analyses incorporates space and time. The following is a summary of the preliminary analyses:

- One location; Whychus Creek at City of Sisters city park gauge
- Explanatory variable; Continuous flow QD
- Dependant variable; Continuous temperature 7DMAX
- Apply autocorrelation function to establish appropriate degree of aggregation within dataset
- Analyze dataset with linear regression to approach research question

Continuous flow and temperature readings are selected from the City of Sisters city park monitoring location located downstream from the TSID canal diversion off Whychus Creek (**Map 1** and **Map 2**). The time period for the dataset is 2003 – 2006 since this is the most complete period of record. Continuous flow as the explanatory variable will be used to model the response of the dependant variable continuous temperature 7DMAX.

Time series autocorrelation

Information from a time series autocorrelation provides indication to whether summing over the structure in the data will conclude misleading results that over estimate or underestimate the target (OSU 2007). The results of autocorrelation analyses indicate that serial autocorrelation exists within the QD and 7DMAX 2003 – 2006 dataset with a Lag time k of 15 at N = 424. Therefore aggregating all data within the 2003 - 2006 years is not appropriate due to the possibility of concluding misleading results. The dataset is sub-grouped by month, and July is selected to perform preliminary analyses because this is the hottest water month each year during a time of increased out-of-stream water usage. Sup-grouping by July over all years indicates a lower degree of autocorrelation with a Lag time k of 5 at N = 101. This detected autocorrelation may be explained by seasonal differences between years (CSU 2007). Sub-grouping then aggregating provides some protection against the influences of seasonal trends (USGS 1991). In addition, it may be desirable to have seasonal differences between years in order to adequately represent long-term conditions.

An analysis of the sub-group July aggregated over 2003 – 2006 is performed under the assumption that there is a negligible amount of serial correlation and that sub-grouping July and aggregating all data 2003 – 2004 protects from seasonal influences. A comparison is made to results from sub-grouping July non-aggregated; July 2003, July 2004, July 2005, and July 2006.

Linear regression

A Log transformation is utilized to normalize the QD dataset, and then a linear regression is performed for 7DMAX versus Log QD. The linear regression model for July aggregated 2003 - 2006 is used to solve for y = 18 C; the state standard for 7DMAX. The resulting x depicts the Log QD that meet criteria during that July and year. A recommended in-stream flow target for the month of July based on Log QD and a 95% confidence limit are calculated.

Figure 1 depicts the linear regression between July aggregated 2003 – 2006 7DMAX versus Log QD. **Table 2** contains the results of the linear regression that depict an average daily flow of 17.8 $\pm$ 1.2 cfs 95% confidence limit as the predicted in-stream flow target for July.

For comparison, a Log transformation is utilized to normalize the QD dataset of each July non-aggregated 2003 - 2006, and then a linear regression is performed for 7DMAX versus Log QD. The linear regression model for July each year is used to solve for y = 18 C. The resulting x depicts the Log QD that meet criteria during that July and year. The mean Log QD for July non-aggregated 2003 – 2006 is established and used to calculate a recommended in-stream flow target for the month of July and a 95% confidence limit.

Figure 2 depicts the linear regression between July non-aggregated 2003 – 2006 7DMAX versus Log QD. **Table 4** contains the results of linear regression that depicts an average daily flow of 13.8 $\pm$ 1.4 cfs 95% confidence limit as the predicted in-stream flow target for July.

Figure 1. Scatter plot 7DMAX and Log QD with linear regression; July aggregated 2003 - 2006

