UPPER DESCHUTES
WATERSHED COUNCIL

MEMORANDUM

To: Basin Study Work Group

From: Lauren Mork & Ryan Houston

Date: April 5, 2016

Re: Whychus Creek and Middle Deschutes River Temperature Assessments

Introduction

The Deschutes Basin Board of Control, working on behalf of the Basin Study Work Group, contracted with the Upper Deschutes Watershed Council to prepare a series of stream temperature analyses for Whychus Creek, the Middle Deschutes, and Tumalo Creek as part of the Basin Study. The specific scope of work includes the preparation of regression analyses describing the relationships between stream temperature, stream flow and air temperature at three sites within the focal watersheds using up to 12 years of data collected between the months of April and October.

This memo presents the results of our analyses. The Basin Study Work Group will use the regression equations presented in this memo to evaluate the impacts to stream temperature from climate change scenarios and water management alternatives that are being evaluated in the Basin Study. The climate change scenarios and water management alternatives are being developed elsewhere in the Basin Study and, therefore, are not included in this memo.

Methods

Sites

We selected one site each from Whychus Creek, the Middle Deschutes River, and Tumalo Creek to develop relationships between stream temperature, stream flow and air temperature at each site during the irrigation season (April-October):

- For Whychus Creek we selected WC 006.00, the farthest downstream site characterized by the highest temperatures before the stream enters a canyon and is subsequently cooled by cold groundwater inputs at river mile 1.5.

- For the Middle Deschutes River we selected DR 160.25 to represent stream temperature approximately five miles below North Canal Dam, the site of all stream flow restoration in the Middle Deschutes upstream of Tumalo Creek.

- For Tumalo Creek we selected TC 000.25, immediately upstream of the confluence with the Deschutes, to represent the stream temperature that occurs at the farthest downstream and warmest point below the Tumalo Irrigation Diversion, and the temperature at which Tumalo Creek flows enter the Deschutes.

Data collection

Stream temperature
We utilized continuous stream temperature data collected by the UDWC and the City of Bend between 2000 and 2014 at stream temperature monitoring stations on Whychus Creek, the Middle Deschutes River, and Tumalo Creek (Figure 1), using Vemco and HOBO dataloggers rated to an accuracy of 0.5°C. Monitoring was conducted and data graded according to standard methods and protocols outlined in the ODEQ-approved UDWC Quality Assurance Project Plan (UDWC 2008a) and summarized in UDWC Water Quality Monitoring Program Standard Operating Procedures (UDWC 2008b).

We used the Oregon Department of Environmental Quality (ODEQ) Hydrostat Simple spreadsheet to calculate the seven day moving average maximum stream temperature (7DADM), the statistic used by the State of Oregon to evaluate stream temperature relative to state temperature standards.

Stream flow
We obtained average daily stream flow (QD) data for Whychus Creek, the Middle Deschutes River, and Tumalo Creek from the Oregon Water Resources Department (OWRD 2015) (Figure 1):

- For Whychus Creek we used data from OWRD gage #14076050 at the City of Sisters. This gage is located downstream from the Three Sisters Irrigation District diversion and other major irrigation diversions. We used data collected at this gage from 2001 to 2014 in this analysis, including some data considered by OWRD to be provisional and subject to change.

- For the Middle Deschutes River we used stream flow data from OWRD gage #14070500, Deschutes River below Bend. All Deschutes River flow data through September 2012 are considered published; Deschutes flow data from October 1, 2012 to October 31, 2014 are considered provisional and subject to change.

- For Tumalo Creek we used data from OWRD gage #14073520, Tumalo Irrigation District Feed Canal. All Tumalo Creek flow data through September 2008 and from October 2009 through September 2011 are considered published; Tumalo Creek flow data from October 2008 through September 2009 and from October 2011 to October 2014 are considered provisional and subject to change.

Because the distribution of average daily flow data for many of the site/month datasets was non-normal, we calculated the natural logarithm of the average daily flow (LnQD) for each data day to improve the normality of the distribution of the data.

Air temperature

We obtained daily maximum air temperature data from the three Western Regional Climate Center (WRCC 2015) RAWS stations closest to the three stream temperature monitoring stations:

- For Whychus Creek we used air temperature data from the Colgate, OR RAWS station (44° 18’ 57”, 121° 36’ 20”).

- For the Middle Deschutes River and Tumalo Creek we used air temperature data from the Tumalo Ridge, Oregon RAWS station (44° 02’ 58”, 121° 24’ 01”). Where air temperature data were not available for the Tumalo Ridge station we used data from the Lava Butte, Oregon RAWS station (43° 55’ 48”, 121° 19’ 48”).

We calculated the 3-day moving average daily maximum air temperature for each day to evaluate the cumulative influence of air temperature on stream temperature. While the use of air temperature to predict stream temperature has been the subject of debate within the scientific community, we included air temperature in regressions on the basis of an extensive body of scientific literature supporting its application for this purpose. Air temperature has been shown to be a useful proxy for heat energy transfer from the atmosphere to water by long-wave radiation and sensible heat transfer (Webb and Zhang 1997; Mohseni and Stefan 1999), and multiple studies have used air temperature to accurately predict stream temperature variation (e.g. Webb et al. 2003; Mohseni et al. 2003; Morrill et al. 2005; Carlson et al. 2015).

