APPENDIX 3A – DETAILS OF RECONSTRUCTION MODELING
GAGE A – COLORADO RIVER AT LEES FERRY

This reconstruction uses two sub-period models (M1 and M2), with data starting in A.D. 1279 and A.D. 1521. The predictand for modeling is water-year average daily flow in units of cms.

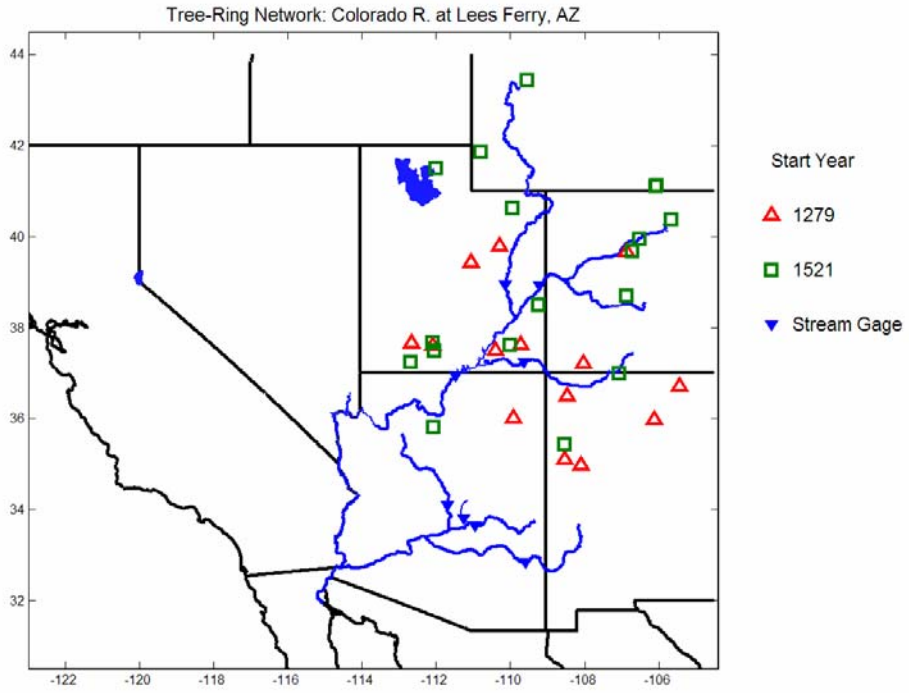

Figure 3A_1. Map showing tree-ring site locations for sub-period models used in reconstructing Colorado River at Lees Ferry.

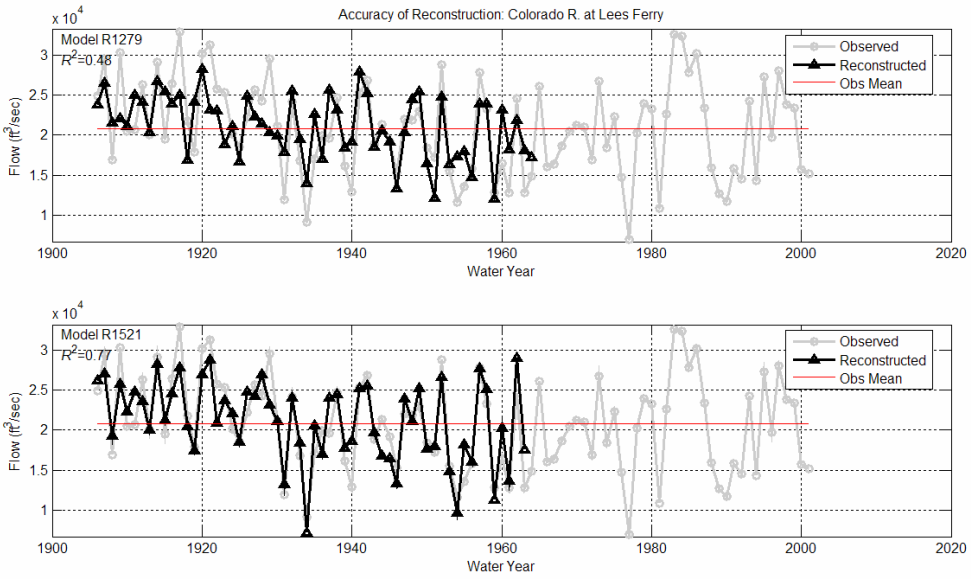

Figure 3A-2. Time series plots of observed and reconstructed flows for calibration period, Colorado River at Lees Ferry. Top: earliest model, allowing reconstruction to A.D. 1279. Bottom: most recent model, allowing reconstruction to A.D. 1521.