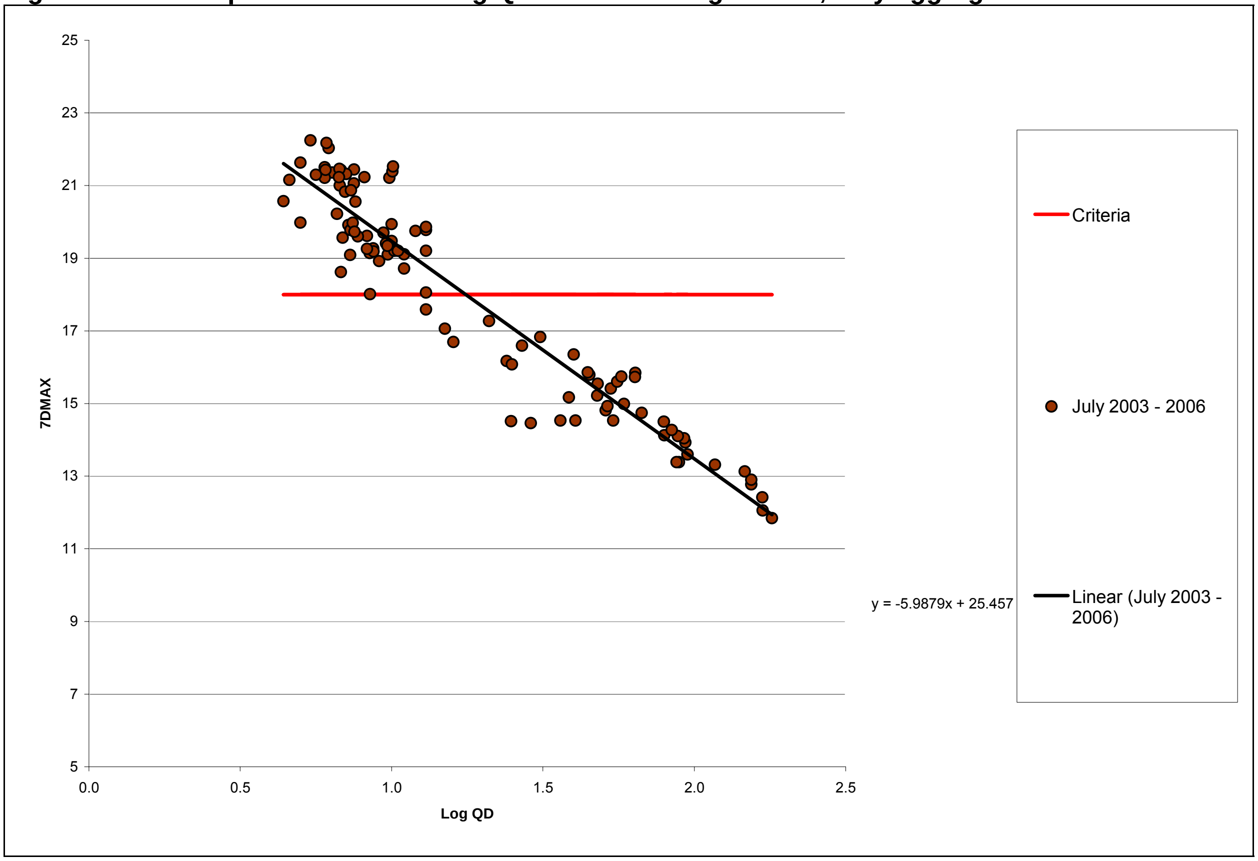


Table 2 Results of linear regression July aggregated all years

Time period	Linear regression	y = 18, x =?
July 2003 - 2006	y = -5.9879x + 25.457	1.25

1.25 $\underline{y}$

0.47 s ($\underline{y}$)

A two sided 95% confidence limit for the mean is calculated as:

$$10^{(\underline{y})} \pm 10^{(Z1\text{-}\alpha/2\ s_{\underline{y}}/\sqrt{n})}$$

From TA1 (Gilbert 1987) $Z_{.975} = 1.9$

$$10^{(1.25)} \pm 10^{[1.9\ (0.47/\sqrt{101})]}$$

$$17.8 \pm 1.2$$

Figure 2. Scatter plot 7DMAX and Log QD with linear regression; July non-aggregated 2003 - 2006

