US Army Corps
of Engineers®
Walla Walla District

Dworshak Water Supply Forecast

June 2013

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Executive Summary

Walla Walla District U.S. Army Corps of Engineers completed this updated Dworshak runoff volume forecast in the Spring of 2012. The result of this study was the selection of an updated Principle Components Regression (2011PCR) forecast. Investigations included review of available runoff volume forecast procedures, development of two new runoff volume forecast procedures, comparison to the existing runoff volume forecast procedure and selection of a new runoff volume forecast procedure. In development of these equations, indicator stations reviewed included 18 snow water equivalent stations, 5 precipitation stations, and single and multiple month accumulations of the southern oscillation index.

Objective of this forecast update include:

1. Provide an accurate forecast
2. Enhance basin coverage with increased number of Snow Water Equivalent (SWE) stations employed to capture an unusual snowpack distribution.
3. Reduce maximum absolute forecast errors for each month
4. Eliminate the use of Dworshak's prior month's basin conditions to forecast the current month. The 2005 Dworshak forecast procedure showed a low correlation between prior month's basin conditions and the seasonal volume.
5. Provide more consistency in snow stations employed during drawdown and refill periods. This allows forecasters to better evaluate month to month changes in the basin state.
6. Ability to make correction to the forecast when the official runoff volume forecast is not supported by basin conditions.

Based on the results of the investigations and subsequent reviews, the 2011 Principle Components Regression will be the official forecast for Dworshak Reservoir. Multiple reviews of the study were conducted, including: the US Army Corps of Engineers Portland District, Columbia River Forecast Group, US Army Corps of Engineers Northwestern Division Water Management, and an Agency Technical Review with reviewers from the US Army Corps of Engineers Hydrologic Engineering Center, National Weather Service River Forecast Center and the US Bureau of Reclamation. The Agency Technical Review found the study alternatives to be statistically sound and comparable.

This update provided for a more accurate forecast through similar Cross Validation Standard Error (CVSE) and moderately reduced maximum absolute forecast errors, eliminated use of prior month's basin conditions. As needed, future forecast updates will work to strike a balance between reducing forecast standard error along with enhancing basin spatial coverage, reducing maximum absolute forecast errors and improving forecast station consistency from month to month.

1. Introduction

Dworshak Dam is located in northern Idaho at river mile 1.9 on the North Fork of the Clearwater River and drains approximately 2,440 square miles. Elevations within the basin range from 900 to 8,000 feet above sea level with an average basin runoff of 4.2 million acre feet. Dworshak Dam is a straight axis concrete-gravity structure with a hydraulic height of 662 feet and an active storage capacity of 2 million acre feet. Dworshak is a multipurpose project that has been in operation since 1973. Dworshak balances the competing demands of flood risk management, power generation, recreation, water quality, and fish and wildlife resources. Dworshak is a critical component in meeting the requirements of the 2008 Biological Opinion to regulate flow and temperature for out migrating juvenile salmon. The runoff volume forecast is an integral part of the operational process to meet all of these competing objectives. Figure 1 shows North Fork of the Clearwater basin and weather stations and SNOTEL stations

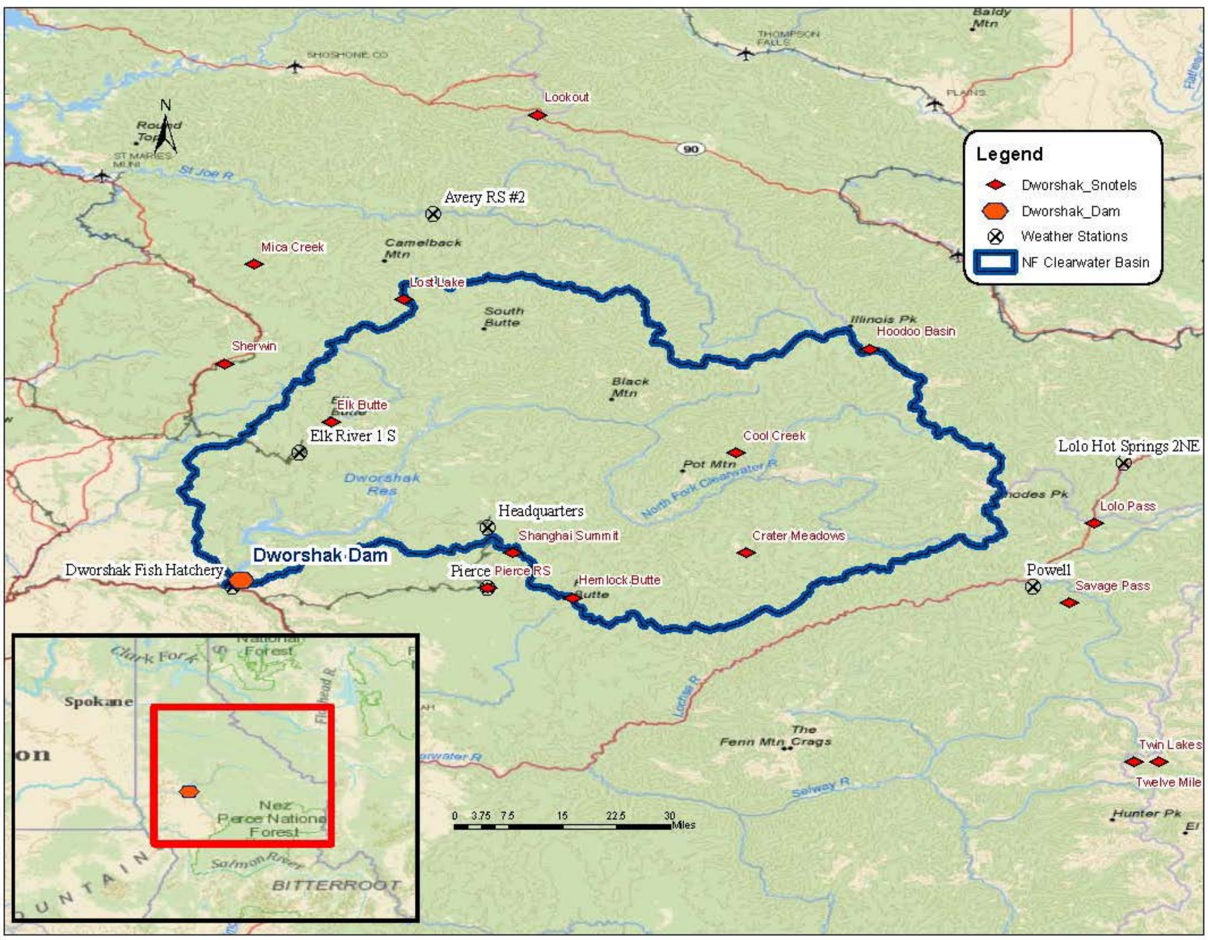

Figure 1 – North Fork Clearwater Basin

The basin runoff is primarily driven by spring snowmelt. The reservoir is drafted during the winter to provide storage space for local and system flood risk management with reservoir refill typically occurring from April through July. A 1-April to 31-July flood risk management runoff volume forecast is generated on the first of each month starting 1-November and continuing until 1-June. The forecast is used to determine the draft and refill operations to meet all authorized objectives from 1-January to 31-July.

Objective of this forecast update include:

1. Provide an accurate forecast
2. Enhance basin coverage with increased number of Snow Water Equivalent (SWE) stations employed to capture an unusual snowpack distribution.
3. Reduce maximum absolute forecast errors
4. Eliminate the use of Dworshak's prior month's basin conditions to forecast the current month. The current Dworshak forecast procedure showed a low correlation between prior month's basin conditions and the seasonal volume.
5. Provide more consistency in snow stations employed during drawdown and refill periods. This allows forecasters to better evaluate month to month changes in the basin state.
6. Ability to make correction to the forecast when the official runoff volume forecast is not supported by basin conditions.

In the development of this forecast methodology Walla Walla District considered the following forecast procedures; an average combination of single indicator linear regression equations (Linear Regression), regression of multiple indicator stations (Multiple Linear Regression), Neural Networks, Principal Components Regression (PCR), and linear regression of a composite z-statistic index (Z-Score). The Walla Walla District selected the latter two methodologies to develop new runoff volume forecasts for Dworshak reservoir. Following review the PCR 2011 forecast was selected as the primary forecast for operations.

2. Dworshak Operational Runoff Volume Forecast History

Multiple iterations of the Dworshak Forecast have been developed by both the Corps and other government agencies and interested stakeholders. The following history only includes those that have been a part of the Corps Dworshak operational forecast history. The Walla Walla District (NWW) developed linear regression equations for individual snow course sites in 1974. The forecasts from the selected sites were averaged to yield a basin wide forecast. The NWW linear regression forecast equations were updated in 1981, 1990, 2000, and 2010. The Northwest River Forecast Center (NWRFC) developed a method to weight and combine predictor variables into a single index which was regressed against runoff volume. The procedure which was developed in 1976 and updated in 1985 used average values for future snow and precipitation observations. At the request of the Northwestern Division (NWD), the Natural Resource Conservation Service (NRCS) developed forecast equations for the Dworshak basin in 1993. The NRCS used principal components regression (PCR) to develop the equations. The NRCS updated the equations in 1995 and 1999. In 2005 NWD updated the principal components Dworshak forecast equations (2005 PCR).

The methodology used to determine the Dworshak operational forecast has changed over time. Initially the Dworshak operational forecast was selected using engineering judgment by Northwestern Division

(NWD) Water Management from the NWRFC and NWW independent forecast procedures. Both the NWRFC and NWW selected indicator stations in their forecasts based on basin conditions. This is the methodology outline in the current Dworshak Water Control Manual and forecasts have been continually made from 1974 through 2011. In 1995 NWD began the practice of following a single forecast procedure using the NRCS Principal Component Forecast (PCR) for Dworshak. While this methodology change was not included in an update to the water control manual, it was adopted in the 2003 Columbia River Treaty Principles and Operating Procedures for Hydroelectric Projects, and has been the practice of making operational runoff volume forecasts from 1995 thru 2013.

3. 2011 PCR Forecast Procedure

A 2011PCR forecast was developed to forecast the 1-April to 31-July runoff volume into Dworshak Reservoir. First of month forecasts are generated during the operations season starting 1-November and continuing to 1-June. The 1-May and 1-June are a Date to 31-July forecast. The 2011PCR forecast was developed primarily to maximize the statistical fit to the historic record, measured solely by cross validation standard error. Maximizing geographic coverage and maintaining station consistency throughout the forecast period were secondary considerations in the development of the forecast equations. The 2011PCR forecast equations were developed using snow water equivalent data, precipitation data, and climate index data from 1961-2011 for the 1-November through 1-May forecast dates and 1967-2011 for the 1-June forecast date.

3.1 Snow Water Equivalent Data

Eighteen snow stations in and near the Dworshak Basin were prescreened for inclusion into the 2011PCR forecast update. The correlation between runoff volume and each station is listed below in Table 1 for each forecast date.

Table 1 – Correlation (R) of SWE to Runoff Volume for Stations Analyzed for use in 2011PCR Forecast

Site Name (Elevation)	April-July Runoff				May-July Runoff	June-July Runoff	
	1 JAN	1 FEB	1 MAR	1 APR	1 MAY	1 MAY	1 JUN
	Correlation (R) of SWE to Runoff Volume						
Cool Creek (6280)	0.64	0.86	0.83	0.87	0.89	0.84	0.89
Lost Lake (6110)	0.56	0.77	0.80	0.86	0.89	0.83	0.91
Hoodoo Basin (6050)	0.62	0.82	0.83	0.88	0.90	0.85	0.91
Crater Meadows (5960)	0.58	0.82	0.83	0.85	0.89	0.84	0.87
Hemlock Butte (5810)	0.61	0.83	0.87	0.89	0.93	0.88	0.92
Elk Butte (5690)	0.57	0.80	0.83	0.87	0.89	0.84	-
Shanghi Summit (4570)	0.56	0.72	0.79	0.84	0.91	0.88	-
Sherwin (3200)	0.68	0.72	0.79	0.78	-	-	-

Correlation coefficients calculated using period of record 1961-2011

3.2 Precipitation Data

Cumulative water year and monthly precipitation values were analyzed for Powell, Dworshak Fish Hatchery, Elk River 1 SE, Headquarters, and Pierce. Table 2 shows the precipitation stations and the correlation coefficients (R) of cumulative water year precipitation with runoff volume.

Table 2 – Correlation (R) of Cumulative Water Year Precipitation to Runoff Volume

Precipitation Sites	**Powell**	**Dworshak Fish Hatchery**	**Elk River 1S**	**Pierce RS**	**Headquarters**
COOP ID	107320	102845	102892	107046	104150
	Correlation (R) with Cumulative Water Year Precipitation				
1-Nov	0.14	0.15	0.21	0.14	0.21
1-Dec	0.24	0.35	0.36	0.33	0.45
1-Jan	0.45	0.54	0.55	0.52	0.65
1-Feb	0.69	0.62	0.68	0.68	0.74
1-Mar	0.78	0.66	0.76	0.74	0.79
1-Apr	0.77	0.62	0.75	0.75	0.79
1-May	0.68	0.49	0.67	0.70	0.72
1-Jun	0.63	0.40	0.62	0.68	0.68

1-April to 31-July volume for 1-Nov, 1-Dec, 1-Jan, 1-Feb, 1-Mar, 1-Apr. Date-31 July volume used for 1-May and1-Jun
Correlation Coefficients calculated using period of record 1961-2011

The correlation with runoff increases as the season progresses, until April when snowpack typically turns over. A sharp drop is seen in the correlation of most stations starting 1-May which is likely the result of the snowpack turning over and the runoff volume being driven by the accumulated SWE.

3.3 Climate Index Data

The Southern Oscillation Index (SOI) has been used in several previous iterations of the Dworshak forecast as well as many forecasts in the Northwestern Division. The SOI values were obtained from the NOAA Climate Prediction Center for the period of 1961-2011. The SOI data were processed as one-month, two-month, and three-month accumulated values. Their correlations with the Dworshak 1-April to 31-July runoff volume were analyzed and are shown below in Table 3.

Table 3 – Correlation (R) of SOI to 1-April to 31-July Runoff Volume

Correlation (R) of SOI to 1-April to 31 July Runoff Volume						
Single-Month SOI	Jul	Aug	Sep	Oct	Nov	Dec
	0.51	0.60	0.63	0.49	0.46	0.56
Two-Month accumulated SOI	Jun+Jul	Jul+Aug	Aug+Sep	Sep+Oct	Oct+Nov	Nov+Dec
	0.56	0.60	0.64	0.59	0.52	0.54
Three-Month accumulated SOI	May+Jun+Jul	Jun+Jul+Aug	Jul+Aug+Sep	Aug+Sep+Oct	Sep+Oct+Nov	Oct+Nov+Dec
	0.56	0.61	0.63	0.61	0.58	0.56

Correlation coefficients calculated using period of record 1961-2011

Six SOI combinations were further analyzed with the May to July and June to July runoff volumes. These included the single-month values for August and September, the two-month accumulation of July and

August, and August and September, and the three-month accumulation of June, July, and August, and July, August, and September. The correlations between the three runoff volumes and the SOI variables are shown below in Table 4.