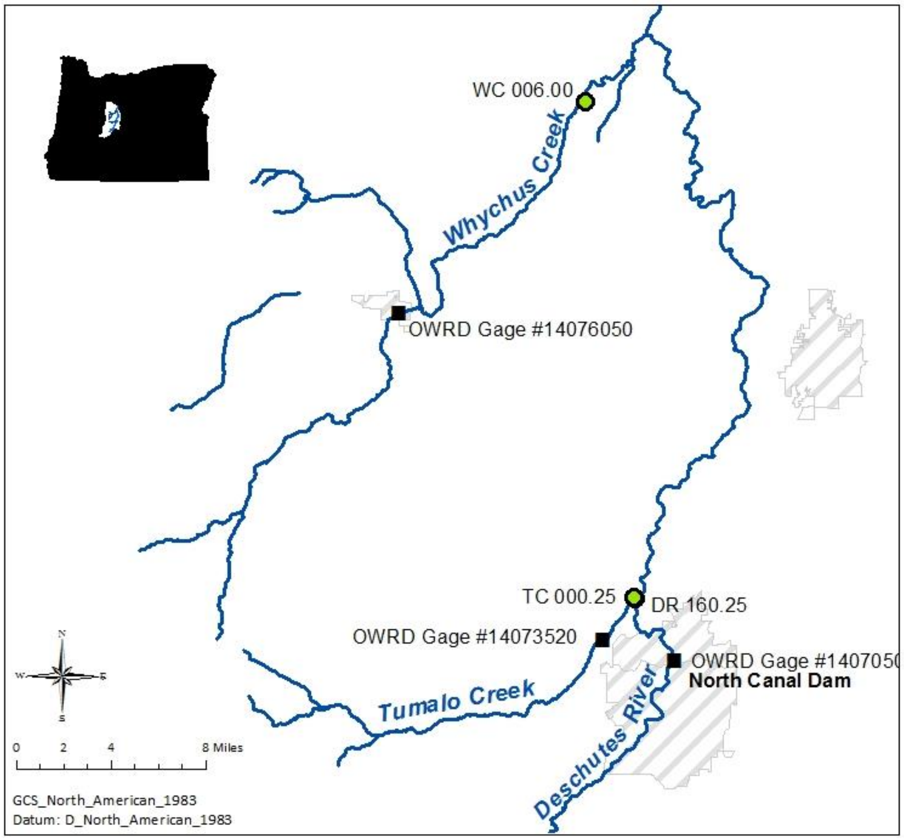

Figure 1. Temperature assessment stream temperature monitoring stations and OWRD stream flow gages.

Data analysis

We performed simple and multiple linear regressions of seven-day moving average stream temperature (7DADM), stream flow, and air temperature data to identify the subset of variables, and produce the regression equations, that best describe the relationship among stream temperature, stream flow and air temperature at the three indicator sites for each month between and including April and October. We performed regressions for all sites and months: 1) with each of two flow metrics (QD and LnQD); and 2) with each of two air temperature metrics, daily maximum air temperature (Air) and three-day moving average air temperature (3DADM), for a total of eight models (Table 1), to evaluate the degree to which each metric improved or detracted from the goodness of fit of the model.

Table 1. Eight regression models evaluated for Whychus Creek and the Middle Deschutes River for April through October and for Tumalo Creek from May through October.

Regression Model	
1.	7DADM ~ Flow
2.	7DADM ~ LnFlow
3.	7DADM ~ Flow + Air
4.	7DADM ~ LnFlow + Air
5.	7DADM ~ Flow + 3DADMAir
6.	7DADM ~ LnFlow + 3DADMAir
7.	7DADM ~ Air
8.	7DADM ~ 3DADMAir

For each site and month we included all dates for which stream temperature, stream flow and air temperature data (daily maximum and 3DADM) were all available (Table 2). For each site and month April through October we used R open source statistical software (R Core Team, 2015) to perform linear and multiple linear regressions for eight models (Table 2). We used the extractAIC function in R to generate Akaike Information Criterion (AIC) values for each regression model. AIC values rank models relative to each other on the basis of goodness of fit and number of parameters, with values decreasing as models improve; the lowest value indicates the best model. A difference of two or more between AIC values for two models denotes a statistically better model. For each site and month we evaluated R-squared (R^2), residual standard error (S), and AIC values to select the model that resulted in the best fit to the observed data; we evaluated residuals plots and normal probability plots for normality of residuals for the best model, and plotted predicted v. observed values for the top three models.

Table 2. Months and years for which data are available represented in regression analyses. The number of days for which data are available for any given month varies.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Whychus Creek (WC 006.00)															
April		x	x			x				x	x		x	x	x
May		x	x			x		x		x	x	x	x	x	x
June	x	x	x			x	x	x		x	x	x	x	x	x
July	x	x	x			x	x	x		x	x	x	x	x	x
August	x	x	x			x	x	x		x	x	x	x	x	x
September	x	x				x	x	x		x	x	x	x	x	x
October		x				x	x	x			x	x	x	x	
Middle Deschutes River (DR 160.25)															
April										x			x	x	x
May				x		x				x			x	x	x
June			x	x		x			x	x	x	x	x	x	x
July			x	x	x	x		x	x	x	x	x	x	x	x
August			x	x	x	x		x	x	x	x	x	x	x	x
September			x	x	x	x		x	x	x	x	x	x	x	x
October			x	x	x	x			x		x	x	x	x	x
Tumalo Creek (TC 000.25)															
May					x	x		x		x	x		x		x
June					x	x		x		x	x	x	x	x	x
July					x	x	x	x		x	x	x	x	x	x
August					x	x	x	x		x	x	x	x	x	x
September					x	x	x	x		x	x	x	x	x	x
October						x	x	x						x	

Results and Discussion

The regression of the natural log of average daily flow and the 3-day moving average daily maximum air temperature (7DADM ~ LnFlow + 3DADMAir) performed best of the eight regression models for every month for Whychus, for four months for the Deschutes (April, June, July, and October), and for four months for Tumalo Creek (May through August) (Appendix A; Appendix B) Distribution of residuals approached normality for the best-performing model for each site and month (Appendix C). The effect of stream flow and air temperature on stream temperature were strongest in June and July for all three sites, suggesting that water resource scenario modeling that involves water temperature as a key objective will be most useful if it focuses in on these two summer months. We hypothesize that these relationships are strongest in the summer months because there is far less variability in stream flow and weather conditions in midsummer than there is during the spring or fall seasons.

Evaluation of residuals from preliminary regressions indicated stream temperature, stream flow and air temperature data are auto-correlated. We did not correct for auto-correlation in the regressions presented here as beyond the scope of work for these study elements. Further analyses may improve on the regression equations provided by accounting for auto-correlation. Using the daily maximum stream temperature as the dependent variable in place of the 7-day moving average maximum stream temperature might also improve the fit of regressions.

<u>Whychus Creek</u>
For Whychus Creek, the natural log of average daily flow and the 3DADM air temperature (7DADM ~ LnFlow + 3DAir) consistently explained the greatest proportion of variation in stream temperature of the eight models, with the two variables explaining the greatest proportion of variation during June and July (R^2 = 0.83 and 0.87, respectively) (Appendix A). This relationship was also strong in April and May (R^2 = 0.74) but diminished from August through October (R^2 = 0.67, 0.54 and 0.48, respectively). The effect of each variable on stream temperature was statistically significant for the three models presented for all sites and months.

<u>Middle Deschutes River</u>
The natural log of stream flow and 3DADM air temperature together explained the greatest proportion of variation in stream temperature in the Deschutes in April (R^2 = 0.66), June (R^2 = 0.75), July (R^2 = 0.75), and October (R^2 = 0.55) (Appendix A). Average daily flow (rather than the natural log) and 3DADM air temperature explained the greatest proportion of variation in stream temperature in May (R^2 = 0.65), August (R^2 = 0.43), and September (R^2 = 0.39). The effect of each variable on stream temperature was statistically significant for the three models presented for all sites and months.

