Tumalo Creek Instream Flow Study

Attachment B: PHABSIM Hydraulic Calibration Report

Models Used

The hydraulic models for the Tumalo Creek Instream flow study were calibrated by HDR Inc. using RHABSIM 3.0 (Riverine Habitat Simulation), a commercial software program written by Thomas R. Payne and Associates of Arcata, California. RHABSIM is a commercial version of the PHABSIM computer model (Milhous et al. 1984).

Water surface elevations were obtained at all transects during each field visit at the calibration flow levels (Table 1.1). Discharge measurements were made at appropriate transects or optimal discharge measuring locations in each transect cluster or study site during each field visit.

The City had anticipated collection of a high calibration flow greater than 100 cfs during a rain-on-snow event using continuous water level recorders (pressure transducers) installed at each transect. Pressure transducers were used because the unpredictable timing and very short duration of a possible rain-on-snow event would have likely precluded the deployment of a field crew. The pressure transducers were installed as described in the Study Plan. However, stream flow did not exceed approximately 80 cfs during the study period.

Modeling Methods

Water Surface Elevations

Hydraulic models were calibrated in the HYDSIM routine of RHABSIM 3.0. Hydraulic modeling procedures appropriate to the study site and level of data collection were used for modeling water surface elevations and velocities across each transect.

For transects where three water surface elevations were collected (Reach B), these procedures included the development of stage/discharge rating curves using log-log regression (IFG4) and Manning's formula (MANSQ). The most appropriate and accurate method was selected based on a direct comparison of results from each model with MANSQ set as the default modeling method. If individual transects did not calibrate sufficiently well using MANSQ, based on general guidelines of maximum Beta (0.5), and/or professional judgment, then log/log was chosen.

For transects where only two water surface elevations were collected (Sub-reaches A1RR, A1B, and A2), stage/discharge rating curves were developed and calibrated using MANSQ. While MANSQ was the primary modeling method, transects were also evaluated in IFG4 to ensure that the β coefficients were similar for each sub-reach modeled. The MANSQ modeling procedure uses a power function of the ratio of simulated discharge to observed discharge for adjusting channel conveyance at different discharges at each transect. When more than one discharge measurement was available for calibration, the exponent (β) was adjusted until good agreement of simulated versus observed water surface elevations was achieved for all discharges (T. Waddle et al 2000).

Stage/Discharge Modeling Guidelines

PHABSIM modeling guidelines considered for each study sub-reach were as follows:

- To determine whether the MANSQ model accurately predicts measured values, the second through fourth of the above criteria must be met, and the beta value parameter used by MANSQ must be within the range of 0.0 to 0.5. The first IFG4 criterion below is not applicable to MANSQ.
- To determine whether the IFG4 model accurately predicts measured values:
  1. The beta value (a measure of the change in channel roughness with changes in stream flow) must be between 2.0 and 4.5;
  2. The mean error in calculated versus given discharges must be less than 10%;
  3. There must be no more than a 25% difference for any calculated versus given discharge; and
  4. There must be no more than a 0.1-foot difference between measured and simulated WSELs.

Velocities

Velocity calibration in the hydraulic model utilized the "one-velocity set" method. This method uses measured velocities across a given transect and estimates a Manning's N value for each cell. Calibration techniques include adjustments to the Manning's N value to obtain accurate predictions of measured velocities as well as reasonable predictions of velocities at simulated flows. The purpose of the velocity calibration is to accurately simulate the measured velocities and water surface elevations at the observed flows while at the same time provide reasonable velocities and water surface elevations over the full range of simulated flows. Changes to velocities should be kept to a minimum and the input data decks revised only when specific changes improve model performance.