Table 4 – Correlation (R) of SOI to the Three Runoff Volume Periods

Runoff Volume Period	Correlation (R) of SOI with Runoff Volumes					
	Aug	Sep	Jul+Aug	Aug+Sep	Jun+Jul+Aug	Jul+Aug+Sep
April to July	0.60	0.63	0.60	0.64	0.61	0.63
May to July	0.58	0.60	0.56	0.61	0.58	0.59
June to July	0.52	0.59	0.50	0.55	0.52	0.54

Correlation coefficients calculated using period of record 1961-2011

3.4 Principal Component Regression Results

The 2011PCR forecast equations were developed using the NRCS principal components regression model. The principal component regression model output contains the top 30 statistically best equations for each forecast date along with the CVSE associated with each equation. In many instances, the equation with the smallest CVSE included 1 or 2 SWE variables which did not adequately represent snow conditions in the basin. When this occurred, the list of equations was reviewed for an equation that better represented the basin conditions. The regression coefficients for the final 2011PCR forecast equations are listed below in Table 5.

Table 5 – Regression Coefficients for the 2011PCR Forecast Equations

Regression Coefficients for the 2011PCR Forecast Equations										
Variable	Type	Observation Date	Forecast Date							
			1-Nov	1-Dec	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-June
SOI	Climate	September	569.47	81.25	355.71	264.27	220.73	171.32	122.04	
Headquarters	Precip	Cumulative Water Year		486.62	48.12	27.04	23.39	22.32		
Cool Creek	Snow	First-of-Month			9.96	11.35				
Lost Lake	Snow	First-of-Month			4.24	7.60	6.99	7.91	9.67	6.14
Hoodoo Basin	Snow	First-of-Month			12.22	10.97	10.01	10.27	11.71	8.21
Elk Butte	Snow	First-of-Month			6.25	12.06	10.16	11.61		
Sherwin	Snow	First-of-Month			44.69	29.17	25.42	19.49		
Crater Meadows	Snow	First-of-Month					13.06	13.37		
Hemlock Butte	Snow	First-of-Month							11.58	7.57
Shanghi Summit	Snow	First-of-Month							14.41	10.26
Intercept			2587.57	1950.56	1119.86	572.93	296.75	-15.43	84.24	138.78

The 1-April Headquarters cumulative water year precipitation has an accumulation period of October through February.
The Shanghi Summit SWE variable in 1-June equation is the Shanghi Summit 1-May SWE value

A summary of the 2011PCR forecast equation statistics is shown in Table 6 and the equation coefficients and calibration data are located in Appendix A – 2011 Principle Components Forecast.

Table 6 – 2011PCR Forecast Equation Statistics

2011PCR Regression Statistics								
Forecast Date	**1-Nov**	**1-Dec**	**1-Jan**	**1-Feb**	**1-Mar**	**1-Apr**	**1-May**	**1-Jun**
Cross Validation Standard Error	705	686	540	409	358	298	250	159
Standard Error	678	651	509	382	337	279	238	150
Adjusted R^2	0.38	0.43	0.65	0.80	0.85	0.89	0.90	0.91
Years of Data	51	51	51	51	51	51	51	45
Variables used, SOI	1	1	1	1	1	1	1	
Variables used, Precipitation		1	1	1	1	1		
Variables used, SWE			5	5	5	5	4	4

The statistics for 1-June were calculated for 1967-2011

4. 2005 PCR Forecast Procedure (recalibrated through 2011)

Regression equations for the Dworshak April-July water supply forecast were developed using principal components regression on all available data updated through 2004. First-of-month regression models were fit to the 44 years of available data (1961-2004) utilizing the NRCS principal components regression model in accordance with the guidelines provided by the NRCS. This model was redeveloped to extend data through 2011 and include the recalibrated SOI. No change in indicator stations occurred.

Table 7 provides the summary statistics for the updated 2005 PCR equations. The variables used in the 2005 PCR model are provided in Table 8.

Table 7 – 2005 PCR statistics

2005 PCR Regression Statistics								
Forecast Date	**1-Nov**	**1-Dec**	**1-Jan**	**1-Feb**	**1-Mar**	**1-Apr**	**1-May**	**1-Jun**
Cross Validation Standard Error	705	688	574	415	373	296	249	154
Standard Error	678	659	534	401	358	283	237	145
Adjusted R^2	0.40	0.43	0.64	0.79	0.83	0.90	0.90	0.92
Years of Data	51	51	51	51	51	51	51	45
Variables used, SOI	1	1	1	1	1	1	1	
Variables used, Precipitation		1	2					
Variables used, Inflow				1	2	3	3	
Variables used, SWE			4	4	3	4	5	5

Table 8 – 2005 PCR Variables

Variables used in 2005 PCR Forecast Equations										
Variable	**Type**	**Observation Date**	**Forecast Date**							
			1-Nov	**1-Dec**	**1-Jan**	**1-Feb**	**1-Mar**	**1-Apr**	**1-May**	**1-June**
SOI	Climate	September	x	x	x	x	x	x	x	
Headquarters	Precip	Nov, Dec		x	x					
Lost Lake	Snow	First-of-Month							x	x
Hoodoo Basin	Snow	First-of-Month			x	x	x	x	x	x
Elk Butte	Snow	First-of-Month			x	x	x	x	x	x
Hemlock Butte	Snow	First-of-Month			x	x	x	x	x	x
Shanghi Summit	Snow	First-of-Month						x	x	x, 1-May
Pierce Ranger Station	Snow	First-of-Month			x	x	x			
DWR Inflow	Inflow	monthly volume				x	x	x		

5. Comparison of Forecast Procedures

The following section compares the 2011 PCR forecast procedures with the 2005 PCR. The 2005 PCR was recalibrated to include data from 2005-2011 and the recalibrated SOI.

The 2011 PCR, like the 2005 PCR, utilized stations somewhat randomly throughout the forecast season. The 2011 PCR is limited to a period of record of 1967-2011 for June because the input data for Hoodoo Basin is limited to 1967-2011.

The 2011PCR forecast procedure has comparable statistics to the 2005 PCR forecast. Table 9 shows the CVSE, SE, Adjusted R-square, Maximum Error, and total indicator used for the two different forecast methods.

Table 9 – Comparison of Forecast Procedures

Comparison of Forecast Procedures								
Forecast Date	**1-Nov**	**1-Dec**	**1-Jan**	**1-Feb**	**1-Mar**	**1-Apr**	**1-May**	**1-Jun**
2005PCR - Cross Validation Standard Error	705	688	574	415	373	296	249	154
2011PCR - Cross Validation Standard Error	705	686	540	409	358	298	250	159
2005PCR - Standard Error	678	659	534	401	358	283	237	145
2011PCR - Standard Error	678	651	509	382	337	279	238	150
2005PCR - Adjusted R^2	0.38	0.41	0.61	0.78	0.82	0.89	0.90	0.92
2011PCR - Adjusted R^2	0.38	0.43	0.65	0.80	0.85	0.89	0.90	0.91
2005PCR – Maximum Error (KAF)	1700	1511	1177	890	757	717	677	504
2011PCR – Maximum Error (KAF)	1700	1611	1193	821	703	786	607	517
2005PCR – Indicators Used	1	2	6	6	6	6	6	5
2011PCR – Indicators Used	1	2	7	7	7	7	5	4

The statistics for the 1-June forecast for the 2005PCR and 2011PCR were calculated for 1967-2011

Further comparisons of the forecasts errors can be found in the Appendices.

6. Protocol for Better Reflecting Basin Conditions and Missing Data

Dworshak basin is comprised of extremely diverse terrain and correspondingly limited climatic station coverage, see Figure 1. When station data is missing or not reflective of basin conditions a similar surrogate gage may be used, if available, to assist in estimating station precipitation or SWE. Factors such as aspect, elevation, and proximity to the official forecast parameter station may be considered for site selection in addition to recorded snow flight or SNODAS information. A data estimation approach will be proposed by the District and NWD CBWM will review each substitution on a case by case basis as part of the monthly forecast review prior to issuance of the official forecast.

7. Review and Conclusion

Multiple reviews of the forecasts included in this study were performed. Early reviews were conducted by US Army Corps of Engineers Portland District, US Army Corps of Engineers Northwestern Division, and the Columbia River Forecast Group. Comments received from these reviews were adapted as appropriate in the developed forecasts. Final developed forecasts were provided for an ATR with the US Army Corps of Engineers Hydrologic Engineering Center, National Weather Service River Forecast Center, and the US Bureau of Reclamation. The forecasts were rigorously reviewed and found to be statistically comparable for operational use. A summary of the ATR results is provided in the Appendices.

The 2011 PCR has been selected as the official runoff volume forecast for Dworshak reservoir. The updated forecasts were compared against the objectives stated in Section 1.0 of this report. This update provided for a more accurate forecast through similar Cross Validation Standard Error (CVSE) and moderately reduced maximum absolute forecast errors, eliminated use of prior month's basin conditions. As needed, future forecast updates will work to strike a balance between reducing forecast standard error along with enhancing basin spatial coverage, reducing maximum absolute forecast errors and improving forecast station consistency from month to month. Variability in project inflow volumes due to climate change may affect forecast reliability and accuracy in the future.

8. Principle Authors

This report was principally authored by personnel from the Walla Walla District's Hydrology Section. Also, contributions were made from both internal and external reviewers.

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Appendix A – 2011 Principle Components Regression Forecast Data

1-November Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	569.47
REGRESSION EQUATION VARIABLES		
Intercept	C7	2587.57

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	705	0.59	678	0.63

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2989	94	2986	91
1962	3031	2637	-394	2645	-386
1963	1800	2838	1039	2815	1016
1964	3401	2211	-1190	2246	-1156
1965	3304	3329	26	3328	24
1966	2145	1828	-317	1847	-298
1967	2689	2469	-219	2474	-215
1968	1971	2894	924	2872	902
1969	2874	2406	-468	2417	-457
1970	2618	1990	-627	2018	-600
1971	4046	3232	-814	3271	-775
1972	4670	3305	-1365	3385	-1285
1973	1327	1823	496	1790	464
1974	4650	3202	-1448	3271	-1379
1975	3217	3214	-3	3214	-3
1976	3361	3836	475	3783	423
1977	1240	1998	758	1961	721
1978	2399	2122	-277	2132	-267
1979	2691	2644	-48	2645	-47
1980	2285	2652	367	2645	359
1981	2160	2307	146	2303	142
1982	3318	2747	-571	2758	-559

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1983	2123	1572	-551	1619	-503
1984	2762	3112	350	3100	338
1985	2946	2638	-307	2645	-301
1986	2032	2599	567	2588	556
1987	1510	2324	814	2303	792
1988	1753	2030	277	2018	265
1989	2751	3693	942	3613	862
1990	2807	2874	67	2872	66
1991	2702	2172	-530	2189	-513
1992	1330	1765	435	1733	403
1993	2199	2653	455	2645	446
1994	1426	2214	788	2189	763
1995	1807	1665	-142	1676	-131
1996	3070	2752	-318	2758	-311
1997	4630	2884	-1745	2929	-1700
1998	2058	1771	-286	1790	-267
1999	3182	3156	-26	3157	-25
2000	2671	2528	-143	2531	-140
2001	1472	3159	1687	3100	1629
2002	3718	2681	-1037	2701	-1017
2003	2296	2244	-52	2246	-50
2004	2428	2533	105	2531	102
2005	1641	2435	793	2417	776
2006	2679	2818	140	2815	137
2007	1800	2259	459	2246	446
2008	3434	2687	-748	2701	-733
2009	2541	3307	767	3271	730
2010	1892	2777	885	2758	866
2011	4040	3813	-227	3840	-200

1-December Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	486.62
PRECIPITATION VARIABLES		
Headquarters Cumulative Water Year Precipitation	X10	81.25
REGRESSION EQUATION VARIABLES		
Intercept	C8	1950.56

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	2	686	0.63	651	0.68

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	3314	419	3285	390
1962	3031	2770	-261	2777	-254
1963	1800	3071	1271	3019	1219
1964	3401	2193	-1209	2228	-1173
1965	3304	3165	-139	3174	-130
1966	2145	1691	-454	1722	-423
1967	2689	2611	-78	2613	-76
1968	1971	2964	993	2938	968
1969	2874	2683	-191	2694	-180
1970	2618	1791	-827	1839	-778
1971	4046	3265	-781	3302	-744
1972	4670	3177	-1493	3273	-1397
1973	1327	1559	232	1537	210
1974	4650	3453	-1198	3553	-1098
1975	3217	2857	-360	2890	-327
1976	3361	3738	378	3696	335
1977	1240	1736	497	1696	457
1978	2399	2271	-128	2277	-122
1979	2691	2350	-342	2368	-323
1980	2285	2557	271	2550	265
1981	2160	2083	-77	2087	-74

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1982	3318	2685	-632	2699	-618
1983	2123	1685	-438	1725	-397
1984	2762	3194	431	3177	415
1985	2946	2671	-275	2676	-270
1986	2032	2511	479	2500	468
1987	1510	2067	556	2034	523
1988	1753	1630	-123	1644	-109
1989	2751	3576	825	3501	750
1990	2807	2692	-115	2696	-110
1991	2702	2480	-223	2496	-206
1992	1330	1737	407	1707	377
1993	2199	2471	273	2462	263
1994	1426	1942	516	1907	481
1995	1807	2109	302	2064	257
1996	3070	3315	245	3280	210
1997	4630	3071	-1559	3144	-1486
1998	2058	1920	-138	1930	-128
1999	3182	3352	169	3342	160
2000	2671	2741	70	2738	67
2001	1472	3141	1669	3082	1611
2002	3718	2852	-866	2882	-836
2003	2296	1954	-342	1975	-321
2004	2428	2622	194	2618	190
2005	1641	2401	759	2383	742
2006	2679	2879	200	2874	195
2007	1800	2731	931	2638	839
2008	3434	2563	-871	2586	-848
2009	2541	3214	673	3180	639
2010	1892	2594	702	2568	676
2011	4040	3725	-316	3763	-277

1-January Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	355.71
PRECIPITATION VARIABLES		
Headquarters Cumulative Water Year Precipitation	X11	48.12
SWE VARIABLES		
Cool Creek Jan SWE	X21	9.96
Lost Lake Jan SWE	X41	4.24
Hoodoo Basin Jan SWE	X51	12.22
Elk Butte Jan SWE	X81	6.25
Sherwin Jan SWE	X31	44.69
REGRESSION EQUATION VARIABLES		
Intercept	C1	1119.86