<u>Tumalo Creek</u>
We performed regressions for TC 000.25 for May through October; no stream temperature data were available for this site in April. The natural log of stream flow and 3DADM air temperature together explained the greatest proportion of variation in stream temperature in Tumalo Creek in May (R^2 = 0.69), June (R^2 = 0.75), July (R^2 = 0.89), and August (R^2 = 0.50) (Appendix A). For May, the regression of the natural log of flow and 3DADM air temperature were only marginally better than the regression of average daily flow and 3DADM air temperature (R^2 = 0.69 and 0.68; AIC = -9.6 and -8.6, respectively); normality of the distribution of residuals for both models was similar (Appendix A). For October, stream temperature was poorly explained by stream flow and air temperature, regardless of metric; of the models evaluated, daily maximum air temperature alone was the best predictor of stream temperature, while still explaining only 5% (R^2 = 0.05) of the variation in stream temperature in October. Low R^2 values and high standard errors for Tumalo Creek in October suggest another environmental factor not included in our regression models is driving stream temperature in Tumalo Creek in October.

Conclusions

The natural log of average daily flow and the three-day moving average daily maximum air temperature explained a high proportion of the variation in stream temperature for April through July on Whychus Creek, the Middle Deschutes River, and Tumalo Creek, suggesting these metrics contribute significantly to stream temperature during these months at these sites and regression equations for these months can be used to predict stream temperatures with a high degree of confidence within the range of values included in analysis.

The relationship between stream temperature, stream flow and air temperature is weaker during later summer and fall months (August through October), but standard error values within 1.5°C for all but two months suggest top regression equations for these months may still be useful in developing scenarios for water management that will best contribute to reducing stream temperatures, particularly during August.

Limitations

The regression equations presented herein are based on historical data from the period 2000-2014. Any significant changes to water management or basin conditions (e.g., riparian shading) would alter the stream temperature/air temperature/streamflow relationship from the historical relationships that the regressions have been trained upon. Although these regressions provide useful information on the general sensitivities of stream temperature to air temperature and streamflow, something more similar to a full energy balance model would be necessary for a comprehensive analysis of stream temperature dynamics.

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APPENDIX A

Table 3. The top three simple and multiple regression models for predicting stream temperatures from stream flow and air temperature for each month of the irrigation season April through October on Whychus Creek, the Middle Deschutes River, and on Tumalo Creek.

Month	Regression Model	Intercept	Coefficient 1	Coefficient 2	n	df	R^2	S	AIC value
Whychus Creek (006.00)									
April	7DADM ~ LnFlow + Air	16.36835	-1.96302[a]	0.14805[a]	100	97	0.66	1.43	75
	7DADM ~ Flow + 3DAir	10.123328	-0.058439[a]	0.280962[a]	100	97	0.70	1.35	63
	7DADM ~ LnFlow + 3DAir	**14.59332**	**-1.87756[a]**	**0.25174[a]**	**100**	**97**	**0.74**	**1.27**	**51**
May	7DADM ~ LnFlow + Air	16.6095	-1.68793[a]	0.21823[a]	273	270	0.63	1.62	265
	7DADM ~ Flow + 3DAir	10.88251	-0.04399[a]	0.31664[a]	273	270	0.60	1.68	285
	7DADM ~ LnFlow + 3DAir	**15.66411**	**-1.8922[a]**	**0.30593[a]**	**273**	**270**	**0.74**	**1.34**	**164**
June	7DADM ~ LnFlow + Air	20.04468	-2.00684[a]	0.17592[a]	294	291	0.74	1.52	248
	7DADM ~ Flow + 3DAir	13.783697	-0.032769[a]	0.224747[a]	294	291	0.64	1.79	344
	7DADM ~ LnFlow + 3DAir	**18.06029**	**-2.12044[a]**	**0.28296[a]**	**294**	**291**	**0.83**	**1.24**	**128**
July	7DADM ~ LnFlow + Air	20.9016	-2.56461[a]	0.26296[a]	313	310	0.83	1.57	286
	7DADM ~ Flow + 3DAir	15.271044	-0.063983[a]	0.274649[a]	313	310	0.84	1.54	274
	7DADM ~ LnFlow + 3DAir	**18.39**	**-2.55601[a]**	**0.345[a]**	**313**	**310**	**0.87**	**1.39**	**210**
August	7DADM ~ LnFlow + Air	20.49901	-1.61962[a]	0.15628[a]	312	309	0.63	1.30	167
	7DADM ~ Flow + 3DAir	15.6517	-0.12186[a]	0.25238[a]	312	309	0.65	1.27	151
	7DADM ~ LnFlow + 3DAir	**18.55486**	**-1.62379[a]**	**0.22118[a]**	**312**	**309**	**0.67**	**1.24**	**136**
September	7DADM ~ LnFlow + Air	15.21517	-1.2721[a]	0.16353[a]	249	246	0.43	1.74	278
	7DADM ~ Flow + 3DAir	10.695593	-0.024946[a]	0.229223[a]	249	246	0.39	1.80	294
	7DADM ~ LnFlow + 3DAir	**13.25576**	**-1.32627[a]**	**0.24628[a]**	**249**	**246**	**0.54**	**1.57**	**227**