In general changes to Manning's N were made for four reasons:

1. Margin velocities measured are very low: Model keeps margin velocities very low thereby limiting the increase in velocity magnitude up the bank during upward simulation.
2. Top of rock conditions: When field measurements were made in very shallow conditions, the model applies a low roughness value thereby artificially allowing a disproportionate amount of flow through the cell at higher discharges.
3. Velocity spike: In certain situations, the model applies a low roughness value to high velocity measurements made in the field. The result, similar to the top of rock condition, is that the model unrealistically puts a disproportionate amount of flow through the cell at higher discharges.
4. Velocity trough: In certain cases, when very low velocities are measured in the field, the model applies a very high roughness value in order to match the flow at that station. The result is that the model unrealistically limits the flow through the cell at higher discharges.

Table 1.1 Discharge summary table for Tumalo Creek Instream flow study

River	Sub-Reach	Number of Transects	Transect Number	Mesohabitat Type	Discharge											
					Low - Low			Low			Mid			High		
					Target (cfs)	Measured (cfs)	Date	Target (cfs)	Measured (cfs)	Date	Target (cfs)	Measured (cfs)	Date	Target (cfs)	Measured (cfs)	Date
Tumalo Creek	A1-RR	8	1	Riffle	-	-	-	60	-	-	78.0	76.2	10/22/2011	100 - 250	-	-
			2	Pool	-	-	-	60	-	-	78.0	80.7	10/22/2011	100 - 250	-	-
			3	Riffle	-	-	-	60	66.6 / 66.9	10/17/2011	78.0	84.9	10/22/2011	100 - 250	-	-
			4	Riffle	-	-	-	60	-	-	78.0	79.3	10/22/2011	100 - 250	-	-
			5	Pool	-	-	-	60	-	-	78.0	75.8	10/22/2011	100 - 250	-	-
			6	Riffle	-	-	-	60	58.8	10/17/2011	78.0	75.8	10/22/2011	100 - 250	-	-
			7	Riffle	-	-	-	60	-	-	78.0	80.2	10/22/2011	100 - 250	-	-
			8	Pool	-	-	-	60	52.3	10/17/2011	78.0	72.8	10/22/2011	100 - 250	-	-
	A1-B	9	1	Riffle	-	-	-	60	66.9	10/18/2011	78.0	82.1	10/21/2011	100 - 250	-	-
			2	Riffle	-	-	-	60	-	-	78.0	74.8	10/21/2011	100 - 250	-	-
			3	Pool	-	-	-	60	-	-	78.0	84.3	10/21/2011	100 - 250	-	-
			4	Rapid	-	-	-	60	-	-	78.0	81.3	10/21/2011	100 - 250	-	-
			5	Rapid	-	-	-	60	64.8	10/18/2011	78.0	81.1	10/21/2011	100 - 250	-	-
			6	Riffle	-	-	-	60	-	-	78.0	73.6	10/21/2011	100 - 250	-	-
			7	Pool	-	-	-	60	-	-	78.0	81.1	10/21/2011	100 - 250	-	-
			8	Pool	-	-	-	60	-	-	78.0	77.4	10/21/2011	100 - 250	-	-
			9	Rapid	-	-	-	60	57.4	10/18/2011	78.0	80.6	10/21/2011	100 - 250	-	-
	A2	6	1	Riffle	-	-	-	69	-	-	78.0	76.9	10/21/2011	100 - 250	-	-
			2	Pool	-	-	-	69	-	-	78.0	72.8	10/21/2011	100 - 250	-	-
			3	Riffle	-	-	-	69	72.1	10/18/2011	78.0	78.5	10/21/2011	100 - 250	-	-
			4	Riffle	-	-	-	69	-	-	78.0	77.0	10/21/2011	100 - 250	-	-
			5	Riffle	-	-	-	69	71.8	10/18/2011	78.0	79.5	10/21/2011	100 - 250	-	-
			6	Pool	-	-	-	69	-	-	78.0	78.6	10/21/2011	100 - 250	-	-
	B	8	1	Pool	10 to 15	-	-	60	-	-	78.0	81.0	10/23/2011	100 - 250	-	-
			2	Riffle	10 to 15	-	-	60	-	-	78.0	78.4	10/23/2011	100 - 250	-	-
			3	Riffle	10 to 15	-	-	60	-	-	78.0	80.6	10/23/2011	100 - 250	-	-
			4	Riffle	10 to 15	-	-	60	-	-	78.0	77.6	10/23/2011	100 - 250	-	-
			Q	Run	10 to 15	23.9	11/16/2011	60	64.0	10/19/2011	78.0	-	10/23/2011	100 - 250	-	-
			5	Riffle	10 to 15	-	-	60	-	-	78.0	72.0	10/23/2011	100 - 250	-	-
			6	Glide	10 to 15	-	-	60	-	-	78.0	76.7	10/23/2011	100 - 250	-	-
			7	Riffle	10 to 15	-	-	60	-	-	78.0	80.4	10/23/2011	100 - 250	-	-
			8	Pool	10 to 15	-	-	60	-	-	78.0	80.5	10/23/2011	100 - 250	-	-