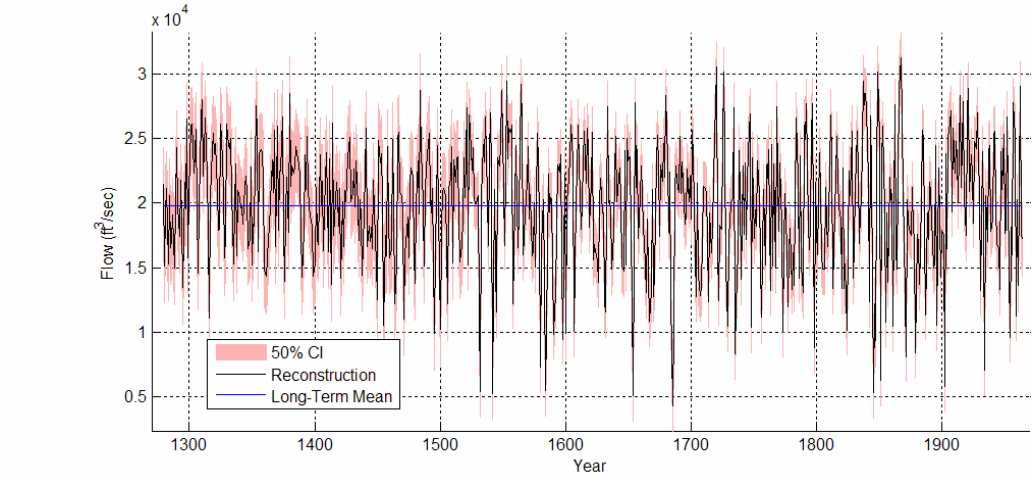

Figure 3A_3. Time series plot of reconstructed annual flows, Colorado River at Lees Ferry. Confidence interval based on root-mean-square error of cross-validation. Reconstruction for given interval of time based on the most accurate sub-period reconstruction available for that period. Accuracy measured by root-mean-square error of cross-validation.

Table 3A_1. Summary of multi-site regression modeling for Colorado River at Lees Ferry, AZ .

		Calibration[3]			Validation[4]	
N[1]	Start[2]	Years	n-p-q	R^2adj	m	RE	RMSE
1	1279	1906-1964	14-4-1	0.48	7	0.45	119.4357
2	1521	1906-1963	32-4-2	0.77	9	0.74	81.8533

[1]Sub-period model number (1 is earliest)
[2]Start year of reconstruction period
[3]Calibration statistics:
  Years=calibration period
  n=number of chronologies
  p=number of potential predictors
  q=number of predictors in final model
  R^2adj = adjusted coefficient of determination
[4]Validation statistics (cross-validation)
  m = number of observations left out in "leave-m-out" cross-validation
  RE = reduction of error statistic
  RMSE = root-mean-square error of cross-validation (units of RMSE are same as units of the predictand in regression)

NOTES:
Predictand is flow (not transformed)
Predictors = Principal components (covariance matrix) from PCA on full reconstruction + calibration period
Units of predictand in regression = cms
Maximum p-value of overall F for any model = 1.262682E-0093

Table 3A_M1_1. Chronology listing and statistics on prewhitening, model M1279.