Month	Regression Model	Intercept	Coefficient 1	Coefficient 2	n	df	R^2	S	AIC value
October	7DADM ~ LnFlow	15.0088	-1.5999[a]	--	154	152	0.39	1.59	144
	7DADM ~ LnFlow + Air	12.80323	-1.41797[a]	0.08862[a]	154	152	0.43	1.53	135
	7DADM ~ LnFlow + 3DAir	**11.20126**	**-1.26511[a]**	**0.14642[a]**	**154**	**152**	**0.48**	**1.47**	**121**
Middle Deschutes River (DR 160.25)									
April	7DADM ~ Flow + Air	9.8044238	-0.002551[a]	0.1303848[a]	59	56	0.56	0.94	-5
	7DADM ~ Flow + 3DAir	8.8956871	-0.0023563[a]	0.1946571[a]	59	56	0.68	0.80	-23.3
	7DADM ~ LnFlow + 3DAir	**12.20686**	**-0.77995[a]**	**0.20357[a]**	**59**	**56**	**0.66**	**0.82**	**-21.0**
May	**7DADM ~ Flow + 3DAir**	**11.9035765**	**-0.003256[a]**	**0.1933199[a]**	**128**	**125**	**0.65**	**0.85**	**-37.6**
	7DADM ~ LnFlow + 3DAir	13.88689	-0.52059[a]	0.19646[a]	128	125	0.65	0.85	-38.4
	7DADM ~ 3DAir	11.12463	0.20966[a]	--	128	125	0.62	0.89	-29
June	7DADM ~ Flow + 3DAir	13.7965611	-0.005315[a]	0.1866995[a]	194	191	0.73	0.64	-171
	7DADM ~ LnFlow + 3DAir	**16.54305**	**-0.71006[a]**	**0.18316[a]**	**194**	**191**	**0.75**	**0.61**	**-190**
	7DADM ~ 3DAir	12.54095	0.21468[a]	--	194	191	0.67	0.70	-137
July	7DADM ~ LnFlow + Air	20.889125	-1.095603[a]	0.124703[a]	307	304	0.67	0.54	-375
	7DADM ~ Flow + 3DAir	15.4175612	-0.007855[a]	0.1685709[a]	307	304	0.71	0.50	-418
	7DADM ~ LnFlow + 3DAir	**19.279265**	**-1.002175[a]**	**0.165172[a]**	**307**	**304**	**0.75**	**0.47**	**-459**
August	**7DADM ~ Flow + 3DAir**	**15.1391388**	**-0.006027[a]**	**0.1448228[a]**	**346**	**343**	**0.43**	**0.69**	**-254**
	7DADM ~ LnFlow + 3DAir	17.294086	-0.619501[a]	0.146259[a]	346	343	0.42	0.70	-246
	7DADM ~ 3DAir	14.59053	0.13953[a]	--	346	343	0.34	0.74	-203
September	**7DADM ~ Flow + 3DAir**	**10.449216**	**0.002598[a]**	**0.182143[a]**	**283**	**280**	**0.39**	**1.10**	**56**
	7DADM ~ LnFlow + 3DAir	9.55104	0.2611[a]	0.18122[a]	283	280	0.39	1.10	57
	7DADM ~ 3DAir	10.70812	0.1829[a]	--	283	280	0.38	1.10	58

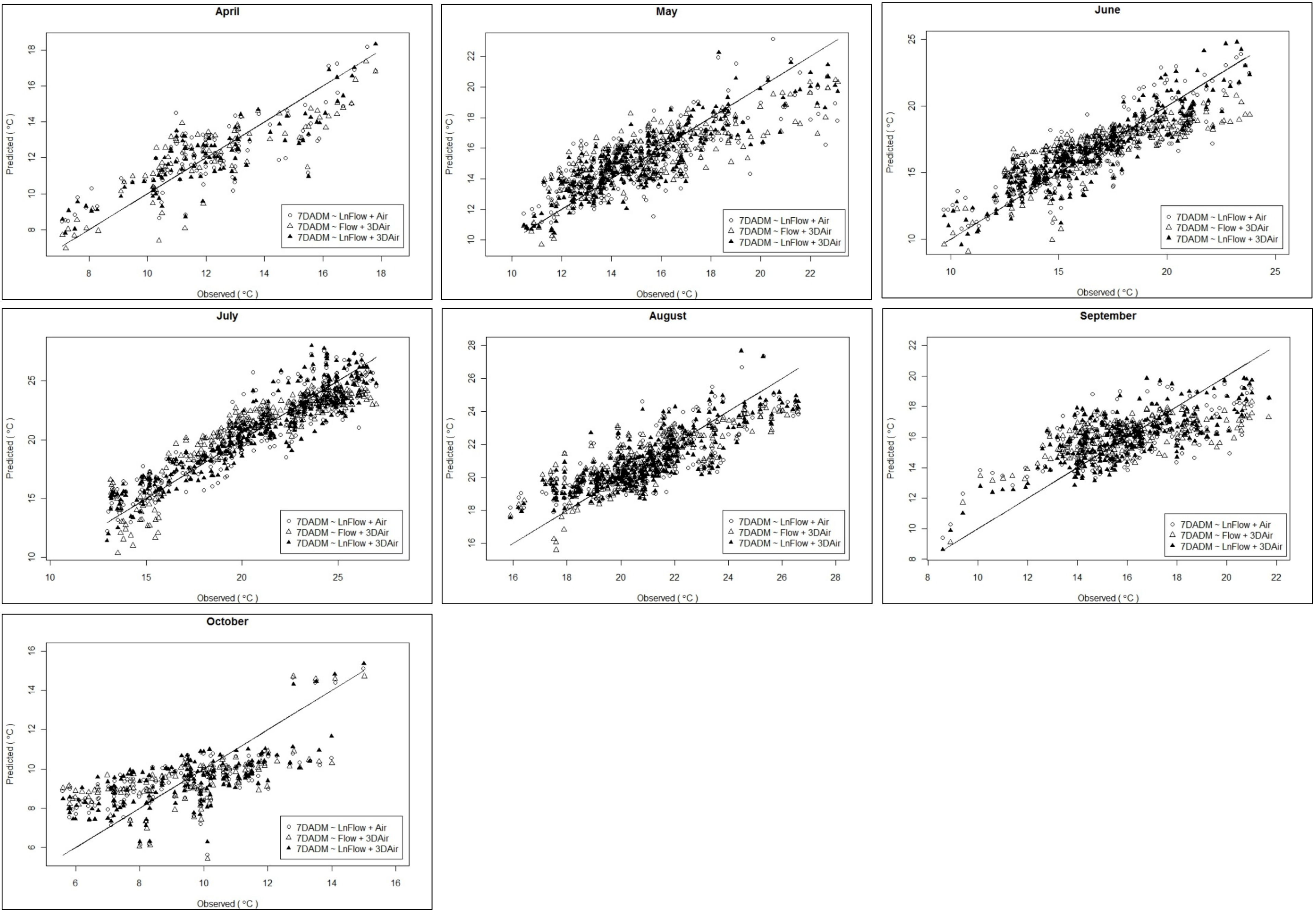
Month	Regression Model	Intercept	Coefficient 1	Coefficient 2	n	df	R^2	S	AIC value
October	7DADM ~ LnFlow + Air	14.6315	-1.22067[a]	0.11288[a]	147	144	0.50	1.41	105
	7DADM ~ Flow + 3DAir	8.3072238	-0.003907[a]	0.17246[a]	147	144	0.50	1.41	105
	7DADM ~ LnFlow + 3DAir	**13.18319**	**-1.09034[a]**	**0.15903[a]**	**147**	**144**	**0.55**	**1.34**	**89**
Tumalo Creek (TC 000.25)									
May	7DADM ~ Flow + Air	8.324927	-0.020283[a]	0.166781[a]	72	69	0.50	1.15	24
	7DADM ~ Flow + 3DAir	7.165902	-0.030271[a]	0.255928[a]	72	69	0.68	0.92	-8.6
	7DADM ~ LnFlow + 3DAir	**10.3834**	**-1.52[a]**	**0.2917[a]**	**72**	**69**	**0.69**	**0.92**	**-9.6**
June	7DADM ~ LnFlow + Air	14.64636	-1.86245[a]	0.21245[a]	220	217	0.65	1.43	162
	7DADM ~ Flow + 3DAir	8.638481	-0.028297[a]	0.247853[a]	220	217	0.64	1.47	172
	7DADM ~ LnFlow + 3DAir	**13.41274**	**-2.09556[a]**	**0.31332[a]**	**220**	**217**	**0.75**	**1.22**	**89**
July	7DADM ~ LnFlow + Air	19.44488	-2.75195[a]	0.20426[a]	272	269	0.86	1.12	64
	7DADM ~ Flow + 3DAir	9.486767	-0.066928[a]	0.33781[a]	272	269	0.81	1.29	141
	7DADM ~ LnFlow + 3DAir	**16.8591**	**-2.68413[a]**	**0.28708[a]**	**272**	**269**	**0.89**	**0.97**	**-13**
August	7DADM ~ LnFlow + Air	17.06358	-1.62144[a]	0.13219[a]	289	286	0.44	1.12	70
	7DADM ~ Flow + 3DAir	12.59033	-0.08657[a]	0.18733[a]	289	286	0.42	1.14	76
	7DADM ~ LnFlow + 3DAir	**15.384**	**-1.61564[a]**	**0.19114[a]**	**289**	**286**	**0.50**	**1.06**	**38**
September	**7DADM ~ Flow + 3DAir**	**7.668481**	**-0.027974[a]**	**0.213838[a]**	**260**	**257**	**0.47**	**1.29**	**134**
	7DADM ~ LnFlow + 3DAir	7.66283	-0.2724[a]	0.22536[a]	260	257	0.44	1.32	146
	7DADM ~ 3DAir	6.76425	0.23393[a]	--	260	257	0.44	1.32	147
October	7DADM ~ LnFlow + Air	8.5642	-0.684	0.2651[a]	81	79	0.05	5.83	288
	7DADM ~ Air	**6.1084**	**0.2555[a]**	**--**	**81**	**79**	**0.05**	**5.78**	**286**
	7DADM ~ 3DAir	5.2786	0.3065[a]	--	81	79	0.04	5.81	287