This Page Left Blank

Modeling Summaries

Sub-Reach A1-RR

Table A-1 in Appendix A below provides a summary of the calibration details for the hydraulic modeling in sub-reach A1-RR.

Water Surface Elevations

- All transects in the study site were calibrated using both IFG4 and MANSQ.
- Water surface elevations were selected within the range of collected data only.
- MANSQ was selected as the preferred calibration method for all transects
- Cross-sectional geometry and a realistic rating curve fit were compared when evaluating the results of the MANSQ method.
- All Log/Log beta values were between 2.0 and 4.5.
- Because only two calibration points were used, all Log/Log mean errors were less than 1%
- All transect MANSQ betas were within the range of 0.0 to 5.0
- All MANSQ mean errors were less than 1%.
- All calculated discharges were within 5% of given discharges.

Velocity Calibration Summary

Listed below are transect-by-transect velocity calibration descriptions for each transect in sub-reach A1-RR.

- No changes were made to velocities on Transect T07.
- T01: Stations 123.5, 126.7, 129.0 and 152.7: Manning's N was increased to limit velocity spikes during simulation.
- T02: Stations 156.0 and 156.5: Manning's N was decreased to allow water velocities to increase on margin during upward simulation. Stations 183.0 and 184.0 Manning's N was increased to limit magnitude of negative velocity during simulation.
- T03: Stations 75.0 and 76.0: Manning's N was decreased to allow water velocities to increase around boulder during upward simulation.
- T04: Station 139.0: Manning's N was decreased to allow water velocities to increase on margin during upward simulation. Station 156.0: Manning's N was increased to restrict velocity spike during upward simulation.
- T05: Stations 50.5 to 53.0: Manning's N was decreased to allow water velocities to increase on margin during upward simulation.
- T06: Stations 41.6 and 41.9: Manning's N was decreased to allow water velocities to increase on margin during upward simulation.

- T08: Stations 315.60 and 316.2: Manning's N was decreased to allow water velocities to increase on margin during upward simulation. Stations 318.0 and 318.5: Manning's N was decreased to allow water velocities to increase during upward simulation. Stations 319.0 to 320.0 and 321.0 and 330.0: Increased Manning's N to restrict shallow water velocity spikes during upward simulation. Station 323.0 reduced Manning's N to allow water velocity to increase during upward simulation. Stations 337.8 to 341.0 reduced Manning's N to allow water velocity to increase on margin during upward simulation.

Sub-Reach A1-B

Table A-2 in Appendix A below provides a summary of the calibration details for the hydraulic modeling in sub-reach A1-B.

Water Surface Elevations

- All transects in the study site were calibrated using both IFG4 and MANSQ.
- Water surface elevations were selected within the range of collected data only.
- MANSQ was selected as the preferred calibration method for all transects
- Cross-sectional geometry and a realistic rating curve fit were compared when evaluating the results of the MANSQ method.
- All Log/Log beta values were between 2.0 and 4.5.
- Because only two calibration points were used, all Log/Log mean errors were less than 1%
- All transect MANSQ betas were within the range of 0.0 to 5.0
- All MANSQ mean errors were less than 1%.
- All predicted discharges were within 10% of given discharges.