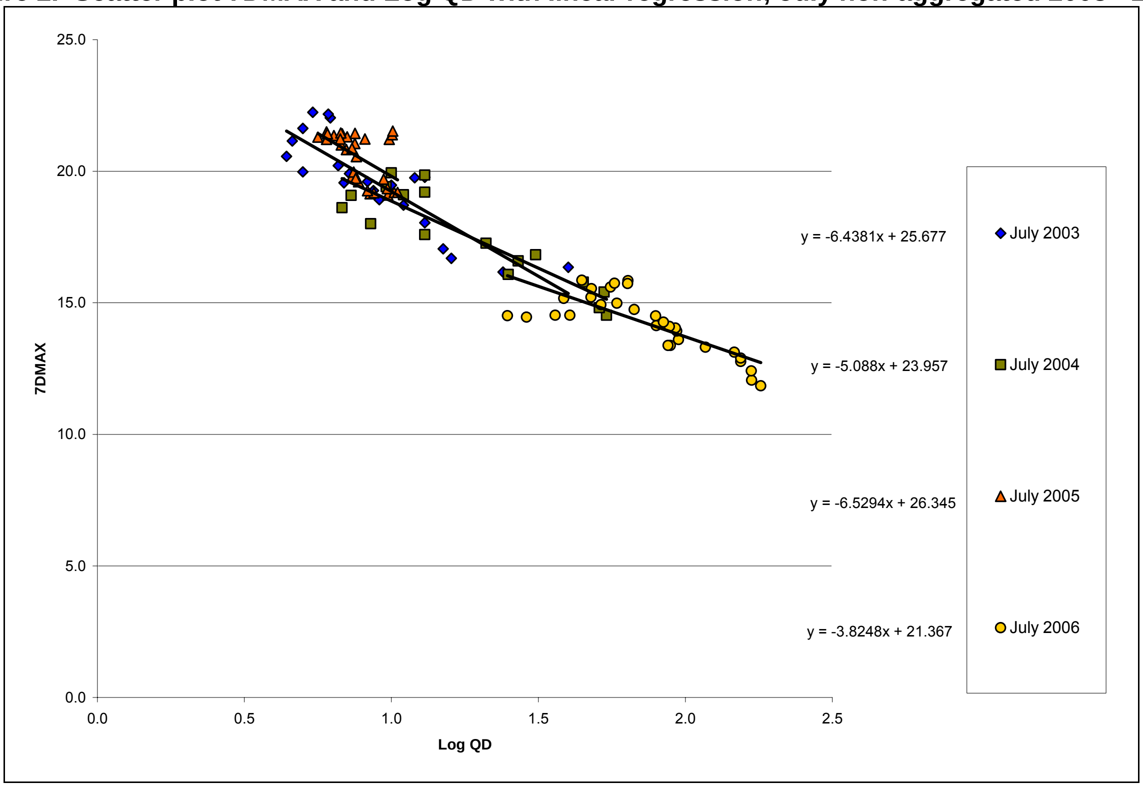


Table 3 Results of linear regression July non-aggregated 2003 - 2006

July year	Linear regression	y = 18, x =?	$(x-\underline{x})$^2
July 2003	y = -6.4381x + 25.677	1.19	0.00
July 2004	y = -5.088x + 23.957	1.17	0.00
July 2005	y = -6.5294x + 26.345	1.28	0.02
July 2006	y = -3.8248x + 21.367	0.90	0.06
		1.14	$\underline{y}$
		0.16	s $(\underline{y})$

A two sided 95% confidence limit for the mean is calculated as:

$$10^{(\underline{y})} \pm 10^{(Z1\text{-}\alpha/2\ s_{\underline{y}}/\sqrt{n})}$$

From TA1 (Gilbert 1987) $Z_{.975} = 1.9$

$$10^{(1.14)} \pm 10^{[1.9\ (0.16/\sqrt{4})]}$$

$$13.8 \pm 1.4$$

Results

Results from the preliminary analyses indicate that the means are significantly different with aggregation compared to non-aggregation (**Figure 3**). It is determined that using the non-aggregated 2003 – 2006 dataset may result in under-estimates of the in-stream flow target. Upon comparison of target performance against actual July requirements 2003 - 2006, it is evident that if the July non-aggregated 2003 - 2006 flow target is used not all years would meet state temperature requirements (**Table 4**). The July aggregated 2003 – 2006 estimated in-stream flow target illustrates a more accurate prediction.