[a] Statistically significant at $\alpha \leq 0.05$

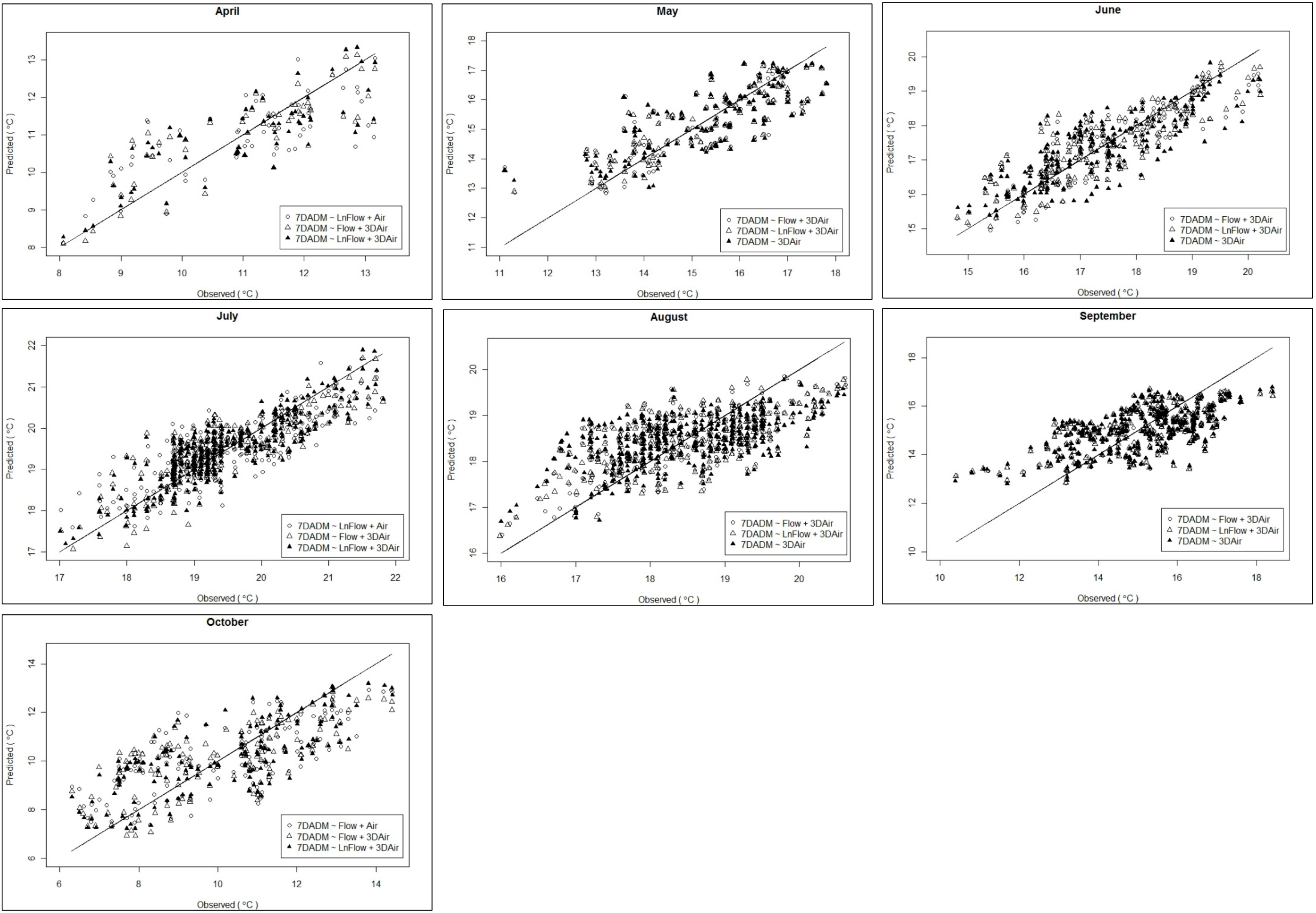
APPENDIX B

Figure 2. Predicted versus observed values for the three best regression models for: a. Whychus Creek (WC 006.00); b. the Middle Deschutes River (DR 160.25); and c. Tumalo Creek (TC 000.25)

a.