Velocity Calibration Summary

Listed below are transect-by-transect velocity calibration descriptions for each transect in sub-reach A1-B.

- No changes were made to velocities on Transects T02 and T04.
- T01: Station 24.0: Manning's N was increased to limit velocity spike during upward simulation.
- T03: Stations 23.5 and 24.0 Manning's N was increased to limit velocity spike during upward simulation. Station 28.0: Manning's N was decreased to allow velocities to increase during upward simulation. Right bank stations 35.5 and 36.1: Increased Manning's N to reduce shallow margin velocities from becoming unrealistic, distributed flow to rest of transect.
- T05: Stations13.5 and 13.8: Increased Manning's N to limit velocity spikes during upward simulation.

- T06: Stations 13.6 and 14.0 and 53.6: Decreased Manning's N to allow flow up margins during upward simulation.
- T07: Stations 19.5 and 31.5: Increased Manning's N to limit shallow water velocity spikes during upward simulation. Stations 50.0 and 50.6: increased N to reduce magnitude of negative margin velocities.
- T08: Stations 23.0 to 27.0: Increased Manning's N to limit velocities during upward simulation. Flow pattern became disproportionately skewed to the LB.
- T09: Stations 20.8 and 21.9: Increased Manning's N to reduce velocity spikes. Station 36.9: Increased N to reduce margin velocity spike.

Sub-Reach A2

Table A-3 in Appendix A below provides a summary of the calibration details for the hydraulic modeling in sub-reach A2.

Water Surface Elevations

- All transects in the study site were calibrated using both IFG4 and MANSQ.
- Water surface elevations were selected within the range of collected data only.
- MANSQ was selected as the preferred calibration method for all transects
- Cross-sectional geometry and a realistic rating curve fit were compared when evaluating the results of the MANSQ method.
- All Log/Log beta values were between 2.0 and 4.5.
- Because only two calibration points were used, all Log/Log mean errors were less than 1%
- All transect MANSQ betas were within the range of 0.0 to 5.0 except T03 and T05 which were -0.1611 and -0.1458 respectively. Negative beta values are not considered to be indicative of a modeling problem, but rather a function of a channel roughness that increases with discharge rather than decreasing as is typically observed.
- All MANSQ mean errors were less than 1%.
- All calculated discharges were within 10% of given discharges.

Velocity Calibration Summary

Listed below are transect-by-transect velocity calibration descriptions for each transect in sub-reach A2.

- No changes were made to velocities on Transects T01, T04 and T06
- T02: Stations 17.5, 26.5, 28.2, 28.6, 50.5 and 50.8: Reduced Manning's N to allow velocity to increase at stations where measured velocities were very low.
- T03: Stations 38.8 and 39.6: Increased Manning's N to restrict flow through stations during upward simulation.
- T05: Stations 45.8 and 46.6: Reduced Manning's N to allow velocity to increase at stations where measured velocities were low compared to neighboring cells.

Reach B

Table A-4 in Appendix A below provides a summary of the calibration details for the hydraulic modeling in Reach B.

Water Surface Elevations

- All transects in the study site were calibrated using both IFG4 and MANSQ.
- Water surface elevations were selected within the range of collected data only.
- MANSQ was selected as the preferred calibration method for T01, T04, T06, T07 and T08.
- LOG/LOG was selected as the preferred calibration method for T02, T03 and T05.
- Cross-sectional geometry and a realistic rating curve fit were compared when evaluating the results of the MANSQ method and IFG4 method.
- All Log/Log beta values were between 2.0 and 4.5.
- All Log/Log mean errors were less than 5%
- All transect MANSQ betas were within the range of 0.0 to 5.0
- All MANSQ mean errors were less than 1%.
- All calculated discharges were within 5% of given discharges.