				LOCATION[5]			TIME COVERAGE[6]		AR[7]	
N[1]	CHRONOLOGY[2]	FILE[3]	SPECIES[4]	LAT	LON	EL(M)	START	END	p	var
1	Elephant Roc	ad1000s	many	36.7	-105.5	2796	1000(1010)	1988	3	11.4
2	Cebolleta Me	ad1000s	many	35.1	-108.6	2114	1000(1000)	1988	2	14.3
3	El Malpais	ad1000s	PSME	35.0	-108.1	2423	1000(877)	1988	3	11.3
4	Mammoth Cree	ad1000s	PILO	37.6	-112.7	2590	1000(873)	1988	3	8.1
5	Gobernador P	ad1000s	many	36.5	-108.5	2195	1000(749)	1988	3	7.5
6	Canyon de Ch	ad1000s	many	36.0	-109.9	1830	1000(591)	1988	3	10.8
7	Durango PLUS	ad1000s	many	37.2	-108.0	2073	1000(804)	1988	3	17.2
8	Natural Brid	ad1000s	many	37.5	-110.4	1859	1000(510)	1988	3	7.7
9	Chama Valley	ad1000s	many	36.0	-106.1	2137	1000(1000)	1988	3	6.2
10	Eagle	co052	PSME	39.6	-106.9	1951	1107(1404)	1964	3	37.9
11	Paria Platea	dgpsme	PSME	37.6	-112.1	2750	1259(1406)	1998	3	26.4
12	Milk Ranch P	UT024	PIED	37.6	-109.7	N/A	1276(N/A)	1970	3	18.1
13	Nine Mile Ca	UT505	PSME	39.8	-110.3	1920	1194(1232)	1964	2	20.3
14	Wild Horse R	UT508	PILO	39.4	-111.1	N/A	286(N/A)	1985	3	18.7

[1]sequential site number
[2]short form of chronology name
[3]computer file (.crn) identifying chronology in ITRDB and elsewhere (e.g., ca528.crn is unique file at International Tree-Ring Data Bank). File “ad1000s” are chronologies from Ni et al. (2002).
[4]species code(see Appendix 2)
[5]latitude and longitude in decimal degrees; elevation in meters above sea level; N/A indicates information not available
[6]first year of standard chronology (first year sub-sample signal strength – see text -- exceeds 0.85); last year of chronology; N/A means not available
[7]order of autoregressive model used to prewhiten chronology, and percent chronology variance due to modeled autocorrelation

Table 3A_M1_2. Summary of single-site regression/reconstruction, model M1279.

N[1]	CHRONOLOGY[2]	REGRESSION MODEL[3] LAGS	R^2	F	RE[4] A	B
1	Elephant Roc	0,-1,-3	0.25	9.5***	0.18	0.33
2	Cebolleta Me	0,-1	0.31	18.1***	0.14	0.49
3	El Malpais	0,-1	0.17	8.4***	0.06	0.38
4	Mammoth Cree	0	0.19	18.7***	0.14	0.23
5	Gobernador P	0,-1	0.33	19.9***	0.20	0.50
6	Canyon de Ch	0,-1	0.32	37.2***	0.15	0.47
7	Durango PLUS	0,-1	0.44	62.7***	0.36	0.55
8	Natural Brid	0,-1	0.39	51.6***	0.31	0.47
9	Chama Valley	0	0.20	20.5***	0.05	0.39
10	Eagle	0,-2	0.47	25.4***	0.67	0.23
11	Paria Platea	0	0.17	17.9***	0.15	0.18
12	Milk Ranch P	0,-1	0.41	43.7***	0.31	0.46
13	Nine Mile Ca	0,-1	0.34	15.2***	0.34	0.47
14	Wild Horse R	0	0.17	16.2***	0.06	0.34

[1]sequential site number
[2]chronology name (truncated)
[3]regression modeling specifications and statistics:
LAGS = lags included on predictors
R^2 = variance explained by regression, adjusted
F = F-level and significance (*, **, *** indicate 0.05, 0.01 and 0.001 alpha-levels)
[4]Reduction of error statistic for split-sample validation;
A = validation on second half of data (calibration on first)
B = validation on first half of data (calibration on second)

Table 3A_M1_3. Summary of stepwise estimation of multi-site reconstruction model M1279.