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	2	540	0.79	509	0.82

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2977	82	2979	84
1962	3031	3250	220	3229	199
1963	1800	2376	576	2366	567
1964	3401	2178	-1223	2209	-1193
1965	3304	3751	448	3728	425
1966	2145	1605	-540	1628	-517
1967	2689	2520	-168	2523	-165
1968	1971	2904	934	2884	914
1969	2874	3007	134	2990	116
1970	2618	1795	-823	1830	-788
1971	4046	3298	-748	3330	-717
1972	4670	3854	-816	3935	-735
1973	1327	1784	457	1729	402
1974	4650	3820	-830	3891	-759
1975	3217	2790	-427	2813	-404
1976	3361	3868	507	3821	461
1977	1240	1291	51	1286	46
1978	2399	2875	476	2825	426

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1979	2691	2540	-152	2543	-149
1980	2285	2261	-24	2264	-21
1981	2160	1826	-335	1840	-320
1982	3318	2760	-558	2772	-546
1983	2123	1944	-179	1961	-162
1984	2762	3033	270	3031	269
1985	2946	3445	499	3362	416
1986	2032	2085	53	2089	57
1987	1510	1858	348	1844	333
1988	1753	1413	-340	1440	-313
1989	2751	3126	375	3122	372
1990	2807	2103	-704	2147	-660
1991	2702	2671	-31	2644	-58
1992	1330	1979	648	1897	566
1993	2199	2563	365	2553	355
1994	1426	1763	337	1745	319
1995	1807	2509	702	2445	638
1996	3070	2824	-246	2870	-199
1997	4630	4354	-275	4408	-221
1998	2058	1731	-326	1749	-309
1999	3182	3571	389	3556	374
2000	2671	2788	117	2785	114
2001	1472	2668	1196	2587	1115
2002	3718	2941	-777	2961	-758
2003	2296	1750	-546	1777	-519
2004	2428	2688	259	2681	253
2005	1641	2044	403	2029	388
2006	2679	2611	-68	2622	-57
2007	1800	2505	706	2487	687
2008	3434	2898	-536	2911	-523
2009	2541	2976	435	2955	415
2010	1892	2189	297	2178	285
2011	4040	3457	-583	3535	-505

1-February Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	264.27
PRECIPITATION VARIABLES		
Headquarters Cumulative Water Year Precipitation	X12	27.04
SWE VARIABLES		
Cool Creek Feb SWE	X22	11.35
Lost Lake Feb SWE	X42	7.60
Hoodoo Basin Feb SWE	X52	10.97
Elk Butte Feb SWE	X82	12.06
Sherwin Feb SWE	X32	29.17
REGRESSION EQUATION VARIABLES		
Intercept	C2	572.93

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	2	409	0.89	382	0.90

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2669	-226	2682	-213
1962	3031	3172	141	3166	135
1963	1800	2050	251	2043	244
1964	3401	2640	-761	2650	-751
1965	3304	3882	578	3842	538
1966	2145	2049	-96	2041	-104
1967	2689	3119	431	3099	410
1968	1971	2548	577	2533	563
1969	2874	3434	560	3387	513
1970	2618	2327	-291	2334	-284
1971	4046	3892	-154	3903	-143
1972	4670	4190	-480	4240	-430
1973	1327	1785	458	1749	422
1974	4650	4354	-296	4390	-260
1975	3217	3259	42	3263	46
1976	3361	3713	352	3679	318
1977	1240	1017	-223	1041	-199
1978	2399	2671	272	2649	250

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1979	2691	2186	-505	2208	-483
1980	2285	2181	-104	2185	-100
1981	2160	1261	-900	1340	-821
1982	3318	2996	-322	3004	-314
1983	2123	1859	-264	1875	-247
1984	2762	2651	-112	2658	-105
1985	2946	2820	-126	2819	-126
1986	2032	2059	28	2060	29
1987	1510	1823	313	1813	303
1988	1753	1499	-254	1515	-238
1989	2751	3287	536	3281	530
1990	2807	2539	-268	2547	-260
1991	2702	2666	-36	2650	-52
1992	1330	1994	664	1927	597
1993	2199	2351	153	2350	151
1994	1426	1620	194	1610	184
1995	1807	2321	514	2275	468
1996	3070	2904	-166	2909	-160
1997	4630	4199	-430	4253	-376
1998	2058	1936	-122	1942	-116
1999	3182	3501	319	3492	309
2000	2671	2842	171	2837	166
2001	1472	2061	590	2001	529
2002	3718	3155	-563	3173	-545
2003	2296	1758	-538	1784	-512
2004	2428	2772	344	2764	335
2005	1641	1639	-2	1642	1
2006	2679	2914	236	2911	232
2007	1800	2296	496	2282	483
2008	3434	2976	-458	2986	-448
2009	2541	2818	277	2800	260
2010	1892	1843	-49	1848	-44
2011	4040	3230	-810	3356	-684

1-March Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	220.73
PRECIPITATION VARIABLES		
Headquarters Cumulative Water Year Precipitation	X13	23.39
SWE VARIABLES		
Lost Lake Mar SWE	X43	6.99
Hoodoo Basin Mar SWE	X53	10.01
Crater Meadows Mar SWE	X63	13.06
Elk Butte Mar SWE	X83	10.16
Sherwin Mar SWE	X33	25.42
REGRESSION EQUATION VARIABLES		
Intercept	C3	296.75

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	2	358	0.91	337	0.92

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2795	-100	2801	-94
1962	3031	3055	24	3052	21
1963	1800	1898	99	1903	103
1964	3401	2711	-691	2718	-684
1965	3304	3718	415	3693	390
1966	2145	2163	18	2155	10
1967	2689	3256	567	3222	533
1968	1971	2485	514	2477	506
1969	2874	3285	411	3255	381
1970	2618	2397	-221	2405	-213
1971	4046	3583	-463	3608	-438
1972	4670	4639	-31	4639	-31
1973	1327	1622	295	1600	274
1974	4650	4419	-232	4440	-210
1975	3217	3307	90	3306	89
1976	3361	3607	246	3585	224
1977	1240	1016	-224	1038	-202
1978	2399	2519	120	2511	112

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1979	2691	2520	-172	2525	-166
1980	2285	2014	-271	2026	-259
1981	2160	1408	-753	1458	-702
1982	3318	3057	-260	3064	-254
1983	2123	2062	-61	2066	-56
1984	2762	2497	-265	2517	-246
1985	2946	2749	-197	2751	-195
1986	2032	2231	199	2228	196
1987	1510	1769	259	1760	249
1988	1753	1582	-171	1593	-160
1989	2751	3096	345	3079	329
1990	2807	2676	-131	2681	-126
1991	2702	2491	-211	2487	-216
1992	1330	1809	479	1754	424
1993	2199	2162	-36	2166	-33
1994	1426	1753	327	1739	313
1995	1807	2134	327	2106	299
1996	3070	2913	-157	2918	-151
1997	4630	4221	-408	4253	-377
1998	2058	1789	-269	1803	-254
1999	3182	3939	756	3881	699
2000	2671	2896	225	2889	218
2001	1472	1998	527	1948	477
2002	3718	3085	-633	3102	-616
2003	2296	1987	-309	2001	-295
2004	2428	2650	222	2645	217
2005	1641	1584	-57	1592	-49
2006	2679	2877	198	2875	196
2007	1800	2389	589	2374	574
2008	3434	3116	-319	3124	-310
2009	2541	2703	162	2696	155
2010	1892	1681	-211	1702	-190
2011	4040	3496	-544	3579	-461

1-April Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	171.32
PRECIPITATION VARIABLES		
Headquarters Cumulative Water Year Precipitation	X13	22.32
SWE VARIABLES		
Lost Lake Apr SWE	X44	7.91
Hoodoo Basin Apr SWE	X54	10.27
Crater Meadows Apr SWE	X64	13.37
Elk Butte Apr SWE	X84	11.61
Sherwin Apr SWE	X34	19.49
REGRESSION EQUATION VARIABLES		
Intercept	C4	-15.43

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	2	298	0.94	279	0.95

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2925	30	2926	31
1962	3031	3187	157	3182	151
1963	1800	2096	296	2083	284
1964	3401	3244	-158	3223	-178
1965	3304	3698	394	3675	372
1966	2145	2328	183	2314	169
1967	2689	3140	452	3122	433
1968	1971	2362	392	2352	382
1969	2874	3030	156	3020	146
1970	2618	2555	-63	2557	-60
1971	4046	3660	-386	3680	-366
1972	4670	4394	-276	4419	-251
1973	1327	1576	249	1559	232
1974	4650	4366	-285	4395	-255
1975	3217	3396	179	3390	173
1976	3361	3555	194	3545	184
1977	1240	1268	28	1266	26
1978	2399	2269	-130	2270	-129

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1979	2691	2345	-346	2355	-336
1980	2285	2133	-152	2139	-147
1981	2160	1314	-846	1375	-786
1982	3318	3072	-246	3078	-239
1983	2123	2092	-30	2090	-33
1984	2762	2559	-203	2571	-192
1985	2946	2770	-176	2770	-176
1986	2032	2056	25	2057	25
1987	1510	1784	273	1774	264
1988	1753	1817	64	1815	62
1989	2751	3210	459	3186	435
1990	2807	2526	-280	2536	-271
1991	2702	2680	-22	2676	-27
1992	1330	1561	230	1539	209
1993	2199	2063	-136	2070	-129
1994	1426	1546	120	1540	114
1995	1807	2113	306	2087	280
1996	3070	2786	-284	2794	-275
1997	4630	4532	-98	4524	-106
1998	2058	1675	-382	1696	-361
1999	3182	3876	694	3830	648
2000	2671	2860	189	2854	183
2001	1472	1677	206	1666	194
2002	3718	3388	-330	3402	-316
2003	2296	2347	50	2343	47
2004	2428	2393	-35	2395	-33
2005	1641	1566	-75	1574	-68
2006	2679	2756	78	2758	79
2007	1800	2011	211	2006	206
2008	3434	3323	-111	3324	-110
2009	2541	2881	341	2860	319
2010	1892	1547	-345	1582	-310
2011	4040	3468	-573	3547	-493

1-May Forecast

Dependant Variable

1-May to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	122.04
SWE VARIABLES		
Lost Lake May SWE	X45	9.67
Hoodoo Basin May SWE	X55	11.71
Hemlock Butte May SWE	X75	11.58
Shanghi Summit May SWE	X95	14.41
REGRESSION EQUATION VARIABLES		
Intercept	C5	84.24

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	250	0.95	238	0.95

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2206	2553	348	2542	336
1962	2005	2114	109	2112	107
1963	1317	1637	320	1629	312
1964	2872	2777	-95	2784	-88
1965	2215	2683	468	2665	451
1966	1445	1599	154	1599	153
1967	2262	2382	120	2379	117
1968	1555	1980	425	1971	416
1969	1883	2100	218	2094	212
1970	2259	2232	-27	2238	-21
1971	3324	2976	-348	2996	-328
1972	3916	3583	-333	3619	-297
1973	1025	1348	324	1338	314
1974	3650	3444	-206	3461	-188
1975	2824	2774	-49	2775	-49
1976	2567	2737	170	2724	157
1977	860	533	-326	567	-293
1978	1746	1627	-119	1630	-115
1979	2085	2076	-9	2076	-9
1980	1631	1248	-383	1264	-367
1981	1635	992	-642	1028	-607

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1982	2664	2678	14	2677	13
1983	1682	1638	-44	1649	-34
1984	2140	2038	-102	2040	-100
1985	2110	2180	70	2178	68
1986	1354	1601	247	1595	241
1987	917	990	73	989	72
1988	1102	1090	-12	1091	-11
1989	1781	2148	367	2127	346
1990	1831	1713	-118	1715	-115
1991	2075	2130	55	2127	52
1992	818	1061	243	1049	231
1993	1618	1734	116	1732	114
1994	860	935	74	931	71
1995	1366	1571	205	1572	207
1996	2069	1994	-75	1995	-74
1997	3595	3469	-126	3474	-121
1998	1547	1100	-446	1121	-426
1999	2567	2801	233	2790	223
2000	1725	1708	-17	1709	-17
2001	1128	1357	229	1346	217
2002	2836	2548	-288	2557	-279
2003	1575	1584	10	1584	10
2004	1767	1418	-349	1430	-337
2005	1131	996	-134	1005	-126
2006	1860	1919	59	1917	57
2007	1230	1366	136	1361	131
2008	3111	2722	-390	2732	-379
2009	1908	2107	199	2100	192
2010	1510	1231	-278	1242	-267
2011	3260	3076	-184	3088	-173

1-June Forecast

Dependant Variable

1-June to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SWE VARIABLES		
Lost Lake Jun SWE	X46	6.14
Hoodoo Basin Jun SWE	X56	8.21
Hemlock Butte Jun SWE	X76	7.57
Shanghi Summit May SWE	X95	10.26
REGRESSION EQUATION VARIABLES		
Intercept	C6	138.78

2011PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
45	1	159	0.95	150	0.96

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1967	1215	1400	185	1392	177
1968	795	867	72	865	70
1969	705	883	179	880	175
1970	1206	1302	96	1297	91
1971	1503	1441	-62	1444	-59
1972	1962	1946	-15	1948	-14
1973	440	506	67	506	66
1974	2365	1986	-379	2033	-332
1975	1703	1658	-45	1660	-43
1976	1063	1070	6	1069	6
1977	340	253	-87	260	-80
1978	910	1022	112	1020	109
1979	740	972	232	966	226
1980	740	596	-144	603	-137
1981	924	378	-546	407	-517
1982	1431	1461	30	1459	28
1983	867	957	90	955	88
1984	1175	1217	42	1216	40
1985	913	951	37	950	36
1986	548	631	82	628	80
1987	311	250	-61	254	-56
1988	475	505	30	505	30
1989	806	1069	263	1063	257

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1990	1024	955	-69	958	-67
1991	1062	1138	76	1135	74
1992	276	277	2	277	2
1993	551	602	51	601	50
1994	356	232	-124	242	-114
1995	641	752	110	749	107
1996	975	1134	159	1130	156
1997	1647	1811	163	1794	146
1998	577	511	-66	514	-63
1999	1534	1543	9	1542	8
2000	748	820	72	818	71
2001	410	417	7	418	8
2002	1644	1529	-116	1534	-110
2003	731	838	108	836	105
2004	812	731	-81	733	-78
2005	411	312	-99	318	-92
2006	763	799	37	800	37
2007	452	549	97	546	93
2008	1795	1497	-299	1508	-287
2009	839	981	141	977	138
2010	892	655	-236	663	-229
2011	1997	1784	-213	1802	-196

Appendix B – 2005 Principle Components Regression Forecast Data

1-November Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	569.47
REGRESSION EQUATION VARIABLES		
Intercept	C1	2587.57

2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	705	0.59	678	0.63

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2989	94	2986	91
1962	3031	2637	-394	2645	-386
1963	1800	2838	1039	2815	1016
1964	3401	2211	-1190	2246	-1156
1965	3304	3329	26	3328	24
1966	2145	1828	-317	1847	-298
1967	2689	2469	-219	2474	-215
1968	1971	2894	924	2872	902
1969	2874	2406	-468	2417	-457
1970	2618	1990	-627	2018	-600
1971	4046	3232	-814	3271	-775
1972	4670	3305	-1365	3385	-1285
1973	1327	1823	496	1790	464
1974	4650	3202	-1448	3271	-1379
1975	3217	3214	-3	3214	-3
1976	3361	3836	475	3783	423
1977	1240	1998	758	1961	721
1978	2399	2122	-277	2132	-267
1979	2691	2644	-48	2645	-47
1980	2285	2652	367	2645	359
1981	2160	2307	146	2303	142
1982	3318	2747	-571	2758	-559

