

APPENDIX C

Model Calibration Statistics

Appendix C. Model Calibration Statistics

Appendix C presents an analysis of the model simulated head residuals for the TAMA groundwater flow model. Assigning weights to observed head data used to calibrate the TAMA groundwater flow model is based on the method suggested by Hill (1998). In Guideline 6 (page 45), Hill suggests using the variance of the measurement error of the observed heads (water level elevations) as the basis for assigning weighting values. The observed water level elevations used in the model calibration come from the ADWR GroundWater Site Inventory (GWSI) database and are determined by subtracting a depth to water measurement from a well site elevation. Since most well site elevations in the GWSI are determined from U.S. Geological Survey (USGS) contour maps, the USGS vertical accuracy standards for contour maps can be used to estimate the variance of measurement error for well site elevation and, by extension, measurement errors for GWSI water level elevations.

The USGS accuracy standard states that 90% of sampled points on contour maps must be within plus or minus one-half of the maps contour interval (U.S. Geological Survey, 1980). The USGS accuracy standard is used when assigning the altitude accuracy of well sites in the GWSI and is one-half the contour interval of the map used to determine the site elevation. The altitude accuracy standard establishes a 90% confidence interval that well site elevations are plus or minus one-half a maps contour interval, or the assigned altitude accuracy in the GWSI. Assuming a normal distribution, a 90% confidence interval is constructed by adding plus or minus 1.65 times the standard deviation of the measurement error. The 1.65 can be looked up in any table that lists cumulative probabilities for the standardized normal distribution.

Substituting the altitude accuracy from the GWSI for the USGS accuracy standard in the formula from Hill (p.46,) for calculating the estimated standard deviation of the measurement error yields the following formula:

$$SD = \text{GWSI Altitude Accuracy}/1.65$$

where: SD = estimated standard deviation

An example using an altitude accuracy of 10 feet (map contour interval equal to 20 feet) is presented below and yields an estimated standard deviation for the well site measurement error of ± 6.06 feet, which is also the measurement error for a GWSI water level from the site.

$$SD = 10 \text{ feet}/1.65$$

$$SD = 6.06 \text{ feet}$$

The MODFLOW-NWT HOB package doesn't assign weighting factors; however, it does calculate an unweighted head residuals. The unweighted head residuals were multiplied by the weighting factors presented in Table 1 based on the site altitude accuracy data from the GWSI database.

Table 1. Weighting factors for observed water levels as determined from site altitude accuracy values in the GWSI database.

GWSI Altitude Accuracy (Ft)	Estimated Standard Deviation	Calculated Weighting Factor (1/SD)	Assigned Weighting Factor
0.1	0.06	16.5	1.0
0.2	0.12	8.250	0.990
0.5	0.30	3.300	0.952
1.0	0.61	1.650	0.909
2.0	1.21	0.825	0.825
2.5	1.52	0.660	0.660
5.0	3.03	0.330	0.330
10.0	6.06	0.165	0.165
15.0	9.09	0.110	0.110
20.0	12.12	0.083	0.083
25.0	15.15	0.066	0.066
40.0	24.24	0.041	0.041
50.0	30.30	0.033	0.033

In Table 1 altitude accuracies of one foot or less have had their elevations determined by land surveys. These well sites have very small altitude accuracies and, therefore, corresponding small elevation measurement errors. As a result, the estimated standard deviations are less than one and the weights, as calculated by MODFLOW-2000, are greater than one. These altitude accuracy values were assigned weighting factors between 0.909 and 1.0, with 1.0 being assigned to wells with the smallest elevation measurement errors (smallest altitude accuracy of 0.1 feet). See Mason and Bota (2006) Chapter 5, Hill (1998), and Hill and others (2000) for a detailed discussion of how the HOB package works and issues relating to weighting of observed data, and Anderson and Woessner for a discussion of model calibration criteria.

Appendix C. Model Calibration Statistics

Table C-1. Final model simulated head residual statistics: 1940 – 2010.