Step	Variables[1]	R^2adj	RE Statistic[2] A	B	cv	RMSEcv[3]	Residuals[4] r_1	T	N
1	1	0.48	0.62	0.48	0.45	119.4357	P	0	P

[1]Variables included as predictors in the model at the indicated step. Variables are principal components (covariance matrix) from PCA on full period of reconstruction and calibration. Variable 1 is PC#1, variable 2 is PC#2, and so forth.
[2]Reduction of error statistics from (A) calibration on 1906-1934 and validation on 1935-1964, (B) calibraton on 1935-1964 and validation on 1906-1934, (cv)cross-validation with 7 observations left out at each iteration
[3]Root-mean-square error of cross-validation, in cms
[4]Results of analysis of residuals: r_1 is Durbin-Watson(DW) test for first-order autocorrelation of residuals; T is test for significant slope in regression of residuals on time (trend); N is Lilliefors test for normality of residuals; "P" for DW and N tests indicates “pass”, or test statistic not significant at 0.05 alpha-level; 0 indicates slope of trend line not significant at 0.05 level, while - or + indicates significant negative or positive trend in residuals

Model Equation: constant term, coefficients, confidence interval, selected statistics:

Var	Coef	95% CI	
Con	565.1716	(533.171	597.1721)
X1	0.4542732	(0.3286431	0.5799034)

R-squared = 0.47912
F-level = 52.4296
sig = 1.262682E-0099

Table 3A_M1_4. Weights[1] of chronologies in principal components and final regression.

		LOADINGS		

N	CHRONOLOGY	X1	W	W*
1	Elephant Roc	0.138	0.0309	0.26
2	Cebolleta Me	0.306	0.0753	0.64
3	El Malpais	0.167	0.0312	0.26
4	Mammoth Cree	0.219	0.0441	0.37
5	Gobernador P	0.264	0.0649	0.55
6	Canyon de Ch	0.342	0.0835	0.70
7	Durango PLUS	0.376	0.1052	0.89
8	Natural Brid	0.325	0.0857	0.72
9	Chama Valley	0.179	0.0355	0.30
10	Eagle	0.201	0.0628	0.53
11	Paria Platea	0.188	0.0323	0.27
12	Milk Ranch P	0.403	0.1184	1.00
13	Nine Mile Ca	0.259	0.0697	0.59
14	Wild Horse R	0.199	0.0408	0.34

[1]Columns X1, X2,... are the principal component loadings on the chronologies. X1 denotes PC1, X2 denotes PC1, and so forth. Final, or multi-site, reconstruction was generated by regression of flow on the PC scores. The final reconstruction can be generated by applying the estimated regression equation to those PC scores. The final reconstruction can alternatively be generated from the individual filtered, scaled chronologies themselves. To generate the final from the chronologies, the applicable weights are in column "W". ("W*" are the same weights proportionally scaled so that the largest weight is 1.0.) The weights W and W* measure the relative importance of the individual chronologies to the final reconstruction. Steps for generating reconstruction from original chronologies:

1) filter and scale the original chronologies into single-site (ss) reconstructions as described in the text
2) convert ss reconstructions to Z scores, using calibration period means and standard deviations
3) multiply those z-score series by the regression weights in next-to-last column (W) above, and sum the weighted series
4) multiply resulting series by calibration-period standard deviation of flow and add the calibration-period mean observed flow

Table 3A_M2_1. Chronology listing and statistics on prewhitening, model M521.