Velocity Calibration Summary

Listed below are transect-by-transect velocity calibration descriptions for each transect in Reach B.

- No changes were made to velocities on Transects T01, T03, T05, T06 and T08.
- T02: Station 40.5: Manning's N was decreased to increase margin velocities during simulation.
- T04: Station 41.1: Manning's N was decreased to increase margin velocities during simulation.
- T07: Station 13.8 and 28.0: Increased Manning's N to reduce velocity spikes during simulation.

References

Milhous, R. T., D. L. Wegner, and T. Waddle. 1984. User's Guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Information Paper No. 11. U.S. Fish and Wildlife Service. FWS/OBS-81/43.

Milhous, R. T., M. A. Updike, and D. M. Schneider. 1989. PHABSIM Reference Manual Version II, Instream Flow Information Paper No. 26. U.S. Fish and Wildlife Service Biological Report 89(16).

Waddle, T. J. (ed.) 2001. PHABSIM for Windows: User's Manual and Exercises. U.S. Geological Survey Open-File Report 2001-340.

APPENDIX A
Summary of Calibration Details

Table A-1. Summary of Calibration Details – Tumalo Creek – Reach A – Sub-reach A1-RR

Summary of Calibration Details - Tumalo Creek Reach A1-RR								
Trans #:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Habtype:	**Riffle**	**Pool**	**Riffle**	**Riffle**	**Pool**	**Riffle**	**Riffle**	**Pool**
Measured Discharge (cfs)								
Low:								
High:	76.20	80.72	84.88	79.28	75.77	75.78	80.16	72.77
Given Discharge (cfs)								
Low:	66.72	66.72	66.72	55.60	55.60	55.60	55.60	55.60
High:	80.60	80.60	80.60	76.75	76.75	76.75	76.75	76.75
Predicted (cfs)								
Low:								
High:	79.00	78.17	85.27	76.65	75.74	78.51	83.59	71.77
Stage (given)(ft.)								
Low:	87.45	88.51	95.99	88.18	94.45	96.19	95.50	93.86
High:	87.56	88.66	96.05	88.33	94.61	96.35	95.67	94.07
Plotting Stage (stage - szf)(ft.)								
Low:	1.89	1.56	1.14	1.25	1.27	1.28	1.29	1.72
High:	2.00	1.71	1.20	1.40	1.43	1.44	1.46	1.93
Ratio of Measured vs Given Discharge								
Low:								
High:	0.9455	1.0015	1.0531	1.0329	0.9872	0.9873	1.0444	0.9482
Percent Mean Error of Stage/Discharge Relationship								
Log/Log	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MANSQ	0.2363	0.3080	0.1192	0.1958	0.1539	0.1811	0.3403	0.2899
MANSQ BETA	0.1924	0.3193	0.3544	0.0789	0.5519	0.1474	0.0050	0.2573
Stage at Zero Flow (ft.)								
	85.56	86.95	94.85	86.93	93.18	94.91	94.21	92.14
Stage/Discharge Relationship: Discharge = A*(Stage - SZF)^B								
A=	7.9540	26.7106	41.1723	29.4721	29.0449	28.2903	28.6475	12.1887
B=	3.3410	2.0586	3.6843	2.8445	2.7168	2.7371	2.6041	2.7985
Stage/Discharge Relationship: Stage = A*(Q^B)+SZF								
A=	0.53759	0.20275	0.36455	0.3044	0.2894	0.2949	0.2757	0.4092
B=	0.29931	0.48576	0.27143	0.3516	0.3681	0.3654	0.3840	0.3573
Modeling Method Chosen								
Method:	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ

Table A-2. Summary of Calibration Details – Tumalo Creek – Reach A – Sub-reach A1-B