Tucson Model 1940-2010 Statistics																
(units – feet)																
Year		Unweighted Residuals						Weighted Residuals						Residual Counts		
		Mean	ABS Mean	SD	Max	Min	RMSE Ratio	Mean	ABS Mean	SD	Max	Min	RMSE Ratio	Totals	>=0	<0
1940	Model-Wide	-0.1	11.6	17.3	51	-101	1.25	-0.1	4.6	9.9	34	-96	0.72	237	128	109
	USC Sub-Basin	-1.4	11.7	18.1	51	-101	1.64	-0.9	3.7	9.4	34	-96	0.85	185	91	94
	Avra Valley Sub-Basin	4.2	11.3	13.3	34	-35	1.45	2.4	7.7	11.3	34	-35	1.23	52	37	15
1945	Model-Wide	3.3	9.7	13	40	-42	0.94	1.6	4.8	8.4	40	-40	0.6	169	107	62
	USC Sub-Basin	2.3	9.5	13.7	40	-42	1.24	0.8	3.9	7.9	40	-40	0.71	129	75	54
	Avra Valley Sub-Basin	6.6	10.4	10	19	-28	1.1	4.2	7.8	9.4	18	-28	1.02	40	32	8
1950	Model-Wide	5.6	10.8	13.5	80	-52	0.97	2.8	5.6	9	76	-39	0.65	301	222	79
	USC Sub-Basin	3.9	10.4	14.2	80	-52	1.29	1.2	4.5	8.3	76	-39	0.75	217	147	70
	Avra Valley Sub-Basin	10.2	11.9	10.4	39	-28	1.13	6.9	8.6	9.5	37	-28	1.03	84	75	9
1955	Model-Wide	6.5	12.5	14.9	54	-62	1.07	3.7	6.5	9.4	40	-51	0.68	379	275	104
	USC Sub-Basin	3.8	10.9	14.4	50	-62	1.3	1.8	4.6	7.4	28	-51	0.67	279	188	91
	Avra Valley Sub-Basin	14.2	16.9	13.4	54	-22	1.47	9.1	11.7	12.1	40	-22	1.32	100	87	13
1960	Model-Wide	6.2	11.7	13.5	52	-35	0.97	4.4	7.3	9.9	41	-28	0.71	377	251	126
	USC Sub-Basin	4.2	10.3	12.7	52	-35	1.15	3.1	5.9	8.5	34	-24	0.77	295	182	113
	Avra Valley Sub-Basin	13.4	16.6	14.1	44	-28	1.54	9.2	12.3	12.8	41	-28	1.39	82	69	13
1965	Model-Wide	3.4	15.3	20.2	72	-129	1.45	2	8	12.9	72	-73	0.93	573	334	239
	USC Sub-Basin	2.5	14.7	19.8	72	-129	1.79	1.6	6.9	11.7	72	-49	1.06	424	242	182
	Avra Valley Sub-Basin	5.7	16.7	21	62	-73	2.3	2.8	10.9	16	62	-73	1.74	138	83	57
1970	Model-Wide	5.5	16.6	21	88	-67	1.51	3.1	8.1	12.9	88	-43	0.93	464	286	178
	USC Sub-Basin	5.8	16.6	20.9	88	-58	1.89	3.2	7.7	12.6	88	-43	1.14	407	253	154
	Avra Valley Sub-Basin	3.1	17.2	21.9	48	-67	2.39	3	10.6	14.9	46	-31	1.63	55	32	24

Appendix C. Model Calibration Statistics

Table C-1. Final Model simulated head residual statistics: 1940 – 2010 (cont).

Year		Unweighted Residuals						Weighted Residuals						Residual Counts		
		Mean	ABS Mean	SD	Max	Min	RMSE Ratio	Mean	ABS Mean	SD	Max	Min	RMSE Ratio	Totals	>=0	<0
1975	Model-Wide	5.8	23.6	29.3	101	-136	2.11	3.8	9.2	13.7	68	-60	0.99	361	220	141
	USC Sub-Basin	6.6	24.2	30.1	101	-136	2.72	4	8.5	12.7	68	-30	1.15	279	178	101
	Avra Valley Sub-Basin	3.1	21.7	26.5	57	-73	2.89	2.9	11.6	16.8	51	-60	1.84	82	42	40
1981	Model-Wide	7.3	21.2	26.9	104	-149	1.93	4.4	9.6	15.3	79	-141	1.1	670	415	255
	USC Sub-Basin	8.4	22	27.3	104	-149	2.47	5	9.7	15.4	79	-141	1.39	590	373	217
	Avra Valley Sub-Basin	-1.1	14.8	21.4	58	-70	2.34	0.3	9	14.4	55	-42	1.58	80	42	38
1988	Model-Wide	4.8	22.1	28.7	158	-106	2.07	4.7	10.1	16.5	119	-48	1.19	781	477	304
	USC Sub-Basin	4.1	23.3	30.4	158	-106	2.75	4.7	10.4	17.3	119	-48	1.56	652	379	273
	Avra Valley Sub-Basin	7.9	15.8	18.2	44	-47	1.99	5.1	9.1	12.2	41	-42	1.33	129	98	31
1995	Model-Wide	2.8	24.7	31.2	176	-92	2.25	3.9	11.8	18.5	121	-61	1.33	1034	575	459
	USC Sub-Basin	2.3	27.3	33.9	176	-92	3.06	4.2	12.8	19.8	121	-61	1.79	801	436	365
	Avra Valley Sub-Basin	4.3	16	19.5	56	-57	2.13	2.6	8.6	12.9	43	-57	1.41	233	139	94
2000	Model-Wide	0.8	26.2	34.5	201	-127	2.48	3.4	12.4	19.9	137	-62	1.43	790	414	376
	USC Sub-Basin	1.3	28.9	37.6	201	-127	3.4	4.4	13.2	21.2	137	-62	1.92	603	328	275
	Avra Valley Sub-Basin	-0.7	17.6	21.6	50	-57	2.37	0.1	9.7	14.4	43	-57	1.57	187	86	101
2005	Model-Wide	1.2	29.9	38.8	129	-122	2.79	3.8	15.1	24	129	-111	1.72	975	536	439
	USC Sub-Basin	3.6	32.8	42	129	-122	3.8	6	16.4	25.6	129	-111	2.32	746	439	307
	Avra Valley Sub-Basin	-6.6	20.3	23.9	69	-61	2.61	-3.6	10.9	15.5	37	-58	1.69	229	97	132
2010	Model-Wide	-2.7	32.5	41.9	120	-149	3.01	2.5	19.3	27.6	120	-123	1.99	708	362	346
	USC Sub-Basin	0.2	36.8	46.5	120	-149	4.21	5.1	22.4	30.7	120	-123	2.78	518	300	218
	Avra Valley Sub-Basin	-10.7	20.7	23.4	84	-92	2.56	-4.7	10.9	14.3	31	-48	1.56	190	62	128
All Years	Model-Wide	3.3	22.5	30.4	201	-161	2.19	3.7	11.3	18.3	137	-141	1.32	8382	4956	3426
	USC Sub-Basin	3.8	23.9	32.3	201	-161	2.92	4.2	11.6	19.2	137	-141	1.74	6618	3932	2686
	Avra Valley Sub-Basin	1.7	17.3	21.6	84	-92	2.36	1.6	10.1	14.6	62	-73	1.59	1751	1014	737