N[1]	CHRONOLOGY[2]	FILE[3]	SPECIES[4]	LOCATION[5] LAT	LON	EL(M)	TIME COVERAGE[6] START	END	AR[7] p	var
1	Elephant Roc	ad1000s	many	36.7	-105.5	2796	1000(1010)	1988	3	11.4
2	Cebolleta Me	ad1000s	many	35.1	-108.6	2114	1000(1000)	1988	2	14.3
3	El Malpais	ad1000s	PSME	35.0	-108.1	2423	1000(877)	1988	3	11.3
4	Mammoth Cree	ad1000s	PILO	37.6	-112.7	2590	1000(873)	1988	3	8.1
5	Gobernador P	ad1000s	many	36.5	-108.5	2195	1000(749)	1988	3	7.5
6	Canyon de Ch	ad1000s	many	36.0	-109.9	1830	1000(591)	1988	3	10.8
7	Durango PLUS	ad1000s	many	37.2	-108.0	2073	1000(804)	1988	3	17.2
8	Natural Brid	ad1000s	many	37.5	-110.4	1859	1000(510)	1988	3	7.7
9	Chama Valley	ad1000s	many	36.0	-106.1	2137	1000(1000)	1988	3	6.2
10	Mount Carmel	carjct	PIED	37.2	-112.7	N/A	1518(1518)	1992	2	21.7
11	Eagle	co052	PSME	39.6	-106.9	1951	1107(1404)	1964	3	37.9
12	Upper Gunnis	co061	PSME	38.7	-106.9	2530	1322(1741)	1964	3	18.1
13	Eagle East	co063	PIED	39.7	-106.7	2164	1314(1403)	1964	3	16.5
14	Timberline P	CO549	PCEN	40.4	-105.7	N/A	1510(1660)	1987	3	33.2
15	Pumphouse	CO579	PIED	40.0	-106.5	N/A	1320(1379)	1999	2	21.6
16	Paria Platea	dgpied	PIED	37.5	-112.1	1986	1406(1540)	2000	3	21.3
17	Paria Platea	dgpsme	PSME	37.6	-112.1	2750	1259(1406)	1998	3	26.4
18	Fort Wingate	NM031	PIED	35.4	-108.5	N/A	1478(N/A)	1972	1	8.7
19	Ditch Canyon	NM503e	PSME	37.0	-107.1	N/A	1487(N/A)	1978	2	16.6
20	Red Butte, A	redbutte	PIED	35.8	-112.1	1940	1448(N/A)	1989	2	22.1
21	South of Pea	speak78	PSME	41.5	-112.0	N/A	1429(N/A)	1990	3	24.5
22	La Sal Mount	ut018	PIED	38.5	-109.3	2323	1489(1597)	1972	3	20.9
23	White Canyon	UT023	PSME	37.6	-110.0	N/A	1347(N/A)	1972	2	25.9
24	Milk Ranch P	UT024	PIED	37.6	-109.7	N/A	1276(N/A)	1970	3	18.1
25	Uinta Mounta	ut502	PIED	40.6	-110.0	2289	1423(N/A)	1971	2	24.7
26	Nine Mile Ca	ut505	PSME	39.8	-110.3	1920	1194(1232)	1964	2	20.3
27	Water Canyon	UT507	PIPO	37.7	-112.1	N/A	1336(N/A)	1964	3	30.4
28	Wild Horse R	UT508	PILO	39.4	-111.1	N/A	286(N/A)	1985	3	18.7
29	Laramie, Sit	WY010	PSME	41.1	-106.1	N/A	1444(1444)	1964	3	22.0
30	Sheep Mounta	WY019	PSME	41.1	-106.1	N/A	1412(N/A)	1990	3	10.9
31	Fossil Butte	WY026	PIFL	41.9	-110.8	N/A	1480(N/A)	1998	2	26.4
32	Whiskey Moun	WY028	PSME	43.4	-109.6	N/A	1459(N/A)	2000	2	14.1

[1]sequential site number
[2]short form of chronology name
[3]computer file (.crn) identifying chronology in ITRDB and elsewhere (e.g., ca528.crn is unique file at International Tree-Ring Data Bank). File “ad1000s” are chronologies from Ni et al. (2002).
[4]species code(see key on Appendix 2)
[5]latitude and longitude in decimal degrees; elevation in meters above sea level; N/A indicates information not available
[6]first year of standard chronology (first year sub-sample signal strength -- see text -- exceeds 0.85), last year of chronology; N/A indicated information not available
[7]order of autoregressive model used to prewhiten chronology, and percent chronology variance due to modeled autocorrelation