The results of the preliminary analyses indicate that it is effective and efficient to estimate in-stream flow restoration targets based upon water quality by:

~ Aggregating QD and 7DMAX within each month over multiple years,

~ Applying a linear regression model of Log QD versus 7DMAX

Figure 3 In-stream flow target estimations from July aggregated and non-aggregated 2003 - 2006

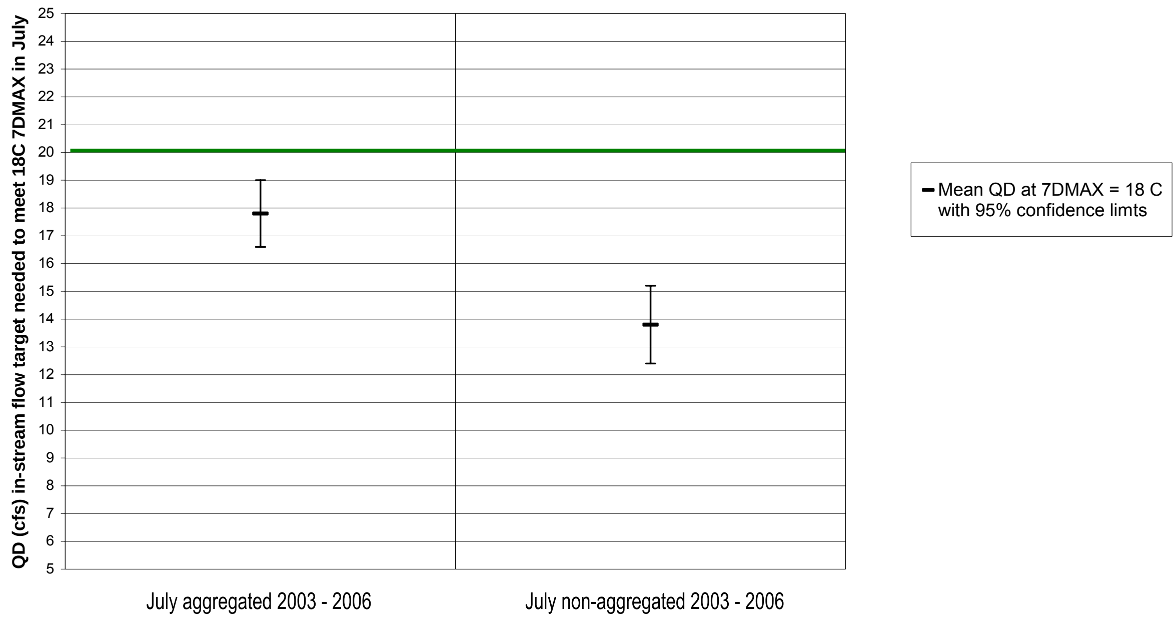


Table 4 Comparison of target performance against actual July requirements 2003 - 2006

July year	QD required to meet 18C 7DMAX	July aggregated 2003 - 2006 target = 16.6 - 19.0	July non-aggregated 2003 - 2006 target = 12.4 - 15.2
July 2003	15.5	Yes	No
July 2004	14.8	Yes	Yes
July 2005	19.1	No	No
July 2006	7.9	Yes	Yes

Yes = state temperature requirements for 7DMAX are met

No = state temperature requirements for 7DMAX are not met

Graduate thesis concept

The DRC has an in-stream flow restoration target for Whychus Creek of 20 cfs that is set the same across all months of the year (green line **Figure 3 & 4**). The target is based on physical habitat and does not consider spatial or temporal water quality changes. The Tennant Method that was used to establish the flow target has recently been shown to inaccurately estimate targets in high gradient watersheds such as Whychus Creek. Whether the target is able to accord the water quality needed to protect trout spawning, rearing, and migration is of interest.