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1983	2123	1572	-551	1619	-503
1984	2762	3112	350	3100	338
1985	2946	2638	-307	2645	-301
1986	2032	2599	567	2588	556
1987	1510	2324	814	2303	792
1988	1753	2030	277	2018	265
1989	2751	3693	942	3613	862
1990	2807	2874	67	2872	66
1991	2702	2172	-530	2189	-513
1992	1330	1765	435	1733	403
1993	2199	2653	455	2645	446
1994	1426	2214	788	2189	763
1995	1807	1665	-142	1676	-131
1996	3070	2752	-318	2758	-311
1997	4630	2884	-1745	2929	-1700
1998	2058	1771	-286	1790	-267
1999	3182	3156	-26	3157	-25
2000	2671	2528	-143	2531	-140
2001	1472	3159	1687	3100	1629
2002	3718	2681	-1037	2701	-1017
2003	2296	2244	-52	2246	-50
2004	2428	2533	105	2531	102
2005	1641	2435	793	2417	776
2006	2679	2818	140	2815	137
2007	1800	2259	459	2246	446
2008	3434	2687	-748	2701	-733
2009	2541	3307	767	3271	730
2010	1892	2777	885	2758	866
2011	4040	3813	-227	3840	-200

1-December Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	367.73
PRECIPITATION VARIABLES		
Headquarters November Precipitation	X2	164.92
REGRESSION EQUATION VARIABLES		
Intercept	C2	1779.43

2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	688	0.62	659	0.66

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	3459	564	3424	529
1962	3031	2683	-347	2690	-341
1963	1800	2746	946	2726	927
1964	3401	2429	-972	2451	-950
1965	3304	3041	-263	3044	-259
1966	2145	1925	-220	1940	-205
1967	2689	2564	-124	2567	-122
1968	1971	2438	468	2430	460
1969	2874	2557	-317	2563	-311
1970	2618	1493	-1125	1590	-1028
1971	4046	3174	-872	3207	-839
1972	4670	3082	-1588	3134	-1536
1973	1327	1589	263	1566	240
1974	4650	3863	-787	3961	-690
1975	3217	2980	-237	2984	-233
1976	3361	3261	-99	3243	-118
1977	1240	1696	456	1660	420
1978	2399	2461	62	2462	63
1979	2691	2562	-129	2565	-126
1980	2285	2274	-11	2276	-9
1981	2160	2265	104	2262	101

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1982	3318	2670	-647	2683	-635
1983	2123	1706	-417	1743	-380
1984	2762	3350	587	3321	558
1985	2946	2769	-177	2773	-173
1986	2032	2463	432	2454	422
1987	1510	2118	607	2095	585
1988	1753	1700	-53	1704	-49
1989	2751	3548	798	3487	736
1990	2807	2543	-263	2549	-258
1991	2702	2459	-243	2465	-237
1992	1330	2111	781	2092	762
1993	2199	2537	339	2530	332
1994	1426	1931	505	1905	479
1995	1807	2481	674	2474	667
1996	3070	3370	301	3348	278
1997	4630	3115	-1515	3173	-1457
1998	2058	1838	-219	1855	-202
1999	3182	3676	494	3633	451
2000	2671	2735	64	2734	63
2001	1472	2631	1159	2608	1137
2002	3718	2613	-1105	2635	-1083
2003	2296	2047	-249	2057	-239
2004	2428	2838	409	2828	400
2005	1641	2345	704	2327	686
2006	2679	2807	128	2804	125
2007	1800	3470	1671	3338	1538
2008	3434	2390	-1045	2414	-1021
2009	2541	3330	789	3291	750
2010	1892	2383	491	2373	481
2011	4040	3341	-699	3354	-687

1-January Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	335.76
PRECIPITATION VARIABLES		
Headquarters November Precipitation	X2	63.63
Headquarters December Precipitation	X5	73.57
SWE VARIABLES		
Pierce Ranger Station Jan SWE	X10	48.18
Hoodoo Basin Jan SWE	X12	12.05
Elk Butte Jan SWE	X14	5.94
Hemlock Butte Jan SWE	X15	11.29
REGRESSION EQUATION VARIABLES		
Intercept	C3	1175.10

2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	2	574	0.76	534	0.80

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2888	-7	2919	23
1962	3031	3197	166	3166	136
1963	1800	2221	422	2225	426
1964	3401	2249	-1153	2276	-1126
1965	3304	3885	581	3885	581
1966	2145	1599	-546	1623	-522
1967	2689	2462	-226	2467	-222
1968	1971	2659	688	2652	682
1969	2874	3000	127	2982	108
1970	2618	1716	-902	1756	-862
1971	4046	3242	-804	3274	-772
1972	4670	3369	-1301	3493	-1177
1973	1327	1934	608	1855	528
1974	4650	3952	-698	4028	-622
1975	3217	2932	-285	2946	-271
1976	3361	3678	317	3685	325
1977	1240	1277	37	1272	32
1978	2399	3068	669	2995	596

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1979	2691	2670	-21	2672	-19
1980	2285	2290	5	2295	10
1981	2160	1909	-252	1926	-234
1982	3318	2883	-435	2894	-424
1983	2123	1875	-248	1900	-222
1984	2762	3004	242	3015	253
1985	2946	3254	308	3195	249
1986	2032	2027	-4	2045	14
1987	1510	1859	348	1844	334
1988	1753	1490	-263	1506	-247
1989	2751	3054	304	3098	348
1990	2807	2021	-785	2086	-721
1991	2702	2430	-272	2404	-298
1992	1330	2129	799	2033	703
1993	2199	2576	378	2566	367
1994	1426	1798	372	1778	352
1995	1807	2654	847	2495	688
1996	3070	2602	-468	2749	-320
1997	4630	4265	-364	4268	-361
1998	2058	1696	-362	1714	-343
1999	3182	3692	510	3675	493
2000	2671	2797	126	2793	122
2001	1472	2532	1061	2506	1034
2002	3718	2827	-891	2846	-872
2003	2296	1896	-400	1913	-383
2004	2428	2813	384	2801	373
2005	1641	2045	404	2030	389
2006	2679	2640	-39	2653	-26
2007	1800	2796	997	2647	847
2008	3434	2854	-580	2866	-568
2009	2541	3219	678	3193	652
2010	1892	2245	353	2239	347
2011	4040	3496	-544	3639	-401

1-February Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	116.44
SWE VARIABLES		
Pierce Ranger Station Feb SWE	X17	50.18
Hoodoo Basin Feb SWE	X19	19.24
Elk Butte Feb SWE	X21	21.02
Hemlock Butte Feb SWE	X22	18.15
ANTECEDENT STREAMFLOW VARIABLES		
Dworshak January Flow	X48	0.79
REGRESSION EQUATION VARIABLES		
Intercept	C4	409.32

2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	415	0.88	401	0.89

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2359	-536	2371	-524
1962	3031	3188	157	3184	153
1963	1800	1770	-30	1770	-29
1964	3401	2922	-480	2937	-464
1965	3304	3859	555	3826	523
1966	2145	2361	216	2360	215
1967	2689	3095	406	3085	396
1968	1971	2455	485	2445	474
1969	2874	3540	666	3513	639
1970	2618	2316	-302	2324	-294
1971	4046	3951	-95	3957	-89
1972	4670	4249	-421	4303	-367
1973	1327	2060	733	2040	714
1974	4650	4603	-47	4630	-20
1975	3217	3139	-78	3140	-77
1976	3361	3589	228	3576	216
1977	1240	983	-257	1009	-231
1978	2399	2897	498	2889	490
1979	2691	2183	-508	2194	-497

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1980	2285	2180	-105	2184	-102
1981	2160	1314	-846	1366	-795
1982	3318	3079	-238	3088	-230
1983	2123	2003	-120	2011	-112
1984	2762	2471	-291	2476	-287
1985	2946	2878	-68	2885	-61
1986	2032	2117	86	2115	83
1987	1510	1894	383	1878	367
1988	1753	1684	-69	1685	-68
1989	2751	3061	311	3052	301
1990	2807	2426	-381	2434	-372
1991	2702	2743	41	2744	41
1992	1330	2238	908	2220	890
1993	2199	2441	242	2437	239
1994	1426	1684	258	1671	245
1995	1807	2510	703	2508	701
1996	3070	2709	-360	2708	-362
1997	4630	4176	-454	4221	-409
1998	2058	1987	-70	1991	-67
1999	3182	3324	142	3320	138
2000	2671	2739	68	2737	66
2001	1472	1812	341	1792	320
2002	3718	3117	-601	3131	-587
2003	2296	1796	-500	1819	-477
2004	2428	2688	260	2684	256
2005	1641	1673	32	1665	24
2006	2679	2752	73	2749	70
2007	1800	2191	391	2180	380
2008	3434	2811	-624	2827	-607
2009	2541	2706	165	2700	159
2010	1892	1775	-117	1780	-112
2011	4040	3169	-871	3180	-860

1-March Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	123.33
SWE VARIABLES		
Pierce Ranger Station Mar SWE	X24	38.57
Hoodoo Basin Mar SWE	X26	15.41
Elk Butte Mar SWE	X28	15.95
Hemlock Butte Mar SWE	X29	15.98
ANTECEDENT STREAMFLOW VARIABLES		
Dworshak January Flow	X48	0.86
Dworshak February Flow	X49	0.22
REGRESSION EQUATION VARIABLES		
Intercept	C5	307.66

2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	373	0.91	358	0.91

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	2654	-241	2657	-238
1962	3031	2816	-214	2821	-210
1963	1800	1822	23	1818	19
1964	3401	2773	-628	2792	-610
1965	3304	3848	545	3818	515
1966	2145	2286	141	2284	139
1967	2689	3138	450	3126	438
1968	1971	2300	329	2284	313
1969	2874	3324	450	3311	437
1970	2618	2485	-132	2492	-126
1971	4046	3544	-502	3572	-474
1972	4670	4766	96	4752	82
1973	1327	1926	599	1902	576
1974	4650	5011	361	4965	314
1975	3217	3219	2	3223	6
1976	3361	3605	244	3590	230
1977	1240	1123	-117	1127	-113
1978	2399	2704	305	2700	301

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1979	2691	2580	-111	2584	-107
1980	2285	1994	-291	2004	-282
1981	2160	1648	-512	1660	-500
1982	3318	3091	-227	3103	-214
1983	2123	2263	140	2269	146
1984	2762	2444	-318	2450	-313
1985	2946	2760	-186	2770	-176
1986	2032	2435	404	2424	392
1987	1510	1853	342	1837	326
1988	1753	1755	2	1750	-3
1989	2751	2893	142	2883	133
1990	2807	2761	-46	2762	-45
1991	2702	2501	-201	2505	-197
1992	1330	1979	648	1959	629
1993	2199	2135	-64	2135	-64
1994	1426	1864	438	1842	416
1995	1807	2285	478	2258	451
1996	3070	2994	-76	2945	-124
1997	4630	3985	-644	4037	-592
1998	2058	1881	-176	1889	-169
1999	3182	3803	621	3763	581
2000	2671	2782	111	2779	108
2001	1472	1808	336	1781	310
2002	3718	2943	-775	2961	-757
2003	2296	1934	-362	1940	-356
2004	2428	2479	51	2479	51
2005	1641	1463	-178	1466	-175
2006	2679	2672	-7	2670	-8
2007	1800	2275	475	2264	464
2008	3434	2867	-568	2885	-549
2009	2541	2479	-62	2474	-67
2010	1892	1604	-288	1616	-277
2011	4040	3391	-649	3409	-632

1-April Forecast

Dependant Variable

1-April to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	123.36
SWE VARIABLES		
Shanghi Summit Apr SWE	X30	17.92
Hoodoo Basin Apr SWE	X33	13.92
Elk Butte Apr SWE	X35	15.71
Hemlock Butte Apr SWE	X36	15.31
ANTECEDENT STREAMFLOW VARIABLES		
Dworshak January Flow	X48	0.75
Dworshak February Flow	X49	0.21
Dworshak March Flow	X50	0.44
REGRESSION EQUATION VARIABLES		
Intercept	C6	-141.94

2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	296	0.94	283	0.95

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2895	3044	149	3045	149
1962	3031	3081	51	3087	56
1963	1800	1990	190	1983	183
1964	3401	3129	-273	3162	-239
1965	3304	3629	326	3619	315
1966	2145	2327	182	2325	180
1967	2689	3056	368	3049	361
1968	1971	2282	311	2264	294
1969	2874	2923	49	2921	47
1970	2618	2650	33	2654	36
1971	4046	3692	-354	3721	-325
1972	4670	4597	-73	4682	12
1973	1327	1786	460	1762	436
1974	4650	4514	-136	4545	-106
1975	3217	3114	-103	3127	-90
1976	3361	3450	89	3446	85
1977	1240	1263	23	1245	5

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1978	2399	2275	-124	2276	-123
1979	2691	2351	-340	2359	-332
1980	2285	2056	-229	2061	-224
1981	2160	1480	-680	1507	-654
1982	3318	3197	-120	3210	-107
1983	2123	2397	274	2400	277
1984	2762	2620	-142	2623	-140
1985	2946	2799	-147	2810	-136
1986	2032	2406	375	2328	297
1987	1510	1837	327	1822	311
1988	1753	1822	69	1813	60
1989	2751	3108	357	3101	351
1990	2807	2598	-209	2602	-205
1991	2702	2570	-132	2573	-129
1992	1330	1547	217	1537	207
1993	2199	2009	-190	2011	-187
1994	1426	1532	106	1519	93
1995	1807	2231	424	2195	388
1996	3070	2781	-289	2702	-368
1997	4630	4442	-187	4464	-165
1998	2058	1733	-325	1747	-310
1999	3182	3951	769	3899	717
2000	2671	2887	216	2882	211
2001	1472	1575	104	1549	78
2002	3718	3325	-393	3340	-378
2003	2296	2493	197	2482	186
2004	2428	2363	-65	2365	-63
2005	1641	1423	-218	1431	-210
2006	2679	2675	-4	2673	-5
2007	1800	2112	313	2094	295
2008	3434	3104	-330	3128	-306
2009	2541	2731	191	2725	184
2010	1892	1468	-424	1483	-409
2011	4040	3423	-617	3440	-601

1-May Forecast

Dependant Variable

1-May to 31-July Volume (KAF)

Independent Variable Name	Variable Symbol	Coefficient
SOUTHERN OSCILLATION INDEX VARIABLES		
September SOI	X1	96.46
SWE VARIABLES		
Shanghi Summit May SWE	X37	11.93
Lost Lake May SWE	X38	7.99
Hoodoo Basin May SWE	X39	9.54
Elk Butte May SWE	X41	10.48
Hemlock Butte May SWE	X42	9.52
REGRESSION EQUATION VARIABLES		
Intercept	C7	86.63