Summary of Calibration Details - Tumalo Creek Reach A1-RB									
Trans #:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Habtype:	**Riffle**	**Riffle**	**Pool**	**Rapid**	**Rapid**	**Riffle**	**Pool**	**Pool**	**Rapid**
Measured Discharge (cfs)									
Low:									
High:	82.14	74.85	84.34	81.27	81.09	73.57	81.06	77.43	80.63
Given Discharge (cfs)									
Low:	65.80	65.80	65.80	65.80	65.80	65.80	65.80	65.80	65.80
High:	79.60	79.60	79.60	79.60	79.60	79.60	79.60	79.60	79.60
Predicted (cfs)									
Low:									
High:	81.52	75.46	80.71	80.51	81.33	79.73	79.91	88.18	80.50
Stage (given)(ft.)									
Low:	96.80	96.11	92.89	93.78	91.37	91.07	94.87	91.74	93.75
High:	96.91	96.24	93.02	93.92	91.51	91.17	94.95	91.87	93.88
Plotting Stage (stage - szf)(ft.)									
Low:	1.30	1.70	1.42	1.86	1.87	1.67	1.27	2.02	1.77
High:	1.41	1.83	1.55	2.00	2.01	1.77	1.35	2.15	1.90
Ratio of Measured vs Given Discharge									
Low:									
High:	1.0319	0.9403	1.0595	1.0210	1.0187	0.9242	1.0183	0.9727	1.013
Percent Mean Error of Stage/Discharge Relationship									
Log/Log	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MANSQ	0.2836	0.3082	0.3509	0.3260	0.3354	0.1674	0.1359	0.2706	0.3200
MANSQ BETA	0.0145	0.0795	0.1018	0.0824	0.0360	0.0200	0.4115	0.4094	0.0085
Stage at Zero Flow (ft.)									
	95.50	94.41	91.47	91.92	89.50	89.40	93.60	89.72	91.98
Stage/Discharge Relationship: Discharge = A*(Stage - SZF)^B									
A=	35.5747	16.7023	30.7064	12.9163	12.6284	12.2763	31.2370	7.6932	14.1924
B=	2.3440	2.5839	2.1735	2.6236	2.6371	3.2739	3.1170	3.0526	2.6865
Stage/Discharge Relationship: Stage = A*(Q^B)+SZF									
A=	0.21790	0.33633	0.20689	0.3771	0.3823	0.4649	0.3315	0.5125	0.3725
B=	0.42662	0.38702	0.46009	0.3812	0.3792	0.3054	0.3208	0.3276	0.3722
Modeling Method Chosen									
Method:	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ

Table A-3. Summary of Calibration Details – Tumalo Creek – Reach A – Sub-reach A2

Summary of Calibration Details - Tumalo Creek Reach A2						
Trans #:	**1**	**2**	**3**	**4**	**5**	**6**
Habtype:	**Riffle**	**Pool**	**Riffle**	**Riffle**	**Riffle**	**Pool**
Measured Discharge (cfs)						
Low:						
High:	76.90	72.76	78.48	77.00	79.49	78.61
Given Discharge (cfs)						
Low:	71.93	71.93	71.93	71.93	71.93	71.93
High:	78.10	78.10	78.10	78.10	78.10	78.10
Predicted (cfs)						
Low:						
High:	75.36	72.28	76.80	73.58	76.84	78.07
Stage (given)(ft.)						
Low:	96.32	93.57	94.65	94.57	95.92	95.05
High:	96.37	93.62	94.70	94.61	95.97	95.11
Plotting Stage (stage - szf)(ft.)						
Low:	1.79	1.39	1.48	1.19	1.39	1.58
High:	1.84	1.44	1.53	1.23	1.44	1.64
Ratio of Measured vs Given Discharge						
Low:						
High:	0.9846	0.9316	1.0049	0.9859	1.0178	1.0065
Percent Mean Error of Stage/Discharge Relationship						
Log/Log	0.001	0.001	0.000	0.000	0.001	0.000
MANSQ	0.2593	0.2845	0.2458	0.1762	0.2894	0.3406
MANSQ BETA	0.0749	0.1551	-0.1611	0.0652	-0.1458	0.3127
Stage at Zero Flow (ft.)						
	94.53	92.18	93.17	93.38	94.53	93.47
Stage/Discharge Relationship: Discharge = A*(Stage - SZF)^B						
A=	12.6396	33.4140	27.2352	46.6508	33.4140	26.1987
B=	2.9866	2.3283	2.4772	2.4892	2.3283	2.2080
Stage/Discharge Relationship: Stage = A*(Q^B)+SZF						
A=	0.42767	0.22156	0.26343	0.2136	0.2216	0.2279
B=	0.33483	0.42949	0.40368	0.4017	0.4295	0.4529
Modeling Method Chosen						
Method:	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ	MANSQ