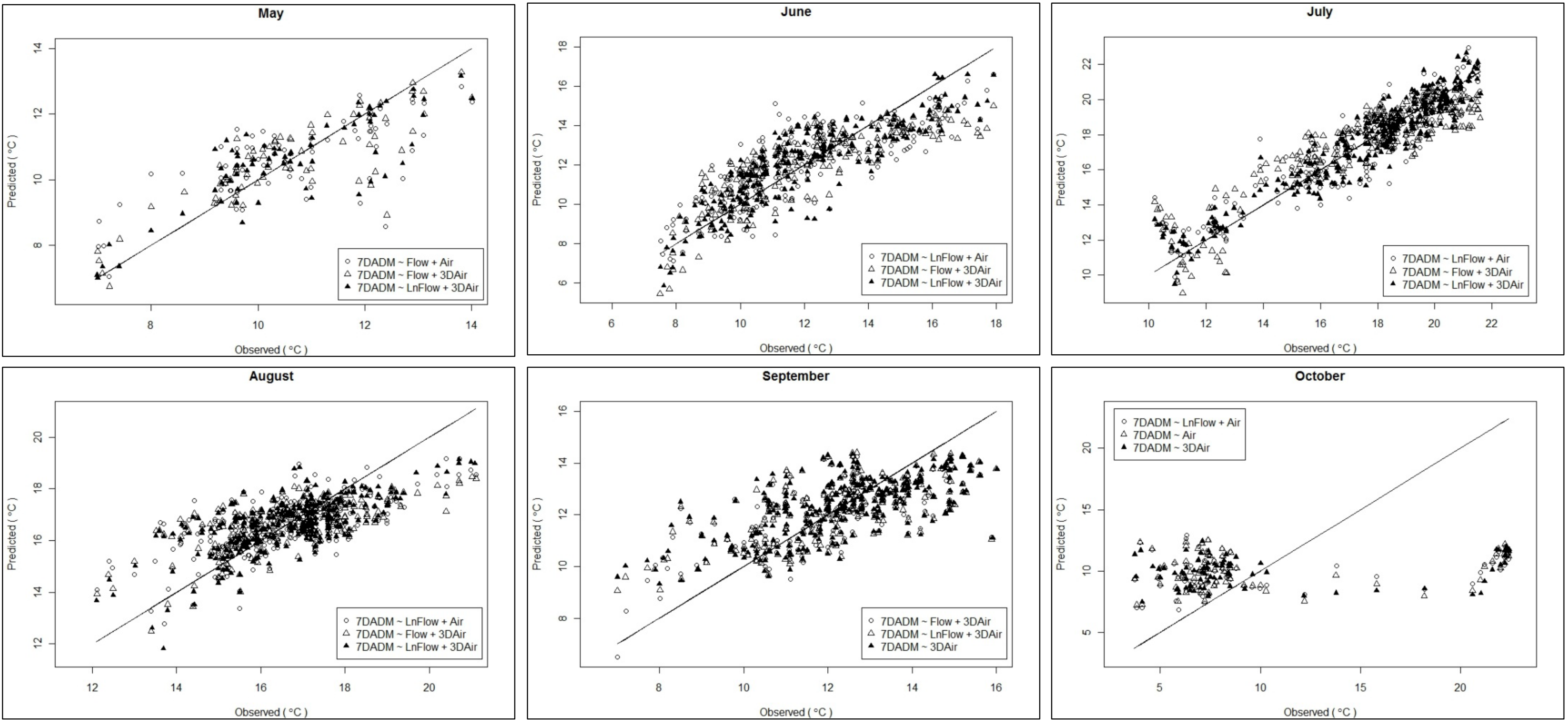

April
May
June
July
August
September
October
Predicted (°C)
Observed (°C)
7DADM ~ LnFlow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir

b.



April
Predicted (°C)
Observed (°C)
7DADM ~ LnFlow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
May
Predicted (°C)
Observed (°C)
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
7DADM ~ 3DAir
June
Predicted (°C)
Observed (°C)
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
7DADM ~ 3DAir
July
Predicted (°C)
Observed (°C)
7DADM ~ LnFlow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
August
Predicted (°C)
Observed (°C)
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
7DADM ~ 3DAir
September
Predicted (°C)
Observed (°C)
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
7DADM ~ 3DAir
October
Predicted (°C)
Observed (°C)
7DADM ~ Flow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir

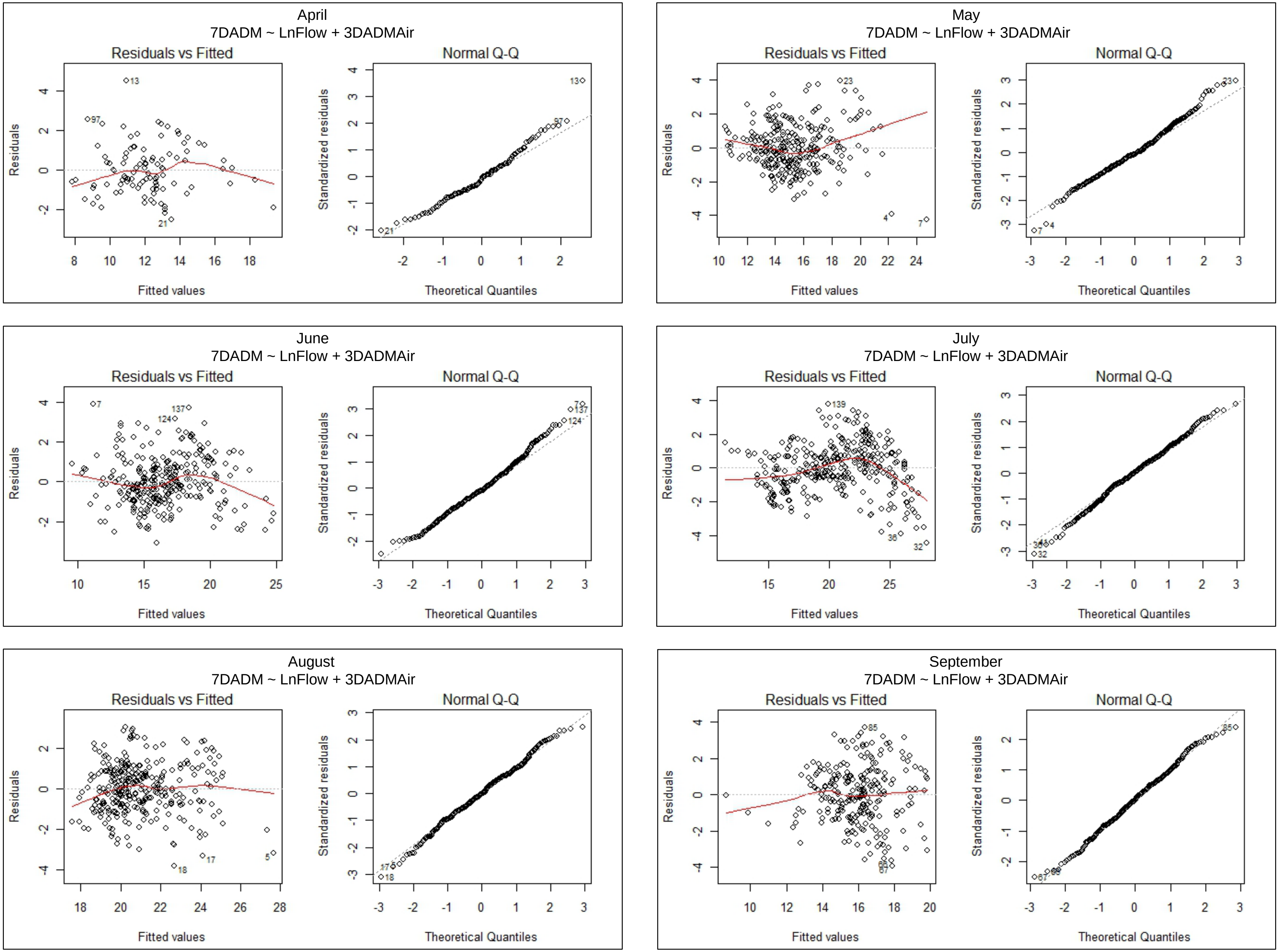
c.