2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	249	0.95	237	0.95

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1961	2206	2511	305	2502	296
1962	2005	2062	57	2061	56
1963	1317	1565	248	1558	242
1964	2872	2863	-9	2866	-6
1965	2215	2545	330	2534	319
1966	1445	1605	160	1603	158
1967	2262	2422	160	2418	156
1968	1555	1892	337	1886	330
1969	1883	2041	159	2037	154
1970	2259	2287	28	2291	32
1971	3324	2948	-376	2969	-355
1972	3916	3459	-457	3502	-414
1973	1025	1324	300	1314	290
1974	3650	3421	-229	3441	-208
1975	2824	2777	-47	2778	-46
1976	2567	2694	127	2684	117
1977	860	519	-341	553	-306
1978	1746	1524	-222	1531	-215
1979	2085	2043	-42	2043	-42
1980	1631	1168	-463	1189	-442

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1981	1635	914	-721	958	-677
1982	2664	2597	-66	2599	-65
1983	1682	1707	25	1715	33
1984	2140	2097	-43	2098	-42
1985	2110	2229	119	2226	116
1986	1354	1601	247	1595	241
1987	917	967	50	966	50
1988	1102	1108	6	1108	6
1989	1781	2118	337	2101	320
1990	1831	1752	-79	1753	-77
1991	2075	2171	96	2168	93
1992	818	1112	295	1099	281
1993	1618	1809	191	1806	188
1994	860	948	88	944	83
1995	1366	1640	274	1639	274
1996	2069	1967	-102	1968	-101
1997	3595	3582	-12	3576	-19
1998	1547	1130	-416	1149	-398
1999	2567	2842	274	2829	262
2000	1725	1791	66	1790	65
2001	1128	1353	224	1342	214
2002	2836	2634	-202	2640	-196
2003	1575	1618	44	1618	43
2004	1767	1453	-314	1463	-304
2005	1131	993	-138	1002	-129
2006	1860	1907	47	1906	46
2007	1230	1395	165	1389	159
2008	3111	2793	-318	2803	-308
2009	1908	2088	180	2082	174
2010	1510	1221	-288	1233	-277
2011	3260	3076	-185	3088	-172

1-June Forecast

Dependant Variable

1-June to 31-July Volume (KAF)

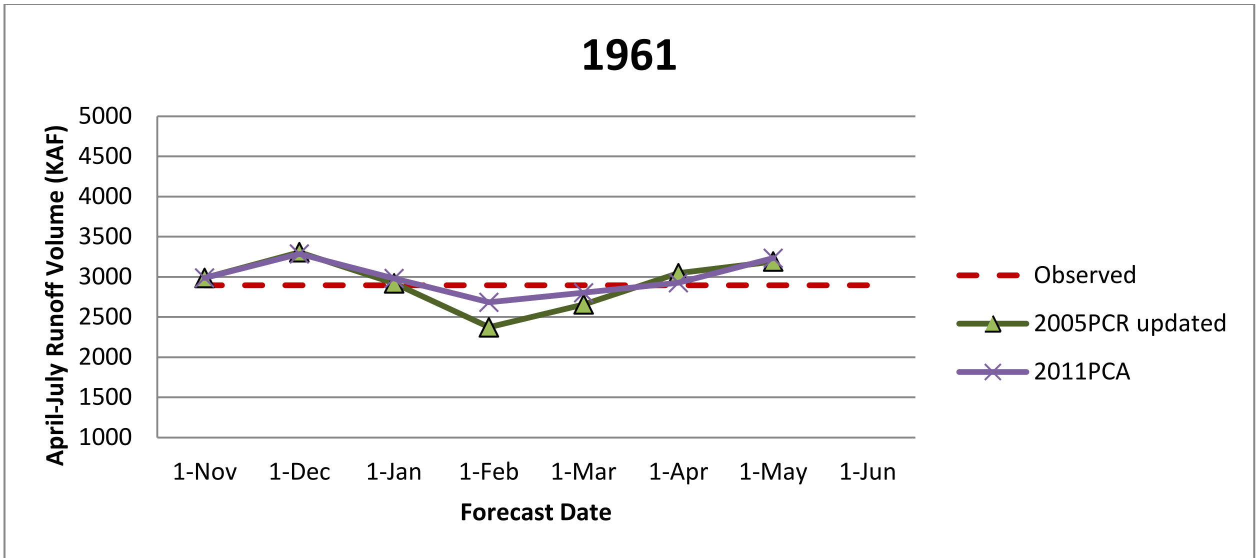
Independent Variable Name	Variable Symbol	Coefficient
SWE VARIABLES		
Shanghi Summit May SWE	X37	8.40
Lost Lake June SWE	X43	5.10
Hoodoo Basin June SWE	X44	6.73
Elk Butte June SWE	X46	6.84
Hemlock Butte June SWE	X47	6.24
REGRESSION EQUATION VARIABLES		
Intercept	C8	145.39

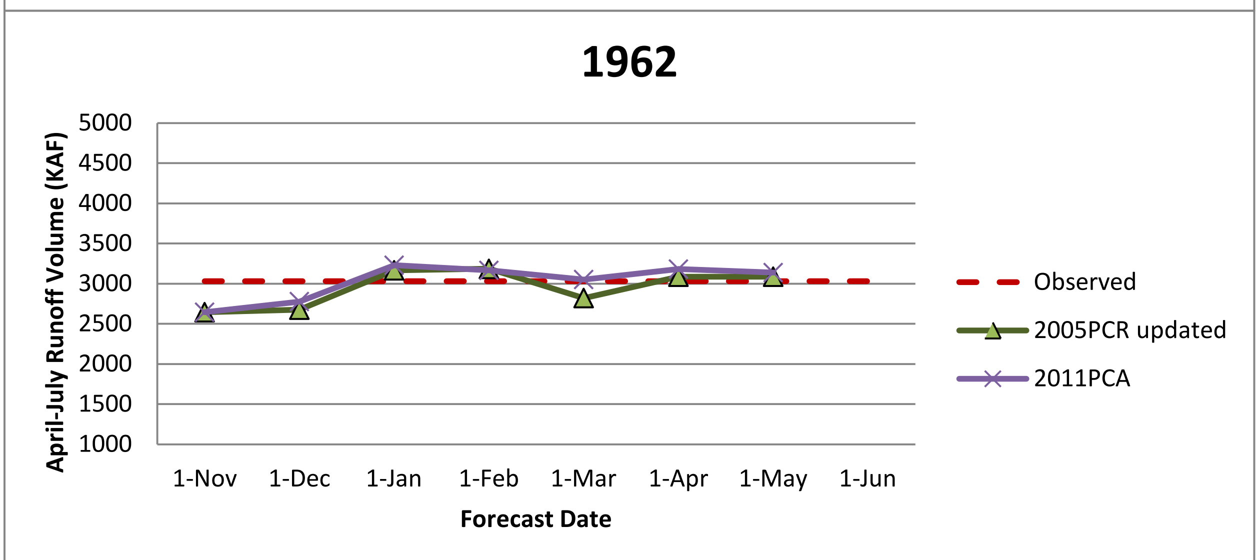
2005PCA Statistics					
Observations	Number of Principal Components	Jackknife Standard Error (CVSE)	Jackknife R	Standard Error	R
51	1	154	0.95	145	0.96

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1967	1215	1484	270	1470	255
1968	795	796	1	796	2
1969	705	811	107	809	105
1970	1206	1151	-55	1152	-54
1971	1503	1502	-1	1502	-2
1972	1962	2001	40	1996	34
1973	440	502	62	501	61
1974	2365	2023	-342	2069	-296
1975	1703	1699	-4	1698	-5
1976	1063	961	-102	964	-99
1977	340	295	-45	299	-41
1978	910	924	13	924	14
1979	740	1018	279	1012	272
1980	740	684	-56	688	-52
1981	924	392	-532	420	-504
1982	1431	1277	-154	1285	-145
1983	867	959	92	957	90
1984	1175	1275	100	1271	96
1985	913	941	28	940	27
1986	548	603	55	601	53
1987	311	292	-18	294	-17
1988	475	507	31	506	31

Year	Observed (KAF)	Jackknife Regression	Jackknife Regression Error	Standard Regression	Standard Regression Error
1989	806	1083	278	1077	271
1990	1024	991	-33	993	-31
1991	1062	1141	79	1138	76
1992	276	315	39	313	37
1993	551	592	41	591	40
1994	356	276	-79	283	-72
1995	641	734	93	732	90
1996	975	1107	133	1103	129
1997	1647	1807	160	1791	144
1998	577	504	-73	508	-69
1999	1534	1555	21	1554	20
2000	748	857	109	855	107
2001	410	428	18	428	18
2002	1644	1582	-62	1585	-60
2003	731	832	102	830	99
2004	812	734	-78	736	-76
2005	411	342	-69	347	-64
2006	763	764	2	765	2
2007	452	547	95	543	91
2008	1795	1500	-295	1513	-283
2009	839	940	100	937	98
2010	892	649	-242	657	-235
2011	1997	1826	-172	1841	-157

Appendix C – Period of Record Hindcast Plots


1961
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA


1962
April-July Runoff Volume (KAF)
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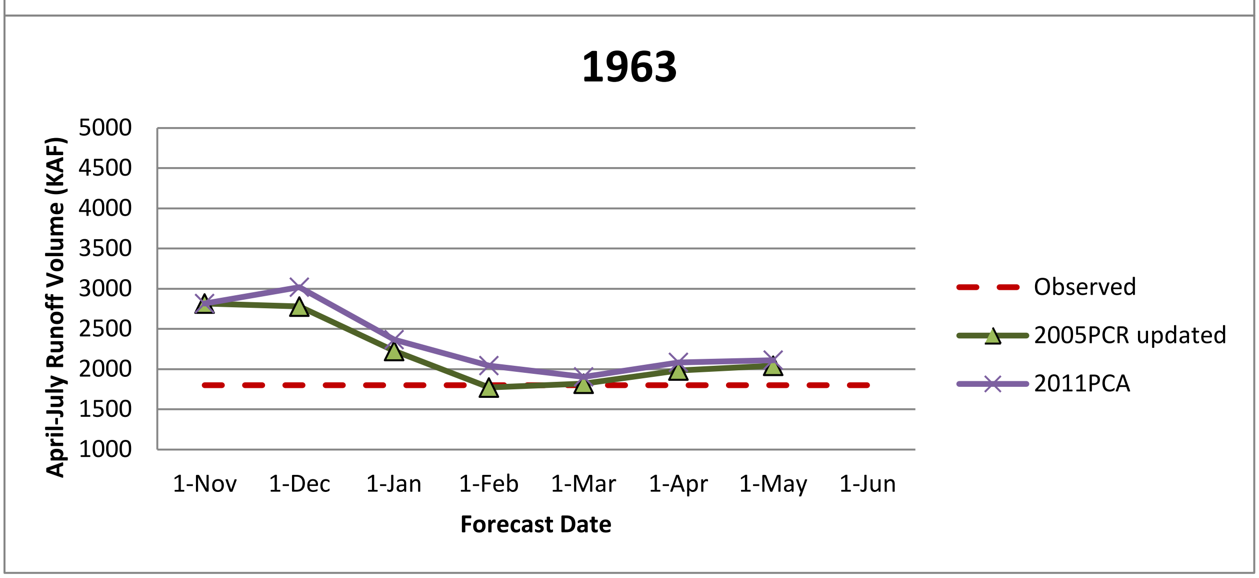
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA


1963
April-July Runoff Volume (KAF)
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1-Jun
Forecast Date
Observed
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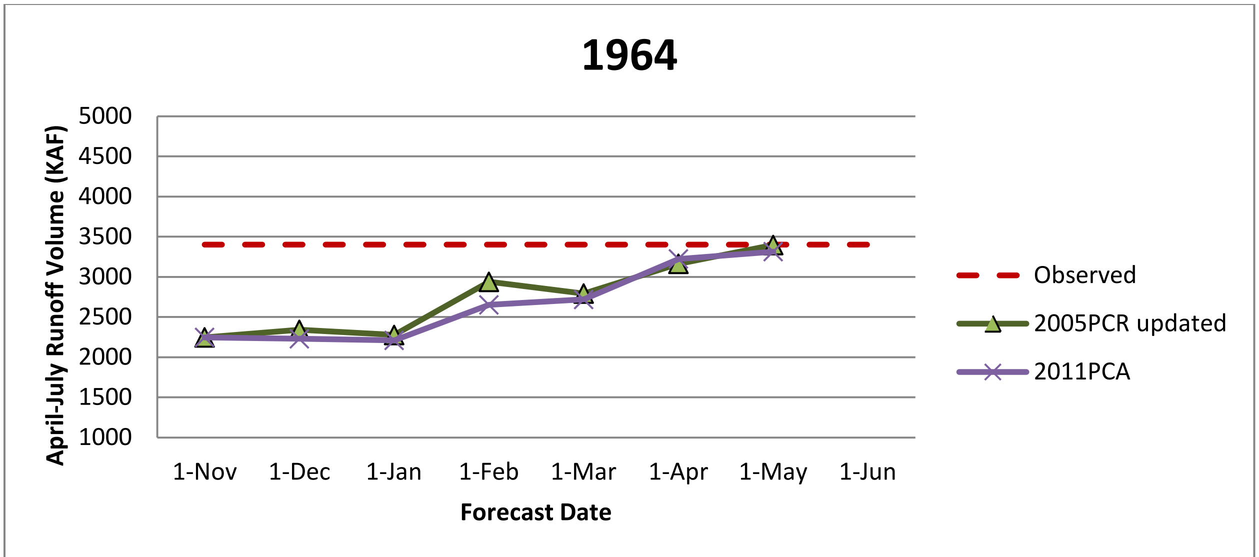
2011PCA


1964
April-July Runoff Volume (KAF)
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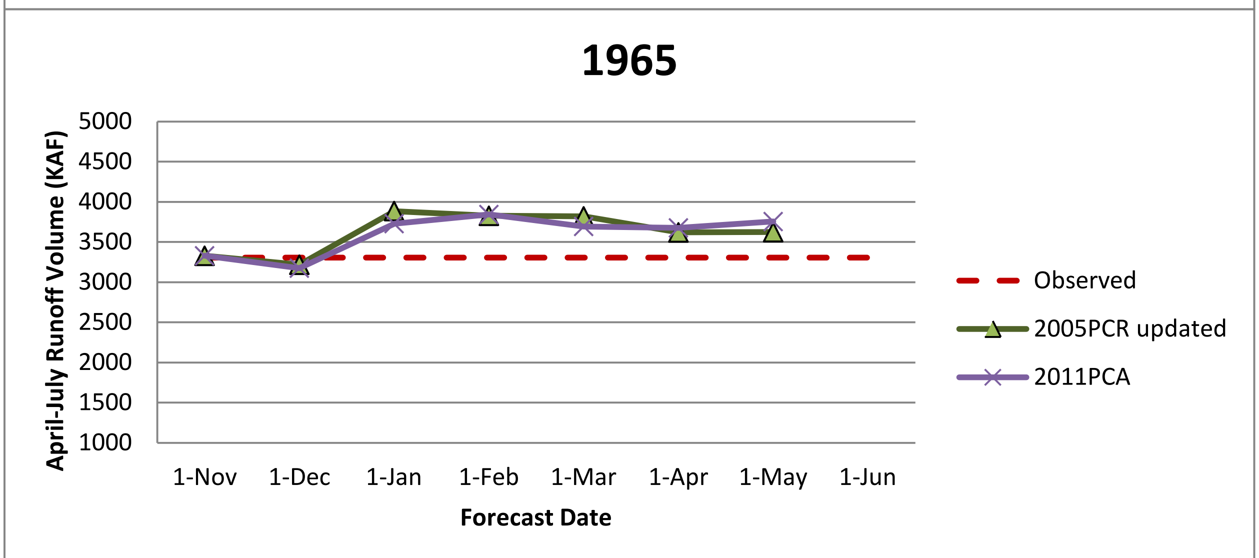
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA


1965
April-July Runoff Volume (KAF)
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Forecast Date
Observed
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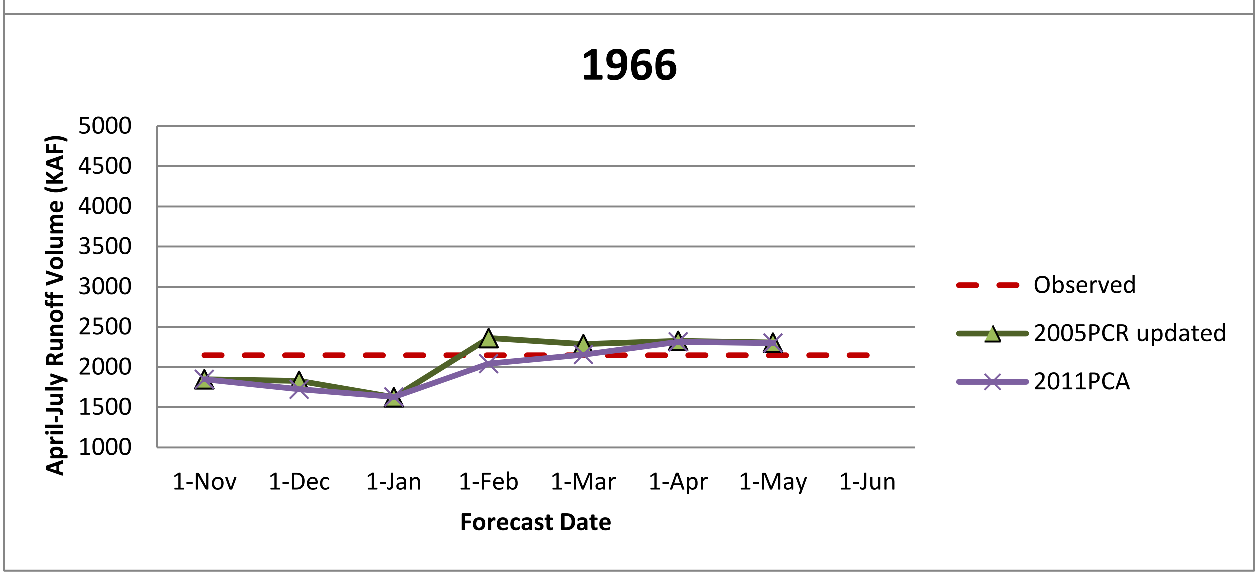
2011PCA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April-July Runoff Volume (KAF)
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Forecast Date
Observed
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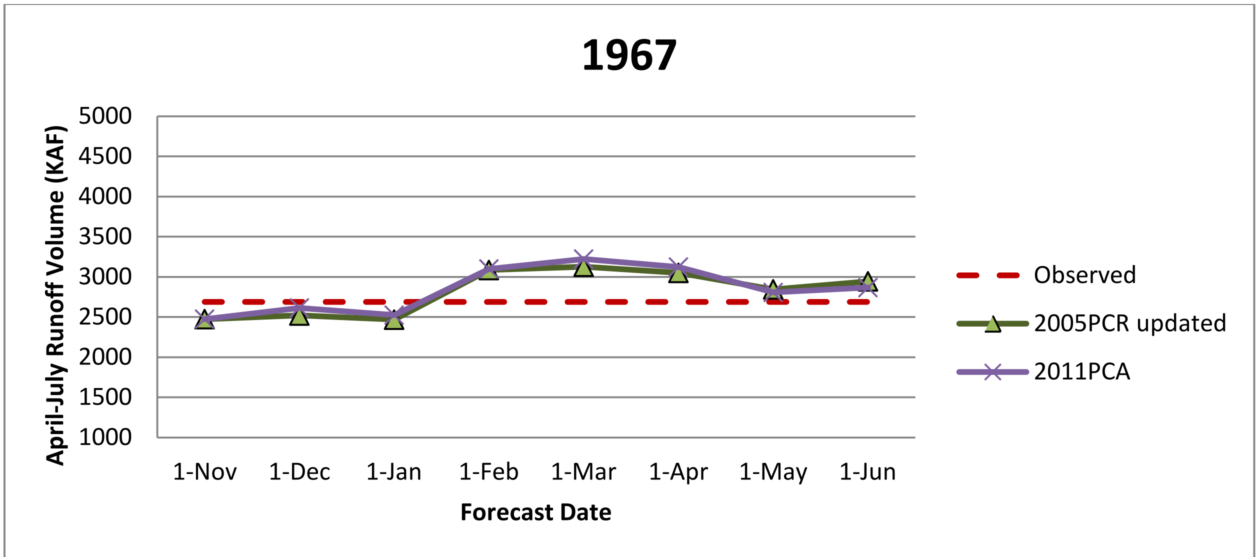
2011PCA


1967
April-July Runoff Volume (KAF)
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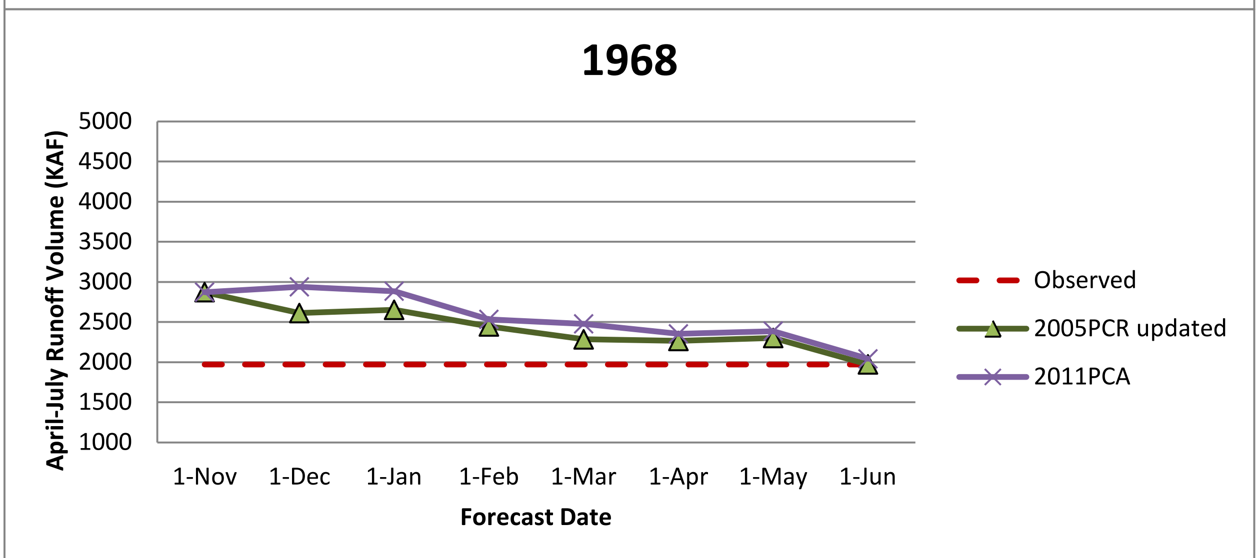
Forecast Date
Observed
2005PCR updated
2011PCA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Observed
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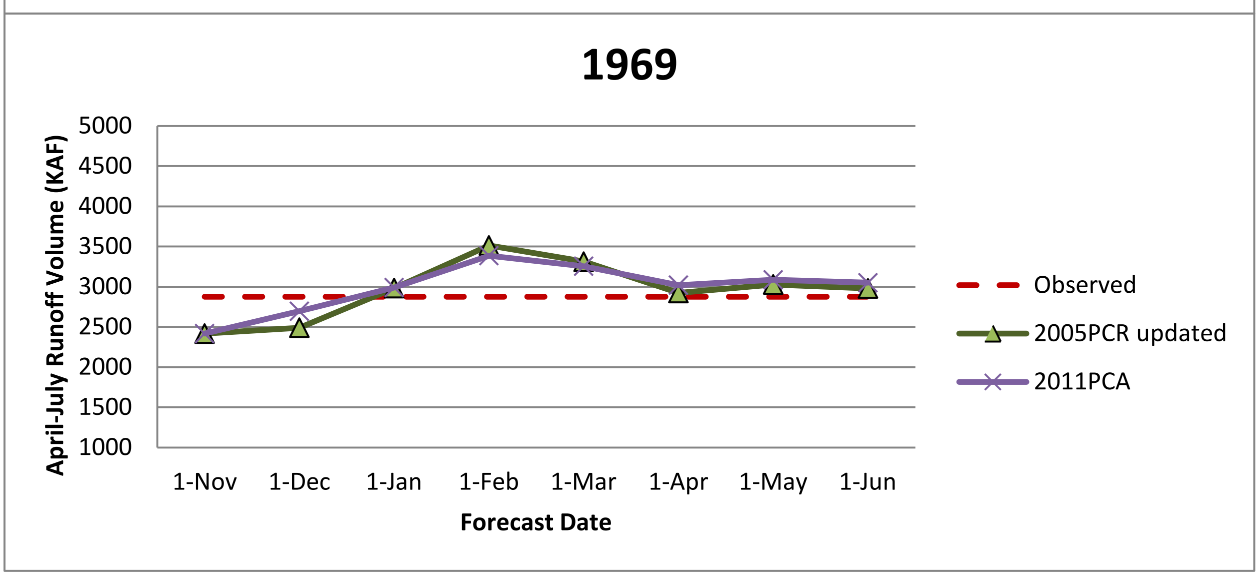
2011PCA


1969
April-July Runoff Volume (KAF)
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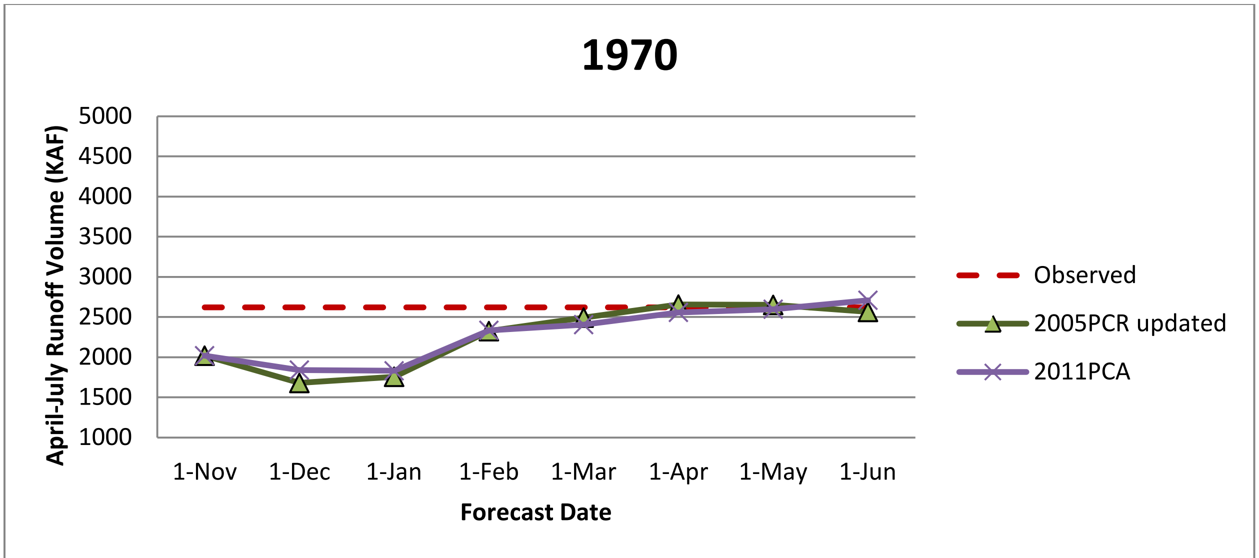
2011PCA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April-July Runoff Volume (KAF)
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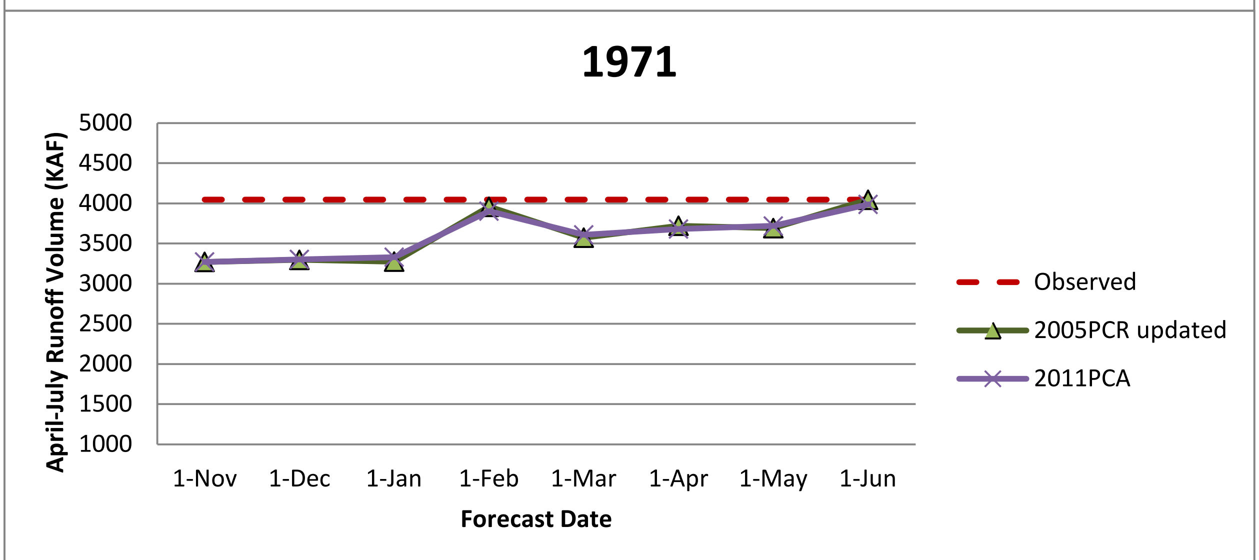
Forecast Date
Observed
2005PCR updated
2011PCA