Table 3A_M22. Summary of single-site regression/reconstruction, model M1521

N[1]	CHRONOLOGY[2]	REGRESSION MODEL[3] LAGS	R^2	F	RE[4] A	RE[4] B
1	Elephant Roc	0,-1,-3	0.25	9.5***	0.18	0.33
2	Cebolleta Me	0,-1	0.31	18.1***	0.14	0.49
3	El Malpais	0,-1	0.17	8.4***	0.06	0.38
4	Mammoth Cree	0	0.19	18.7***	0.14	0.23
5	Gobernador P	0,-1	0.33	19.9***	0.20	0.50
6	Canyon de Ch	0,-1	0.32	37.2***	0.15	0.47
7	Durango PLUS	0,-1	0.44	62.7***	0.36	0.55
8	Natural Brid	0,-1	0.39	51.6***	0.31	0.47
9	Chama Valley	0	0.20	20.5***	0.05	0.39
10	Mount Carmel	0,-1	0.38	26.2***	0.26	0.50
11	Eagle	0,-2	0.47	25.4***	0.67	0.23
12	Upper Gunnis	0,1	0.31	13.1***	0.23	0.33
13	Eagle East	0,-1	0.54	32.9***	0.65	0.58
14	Timberline P	0	0.10	8.4**	0.14	0.08
15	Pumphouse	0,-1	0.44	73.0***	0.40	0.51
16	Paria Platea	0,-1	0.30	20.5***	0.31	0.29
17	Paria Platea	0	0.17	17.9***	0.15	0.18
18	Fort Wingate	0	0.18	14.4***	0.01	0.35
19	Ditch Canyon	0	0.35	37.8***	0.20	0.44
20	Red Butte, A	0	0.21	21.5***	0.08	0.31
21	South of Pea	0,-2,1	0.08	7.4**	0.07	0.10
22	La Sal Mount	0	0.36	36.4***	0.42	0.36
23	White Canyon	0	0.23	19.3***	0.20	0.22
24	Milk Ranch P	0,-1	0.41	43.7***	0.31	0.46
25	Uinta Mounta	0	0.37	37.4***	0.44	0.28
26	Nine Mile Ca	0,-1	0.34	15.2***	0.34	0.47
27	Water Canyon	0	0.24	17.8***	0.14	0.25
28	Wild Horse R	0	0.17	16.2***	0.06	0.34
29	Laramie, Sit	0,-1	0.20	7.5**	0.14	0.20
30	Sheep Mounta	0,-1,1	0.35	15.7***	0.33	0.38
31	Fossil Butte	0	0.14	15.2***	0.08	0.18
32	Whiskey Moun	0,-1	0.09	5.0**	0.10	0.13

[1]sequential site number
[2]chronology name (truncated)
[3]regression modeling specifications and statistics:
LAGS = lags included on predictors
R^2 = variance explained by regression, adjusted
F = F-level and significance (*, **, *** indicate 0.05, 0.01 and 0.001 alpha-levels)
[4]Reduction of error statistic for split sample validation;
A = validation on second half of data (calibration on first)
B = validation on first half of data (calibration on second)

Table 3A_M1_3. Summary of stepwise estimation of multi-site reconstruction, model M1521.

Step	Variables[1]	R^2adj	RE Statistic[2] A	RE Statistic[2] B	RE Statistic[2] cv	RMSEcv[3]	Residuals[4] r_1	Residuals[4] T	Residuals[4] N
1	1	0.63	0.73	0.63	0.60	101.8884	P	0	P
2	1,2	0.77	0.75	0.76	0.74	81.8533	P	0	P

[1]Variables included as predictors in the model at the indicated step. Variables are principal components (covariance matrix) from PCA on full period of reconstruction and calibration. Variable 1 is PC#1, variable 2 is PC#2, and so forth.
[2]Reduction of error statistics from (A) calibration on 1906-1934 and validation on 1935-1963, (B) calibraton on 1935-1963 and validation on 1906-1934, (cv) cross-validation with 9 observations left out at each iteration
[3]Root-mean-square error of cross-validation, in cms
[4]Results of analysis of residuals: r_1 is Durbin-Watson (DW) test for first-order autocorrelation of residual; T is test for significant slope in regression of residuals on time (trend); N is Lilliefors test for normality of residuals; "P" for DW and N test indicates “pass”, or test statistic not significant at 0.05 alpha-level; 0 indicates slope of trend line not significant at 0.05 level, while - or + indicates significant negative or positive trend in residuals