Table A-4. Summary of Calibration Details – Tumalo Creek – Reach B

Summary of Calibration Details - Tumalo Creek Reach B								
Trans #:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Habtype:	**Pool**	**Riffle**	**Riffle**	**Riffle**	**Riffle**	**Glide**	**Riffle**	**Pool**
Measured Discharge (cfs)								
Low:								
Mid:								
High:	80.98	78.42	80.59	77.58	71.96	76.69	80.42	80.47
Given Discharge (cfs)								
Low:								
Mid:								
High:	81.88	78.91	82.82	78.26	71.82	77.38	80.46	78.56
Predicted (cfs)								
Low:	23.85	23.85	23.85	23.85	23.85	23.85	23.85	23.85
Mid:	63.90	63.90	63.90	63.90	63.90	63.90	63.90	63.90
High:	78.39	78.39	78.39	78.39	78.39	78.39	78.39	78.39
Stage (given)(ft.)								
Low:	91.97	93.60	94.87	96.20	94.87	93.85	91.34	93.17
Mid:	92.55	94.15	95.34	96.68	95.23	94.36	91.83	93.64
High:	92.70	94.28	95.44	96.80	95.32	94.47	91.94	93.76
Plotting Stage (stage - szf)(ft.)								
Low:	1.57	1.52	1.56	1.39	1.23	1.28	1.40	1.17
Mid:	2.15	2.07	2.03	1.87	1.59	1.79	1.89	1.64
High:	2.30	2.20	2.13	1.99	1.68	1.90	2.00	1.76
Ratio of Measured vs Given Discharge								
Low:								
Mid:								
High:	0.9890	0.9938	0.9731	0.991	1.002	0.991	1.000	1.024
Percent Mean Error of Stage/Discharge Relationship								
Log/Log	3.122	3.209	3.794	3.318	3.824	2.987	3.319	2.916
MANSQ	0.2160	0.5580	0.5873	0.2034	0.1272	0.7995	0.5699	0.1285
MANSQ BETA	0.3149	0.2726	0.2486	0.3252	0.2777	0.2444	0.2504	0.3090
Stage at Zero Flow (ft.)								
	90.40	92.08	93.31	94.81	93.64	92.57	89.94	92.00
Stage/Discharge Relationship: Discharge = A*(Stage - SZF)^B								
A=	5.8363	6.2164	4.4045	7.9992	10.8140	11.3836	7.7966	15.0923
B=	3.1221	3.2094	3.7944	3.3180	3.8235	2.9874	3.3188	2.9155
Stage/Discharge Relationship: Stage = A*(Q^B)+SZF								
A=	0.56834	0.56590	0.67655	0.5344	0.5365	0.4430	0.5386	0.3942
B=	0.32030	0.31159	0.26355	0.3014	0.2615	0.3347	0.3013	0.3430
Modeling Method Chosen								
Method:	MANSQ	Log/Log	Log/Log	MANSQ	Log/Log	MANSQ	MANSQ	MANSQ