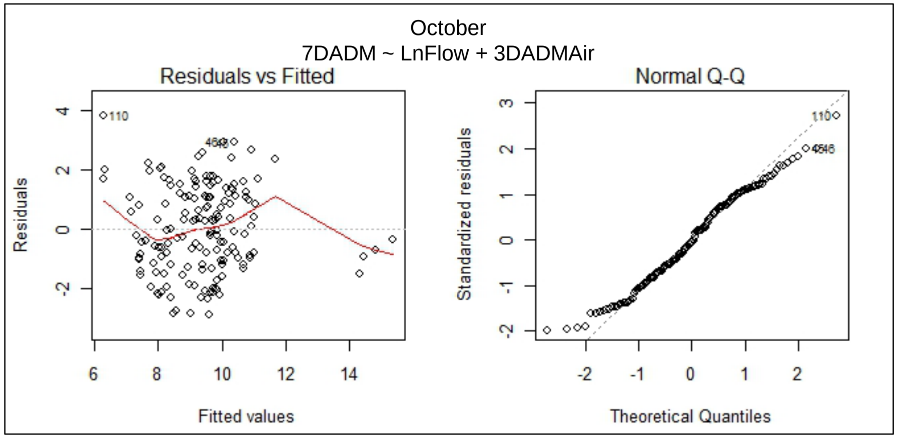

May
7DADM ~ Flow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
Predicted (°C)
Observed (°C)
June
7DADM ~ LnFlow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
Predicted (°C)
Observed (°C)
July
7DADM ~ LnFlow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
Predicted (°C)
Observed (°C)
August
7DADM ~ LnFlow + Air
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
Predicted (°C)
Observed (°C)
September
7DADM ~ Flow + 3DAir
7DADM ~ LnFlow + 3DAir
7DADM ~ 3DAir
Predicted (°C)
Observed (°C)
October
7DADM ~ LnFlow + Air
7DADM ~ Air
7DADM ~ 3DAir
Predicted (°C)
Observed (°C)

APPENDIX C

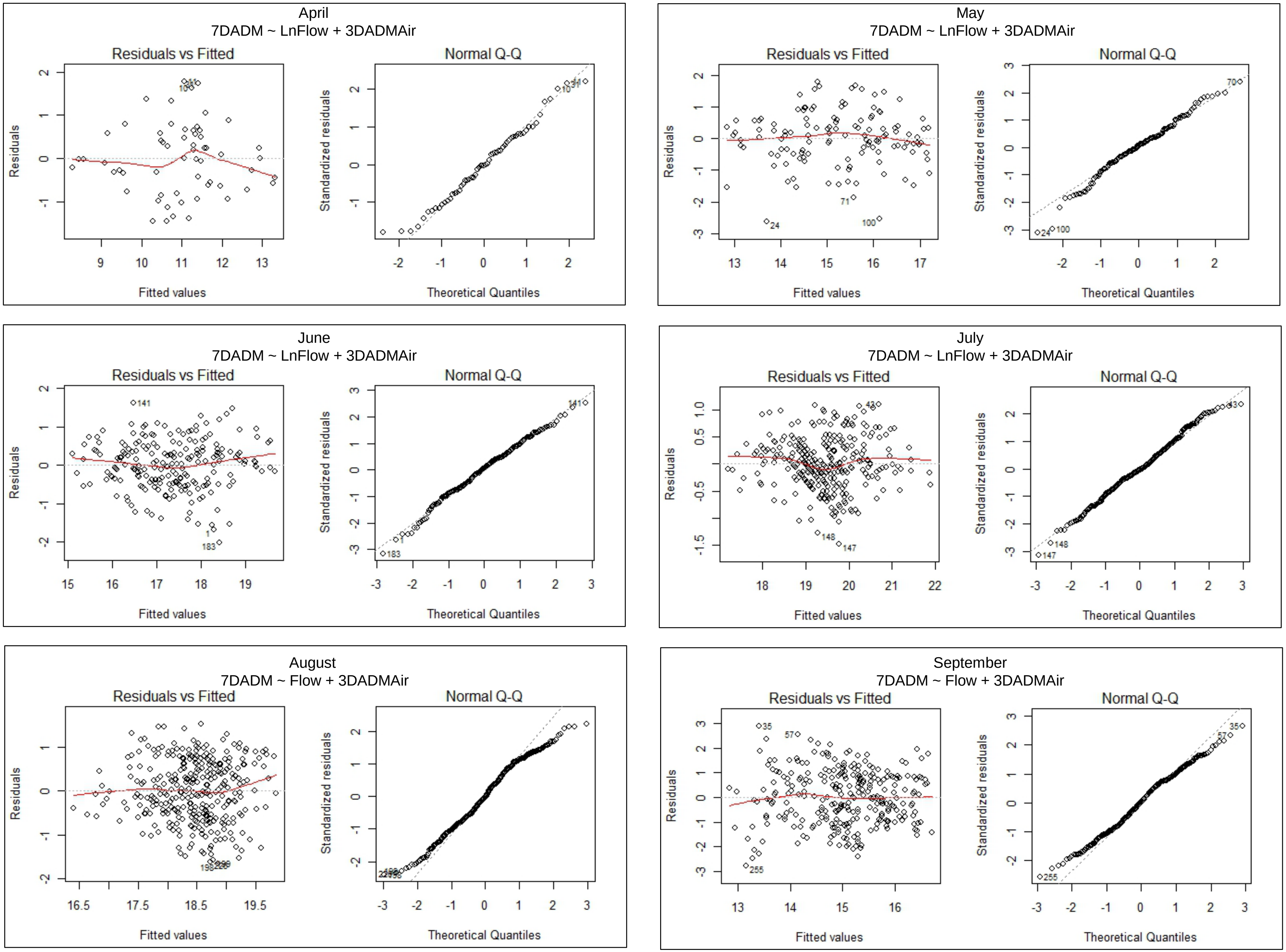
Figure 3. Residuals versus fitted values for the top regression model for each month for: a. Whychus Creek (WC 006.00); b. the Middle Deschutes River (DR 160.25); and c. Tumalo Creek (TC 000.25)

a.