1971
April-July Runoff Volume (KAF)
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Forecast Date
Observed
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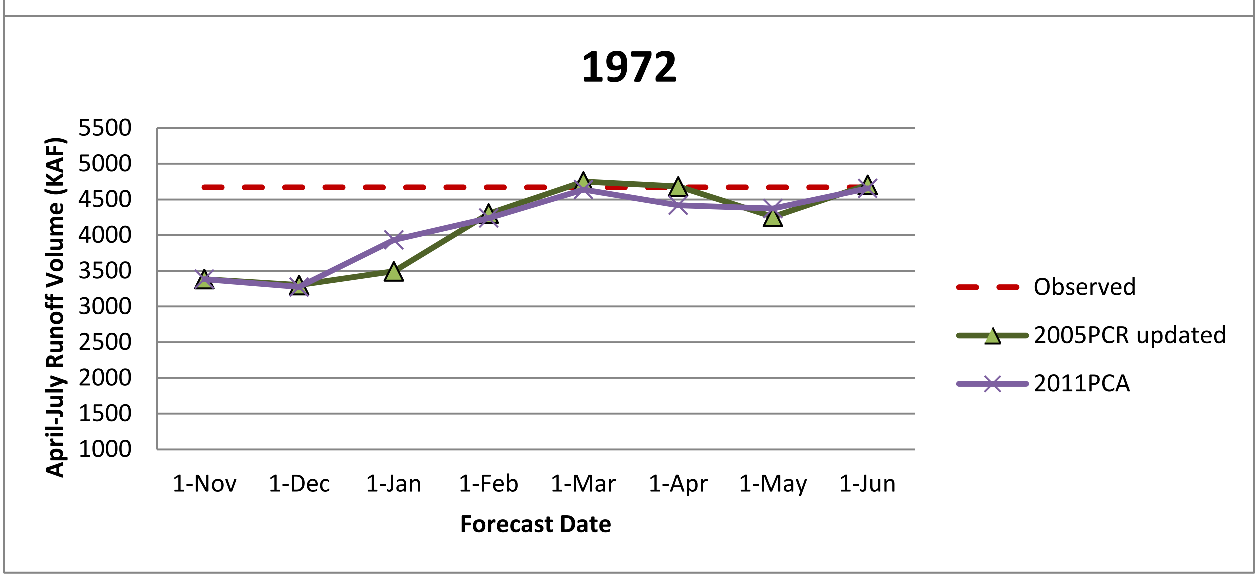
2011PCA


1972
April-July Runoff Volume (KAF)
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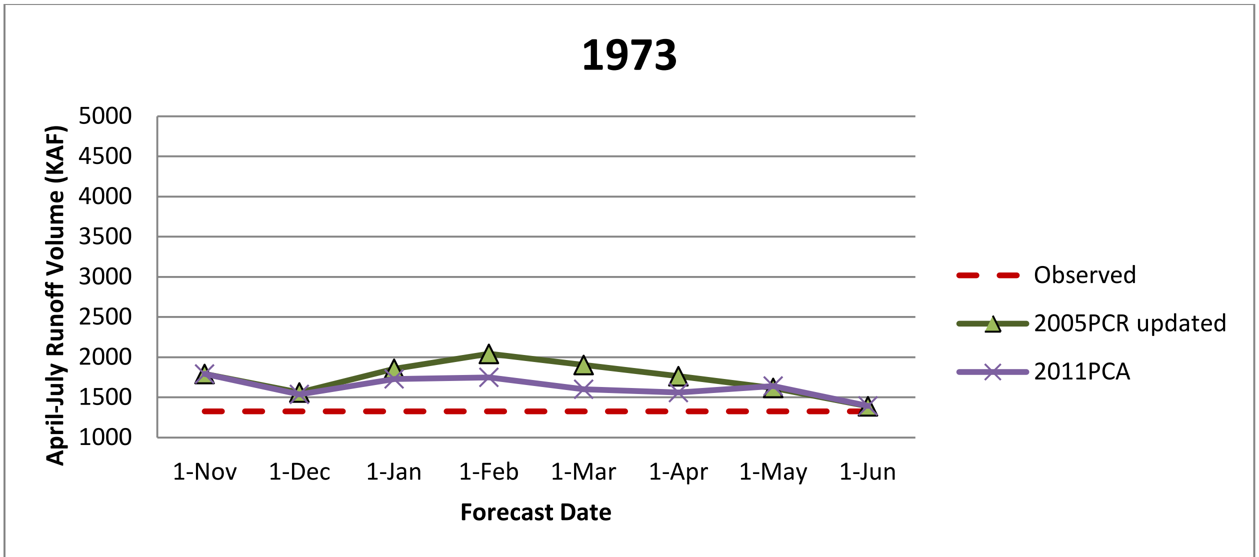
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA


1973
April-July Runoff Volume (KAF)
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1-Jun
Forecast Date
Observed
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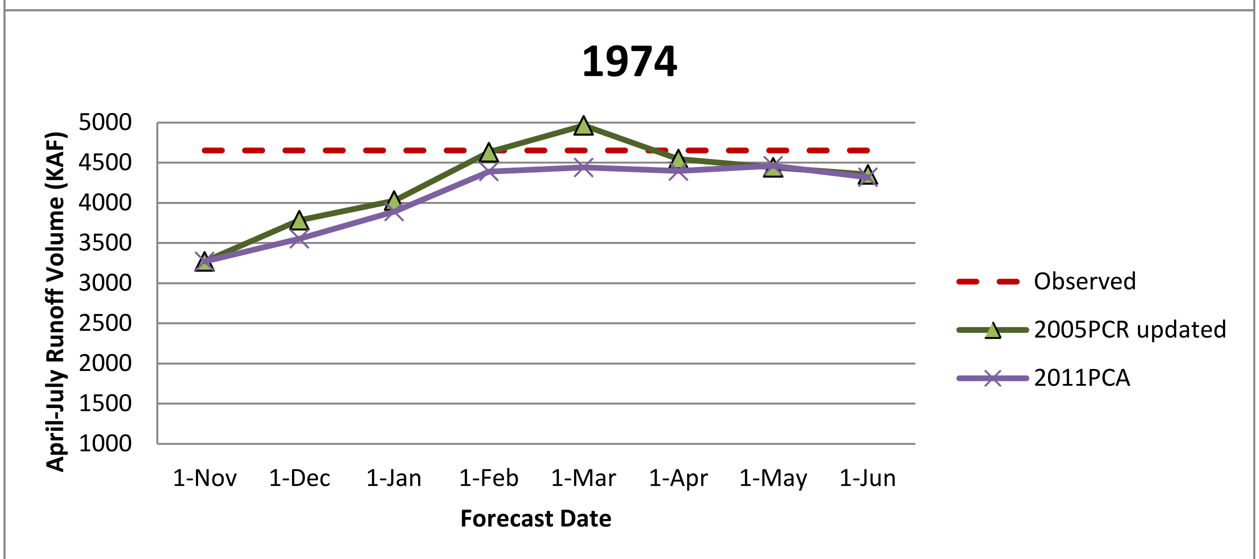
2011PCA