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Table C-2. Frequency distribution of weighted model head residuals: 1940 – 2010.

Model Weighted Residuals								Weighted Residual Percentages		
Residual Range	Number of Model-Wide Residuals	Layer 1 Residuals	Layer 2 Residuals	Layer 3 Residuals	Multi-Layer Residuals	Avra Valley Residuals	USC Residuals	Model-Wide Percentage	Avra Valley Percentage	USC Percentage
<= -100	6	2	2	1	1	0	6	0.1%	0.0%	0.1%
-100 to -90	3	0	3	0	0	0	3	0.04%	0.0%	0.1%
-90 to -80	6	3	3	0	0	0	6	0.1%	0.0%	0.1%
-80 to -70	4	3	1	0	0	1	3	0.1%	0.1%	0.1%
-70 to -60	17	5	9	1	2	2	15	0.2%	0.1%	0.2%
-60 to -50	26	6	17	1	2	9	17	0.3%	0.5%	0.3%
-50 to -40	60	7	31	3	19	15	45	0.7%	0.9%	0.7%
-40 to -30	123	15	76	11	21	25	98	1.5%	1.4%	1.5%
-30 to -20	201	24	114	8	55	55	146	2.4%	3.1%	2.2%
-20 to -10	505	74	228	39	164	148	355	6.0%	8.5%	5.4%
-10 to 0	2,450	376	1,103	247	724	480	1,969	29.2%	27.4%	29.8%
0 to 10	3,088	455	1,276	365	992	642	2,437	36.8%	36.7%	36.8%
10 to 20	842	97	336	98	311	213	629	10.1%	12.2%	9.5%
20 to 30	460	58	225	47	130	104	356	5.5%	5.9%	5.4%
30 to 40	278	33	133	18	94	41	237	3.3%	2.3%	3.6%
40 to 50	102	15	51	7	29	13	88	1.2%	0.7%	1.3%
50 to 60	92	18	54	2	18	2	90	1.1%	0.1%	1.4%
60 to 70	71	9	49	1	12	1	70	0.9%	0.1%	1.1%
70 to 80	12	3	6	0	3	0	12	0.1%	0.0%	0.2%
80 to 90	13	2	9	0	2	0	13	0.2%	0.0%	0.2%
90 to 100	6	4	1	0	1	0	6	0.1%	0.0%	0.1%
>= 100	17	1	11	0	5	0	17	0.2%	0.0%	0.3%
	8,382	1,210	3,738	849	2,585	1,751	6,618	100%	100%	100%

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Table C-3. Frequency distribution of the absolute value of the weighted model head residuals: 1940 – 2010.

Absolute Value of the Model Weighted Residuals								Cumulative Percentages		
Residual Range	Number of Model-Wide Residuals	Layer 1 Residuals	Layer 2 Residuals	Layer 3 Residuals	Multi-Layer Residuals	Avra Valley Residuals	USC Residuals	Model-Wide Percentage	Avra Valley Percentage	USC Percentage
0 to 10	5,552	832	2,386	613	1,721	1,124	4,418	66.2%	64.2%	66.8%
10 to 20	1,341	170	561	137	473	365	974	82.2%	85.0%	81.5%
20 to 30	659	83	337	55	184	155	504	90.1%	93.9%	89.1%
30 to 40	398	47	207	29	115	66	332	94.9%	97.7%	94.1%
40 to 50	160	22	82	10	46	26	133	96.8%	99.1%	96.1%
50 to 60	118	24	72	2	20	11	107	98.2%	99.8%	97.7%
60 to 70	87	14	57	2	14	3	84	99.2%	99.9%	99.0%
70 to 80	17	6	8	0	3	1	16	99.4%	100%	99.2%
80 to 90	18	5	11	0	2	0	18	99.6%	100%	99.5%
90 to 100	9	4	4	0	1	0	9	99.7%	100%	99.7%
>= 100	23	3	13	1	6	0	23	100%	100%	100%
	8,382	1,210	3,738	849	2,585	1,751	6,618			