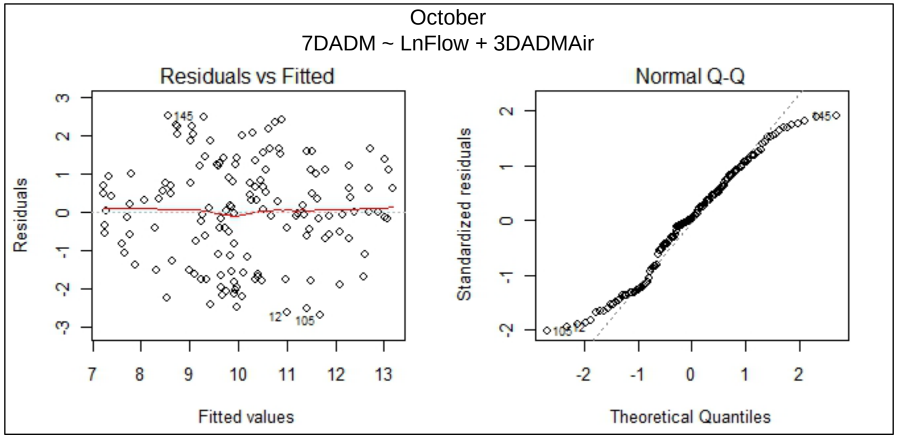

April
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
May
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
June
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
July
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
August
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
September
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles


October
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
110
Normal Q-Q
Standardized residuals
Theoretical Quantiles
110

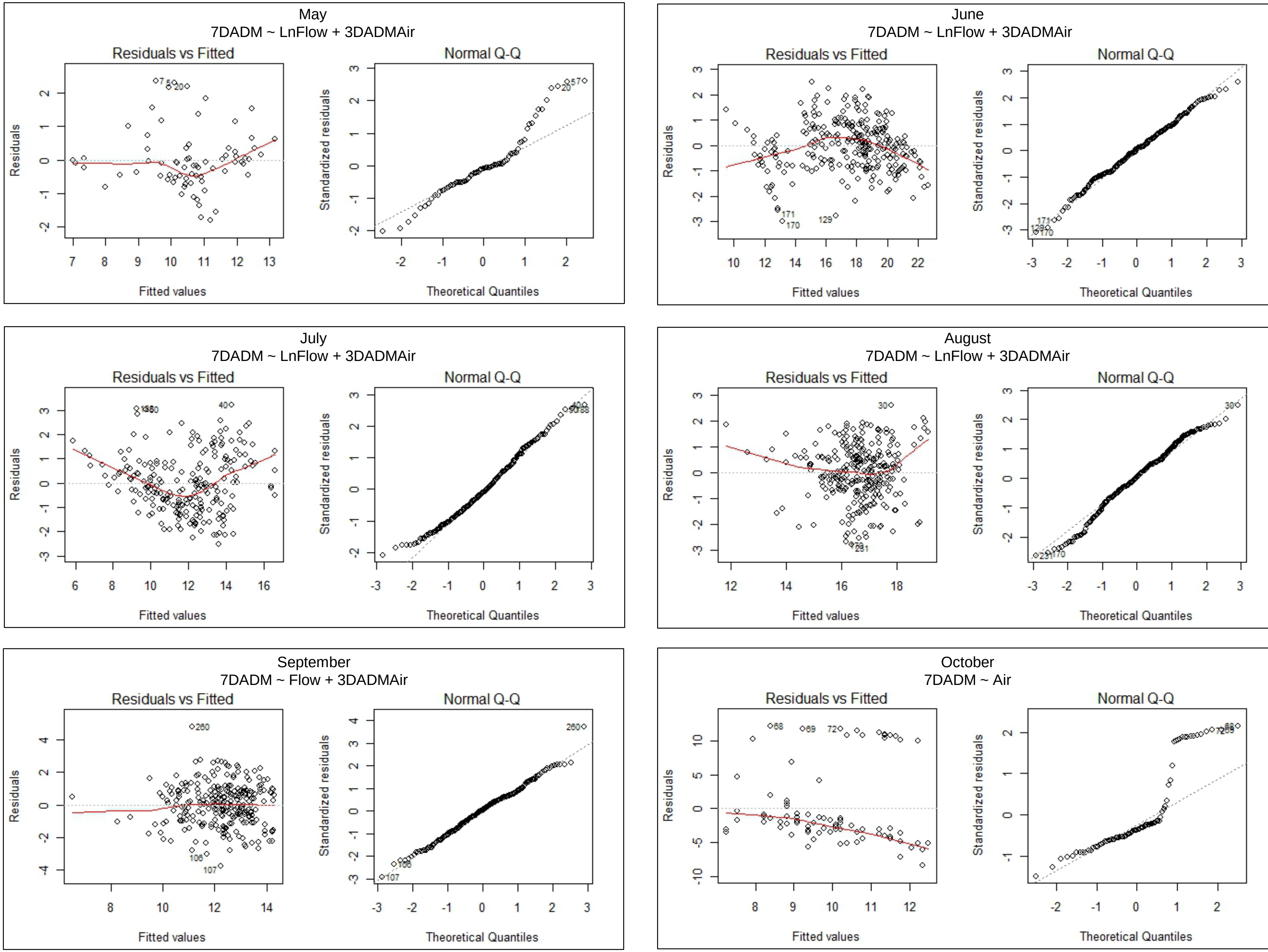
b.



April
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
May
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
June
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
July
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
August
7DADM ~ Flow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
September
7DADM ~ Flow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles


October
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles

c.


May
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Normal Q-Q
June
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Normal Q-Q
July
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Normal Q-Q
August
7DADM ~ LnFlow + 3DADMAir
Residuals vs Fitted
Normal Q-Q
September
7DADM ~ Flow + 3DADMAir
Residuals vs Fitted
Normal Q-Q
October
7DADM ~ Air
Residuals vs Fitted
Normal Q-Q
Residuals
Fitted values
Standardized residuals
Theoretical Quantiles