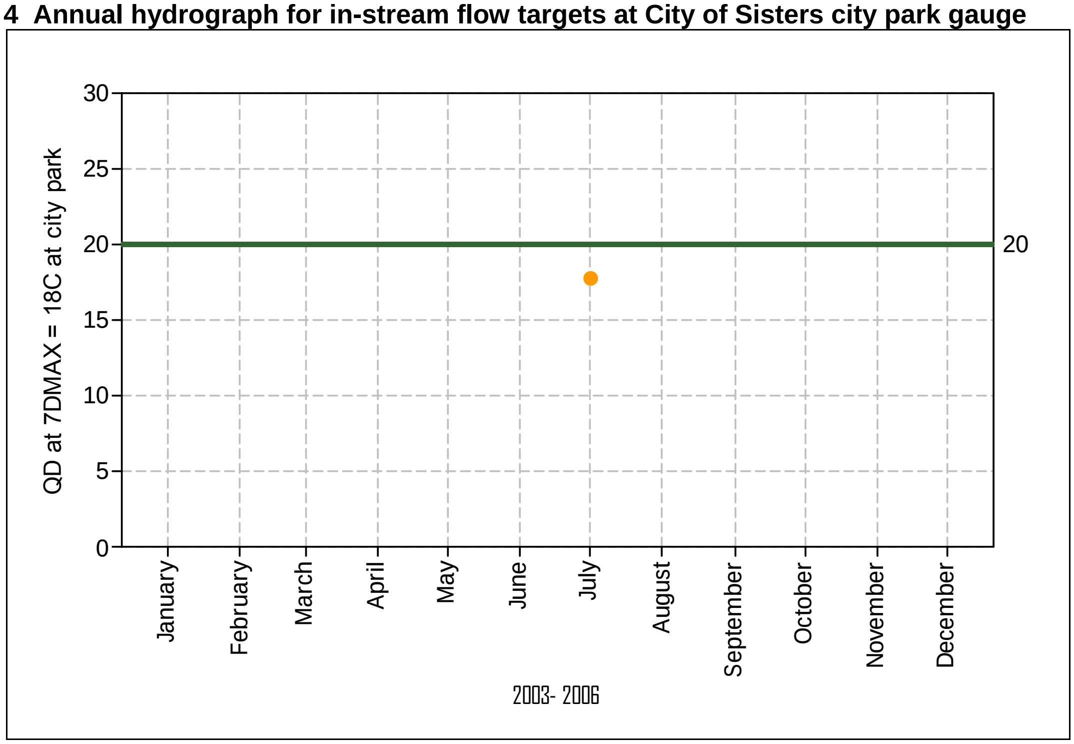
According to the results from July aggregated 2003 – 2006 data, at a 95% significance level 17.8 ± 1.2 accords compliance of 7DMAX with state temperature criteria set to protect trout spawning, rearing, and migration for July during 2003 – 2006 at the City of Sisters city park gauge. Yet the water quality at the city park is not indicative of the most impaired water quality within Whychus Creek. As the water flows downstream, water quality declines due to low in-stream flows. Downstream 18.25 river miles from the city park, the water quality is the most impaired. The 17.8 cfs target at the city park may not accord the water quality requirement of 18 C 7DMAX downstream.

In order to optimize limited restoration budgets and increase the extent of restoration, a graduate thesis concept has been developed that builds upon the implementation of the WCWP, is applicable to central Oregon water resource management, and approaches the research question:

What annual hydrograph for in-stream flow targets at the Whychus Creek gauge City of Sisters city park (RM 24.25) accords the state standards for water quality set to protect trout spawning, rearing, and migration downstream at the Road 6360 crossing (RM 6.0)?

To answer the research question, an annual hydrograph for in-stream flow targets based on water quality requirements for trout will be modeled. An example annual hydrograph depicting the findings under the implementation of the WCWP is provided in **Figure 4**. A similar hydrograph depicting the in-stream flow target for Whychus Creek at the city park based on water quality downstream 18.25 miles at the Road 6360 crossing is to be constructed under the graduate thesis.

Figure 4 Annual hydrograph for in-stream flow targets at City of Sisters city park gauge



Implications for water resource managers

The flow and water quality requirements of trout change along the longitudinal extent of the river and across seasons. A flat target that is the same for every section of the river and every season does not reflect downstream water quality changes and the seasonal water quality needs of fish. Establishing an annual hydrograph for in-stream flow targets is critical since to restore one cfs of in-stream flow into Whychus Creek the cost is $500,000 - $750,000 and therefore targets that do not accord the required water quality for trout are costly (DRC, 2007).

Under the implementation of the WCWP, equipment is installed, data collected, and a preliminary analyses involving QD versus 7DMAX is used to illustrate a simple approach to evaluating in-stream flow restoration targets based on water quality needs of trout. A graduate thesis concept is developed that builds upon the implementation of the WCWP and fills an informational need of central Oregon water resource managers. The graduate thesis will establish an annual hydrograph based on spatial and temporal water quality needs of trout spawning, rearing, and migration. The annual hydrograph will allow for the optimization of limited restoration budgets and increase the extent of restoration along Whychus Creek.

References

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