Model Equation: constant term, coefficients, confidence interval, selected statistics:

Var	Coef	95% CI	
Con	554.8513	(533.1321	576.5705)
X1	0.3896027	(0.3266501	0.4525553)
X2	-0.3918933	(-0.5241754	-0.2596111)

R-squared = 0.77253
F-level = 93.3942
sig <1.0E-99

Table 3A_M2_4. Weights[1] of chronologies in principal components and final regression.

		LOADINGS			
N1	CHRONOLOGY	X1	X2	W	W*
1	Elephant Roc	0.097	0.028	0.0132	0.06
2	Cebolleta Me	0.195	0.138	0.0117	0.05
3	El Malpais	0.102	0.066	0.0058	0.03
4	Mammoth Cree	0.170	0.060	0.0191	0.09
5	Gobernador P	0.178	0.077	0.0212	0.10
6	Canyon de Ch	0.230	0.141	0.0183	0.08
7	Durango PLUS	0.247	0.100	0.0354	0.16
8	Natural Brid	0.243	0.138	0.0235	0.11
9	Chama Valley	0.122	0.047	0.0127	0.06
10	Mount Carmel	0.281	0.129	0.0381	0.17
11	Eagle	0.157	-0.317	0.1285	0.59
12	Upper Gunnis	0.129	-0.146	0.0610	0.28
13	Eagle East	0.237	-0.521	0.2191	1.00
14	Timberline P	0.043	-0.053	0.0121	0.06
15	Pumphouse	0.211	-0.518	0.1832	0.84
16	Paria Platea	0.248	0.105	0.0336	0.15
17	Paria Platea	0.152	0.058	0.0140	0.06
18	Fort Wingate	0.148	0.105	0.0066	0.03
19	Ditch Canyon	0.237	0.166	0.0165	0.08
20	Red Butte, A	0.145	0.117	0.0049	0.02
21	South of Pea	-0.006	-0.028	0.0026	0.01
22	La Sal Mount	0.184	-0.030	0.0483	0.22
23	White Canyon	0.157	0.113	0.0081	0.04
24	Milk Ranch P	0.281	0.195	0.0213	0.10
25	Uinta Mounta	0.177	-0.093	0.0628	0.29
26	Nine Mile Ca	0.170	-0.068	0.0554	0.25
27	Water Canyon	0.186	0.096	0.0171	0.08
28	Wild Horse R	0.136	0.024	0.0198	0.09
29	Laramie, Sit	0.093	-0.152	0.0445	0.20
30	Sheep Mounta	0.139	-0.250	0.0910	0.42
31	Fossil Butte	0.081	-0.063	0.0220	0.10
32	Whiskey Moun	0.038	-0.045	0.0118	0.05

[1]Columns X1, X2,... are the principal component loadings on the chronologies. X1 denotes PC1, X2 denotes PC1, and so forth. Final, or multi-site, reconstruction was generated by regression of flow on the PC scores. The final reconstruction can be generated by applying the estimated regression equation to those PC scores. The final reconstruction can alternatively be generated from the individual filtered, scaled chronologies themselves. To generate the final from the chronologies, the applicable weights are in column "W". ("W*" are the same weights proportionally scaled so that the largest weight is 1.0.) The weights W and W* measure the relative importance of the individual chronologies to the final reconstruction. Steps for generating reconstruction from original chronologies:

1) filter and scale the original chronologies into single-site (ss) reconstructions as described in the text
2) convert ss reconstructions to Z scores, using calibration period means and standard deviations
3) multiply those z-score series by the regression weights in next-to-last column (W) above, and sum the weighted series
4) multiply resulting series by calibration-period standard deviation of flow and add the calibration-period mean observed flow