1974
April-July Runoff Volume (KAF)
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1-Jun
Forecast Date
Observed
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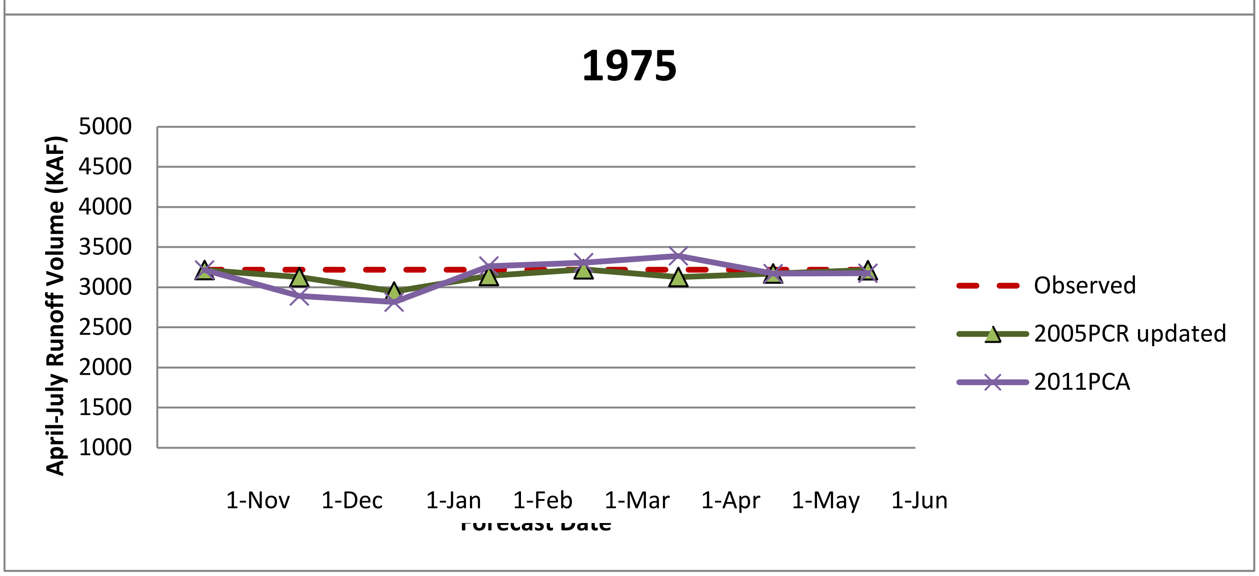
2011PCA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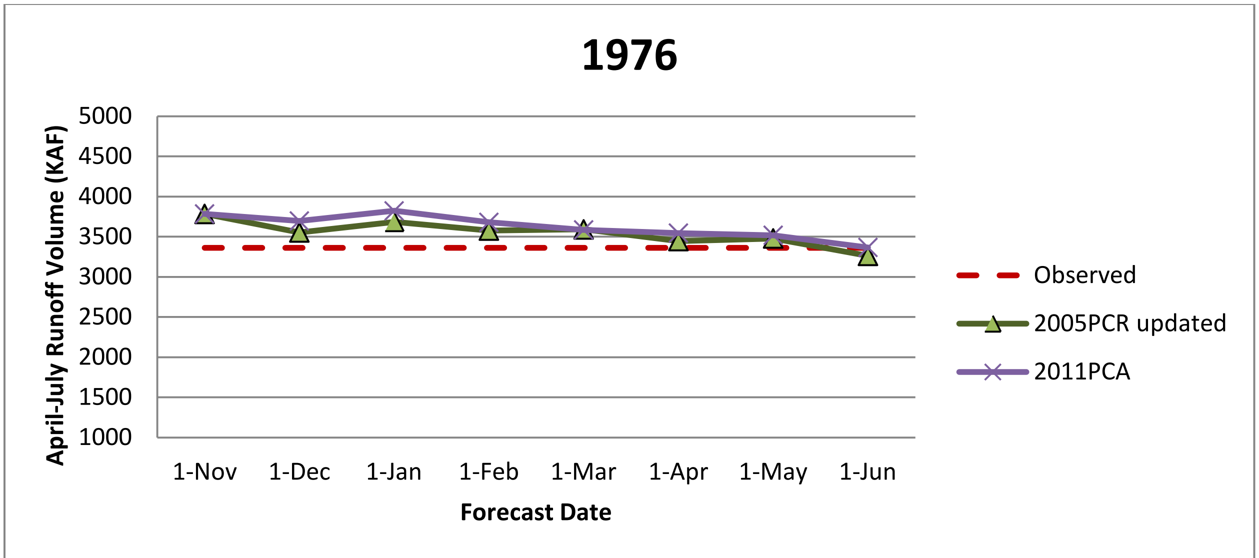
Observed
2005PCR updated
2011PCA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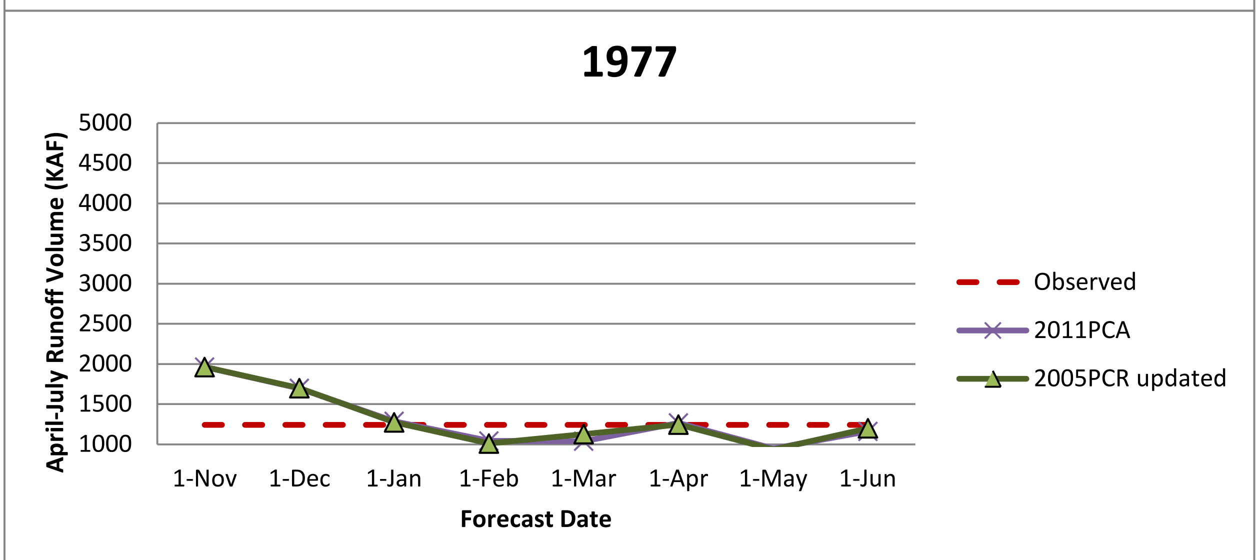
Forecast Date
Observed
2005PCR updated
2011PCA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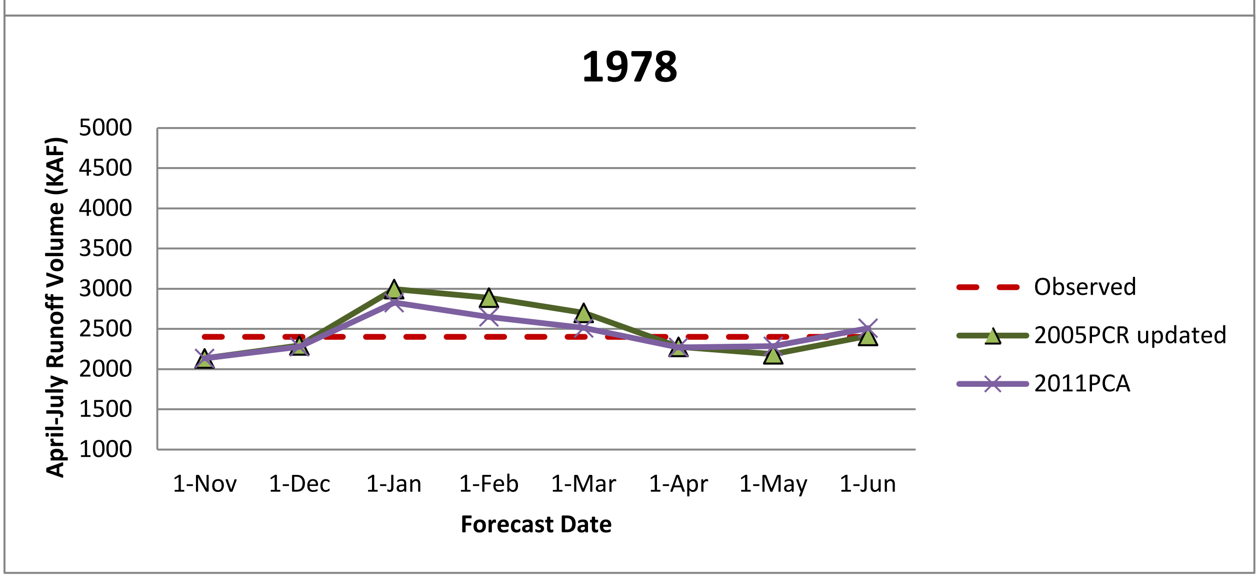
Forecast Date
Observed
2011PCA
2005PCR updated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Forecast Date
Observed
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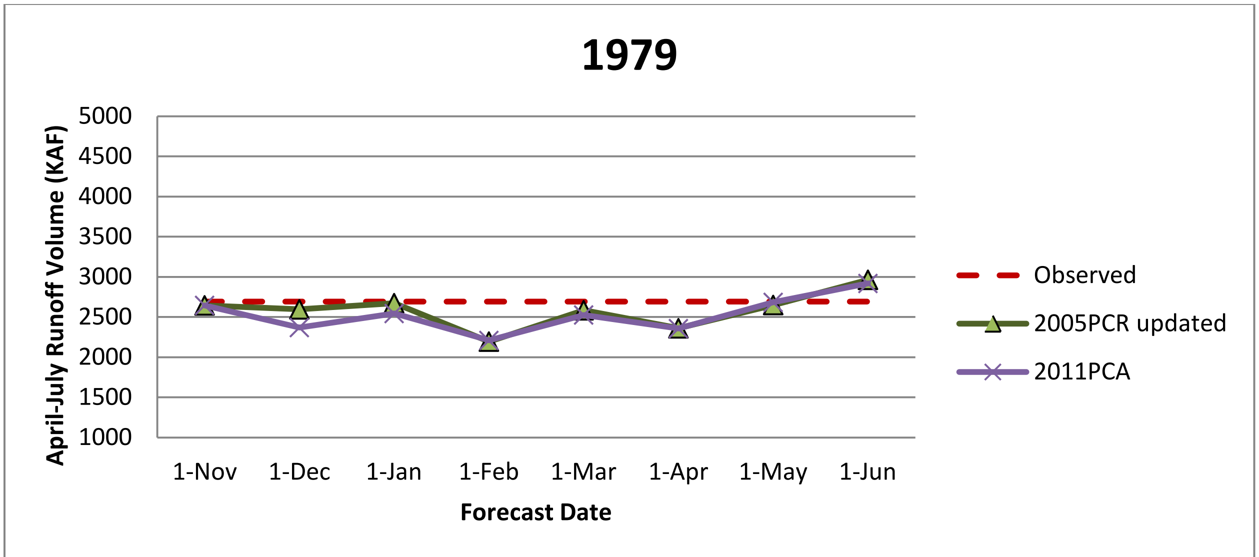
2011PCA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April-July Runoff Volume (KAF)
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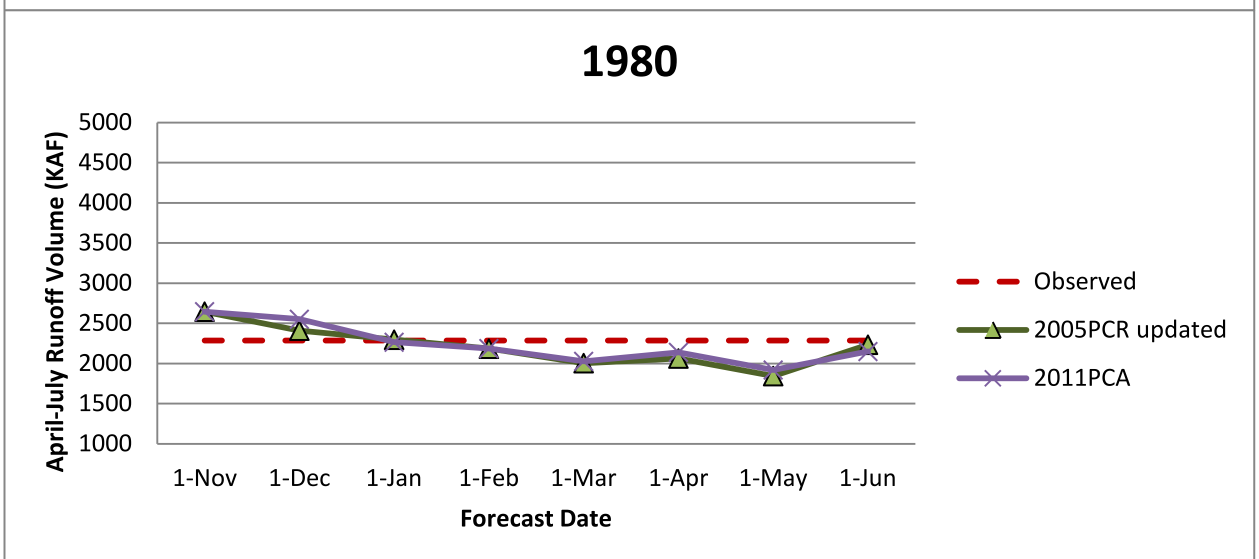
2011PCA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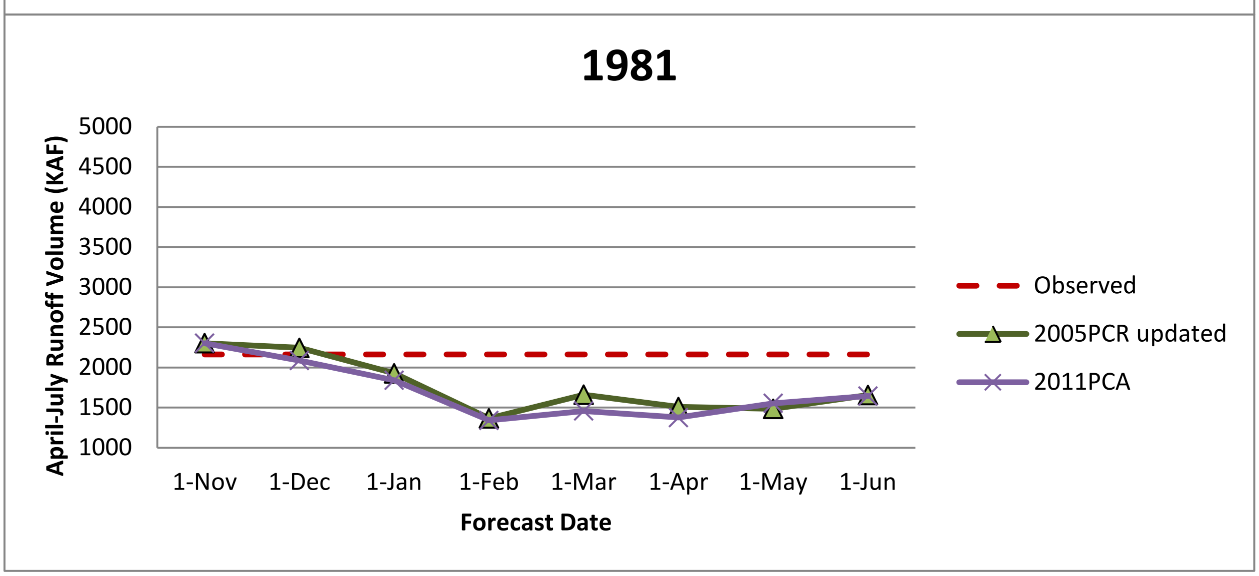
Forecast Date
Observed
2005PCR updated
2011PCA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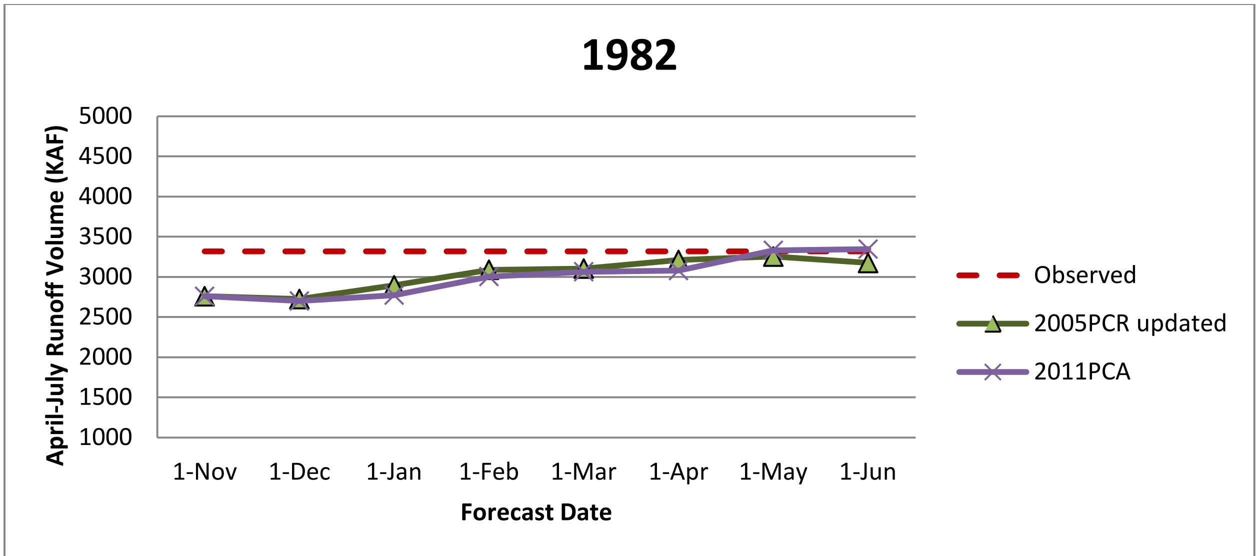
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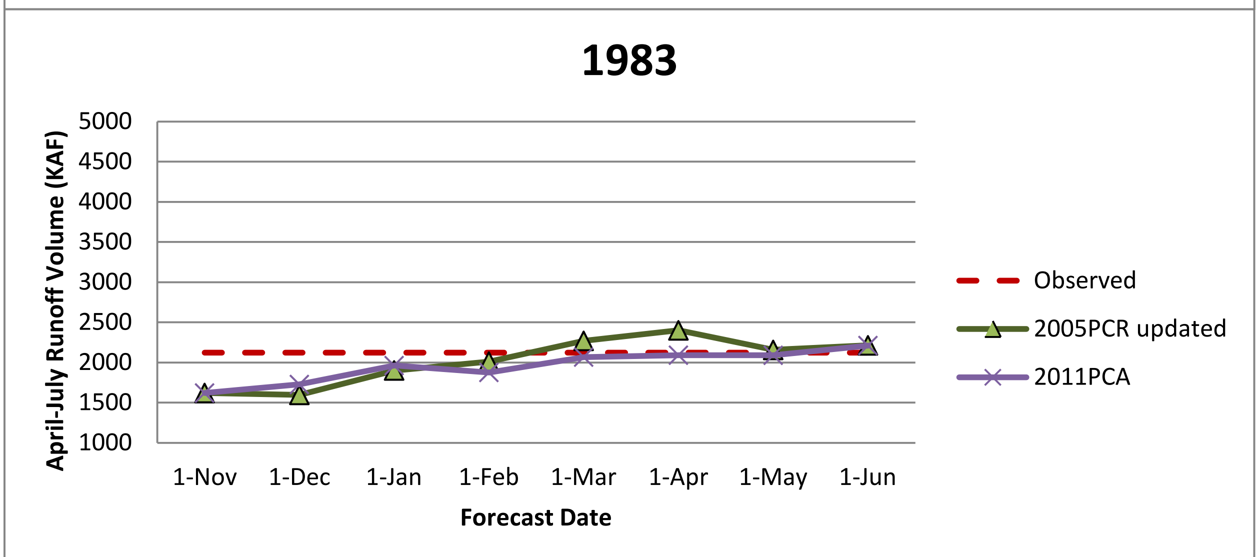
2011PCA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Forecast Date
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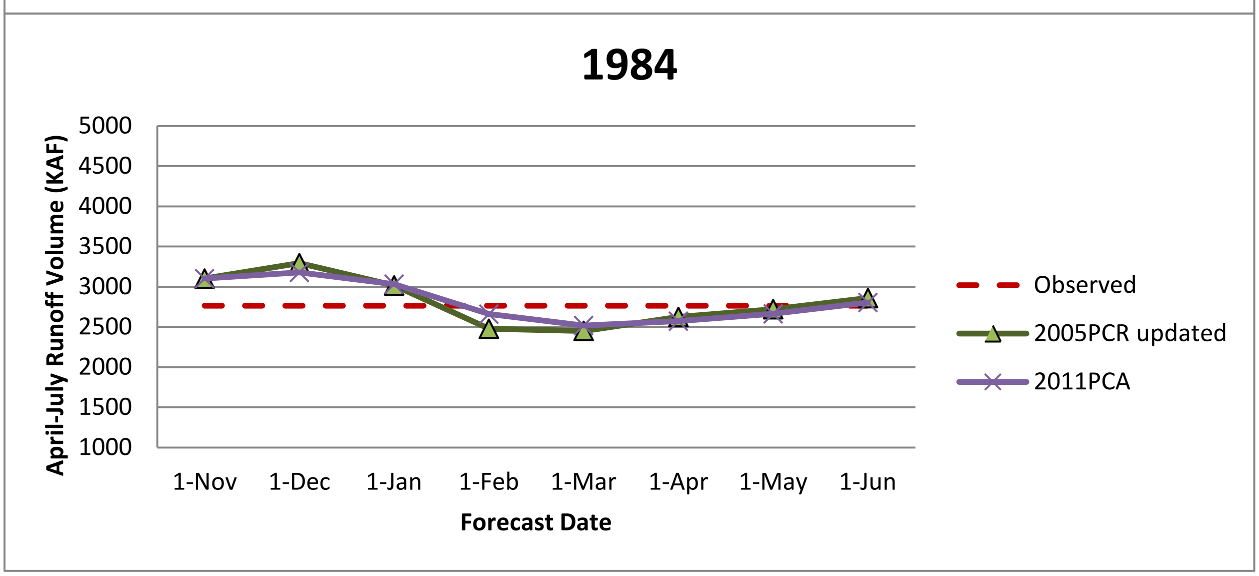
2011PCA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Forecast Date
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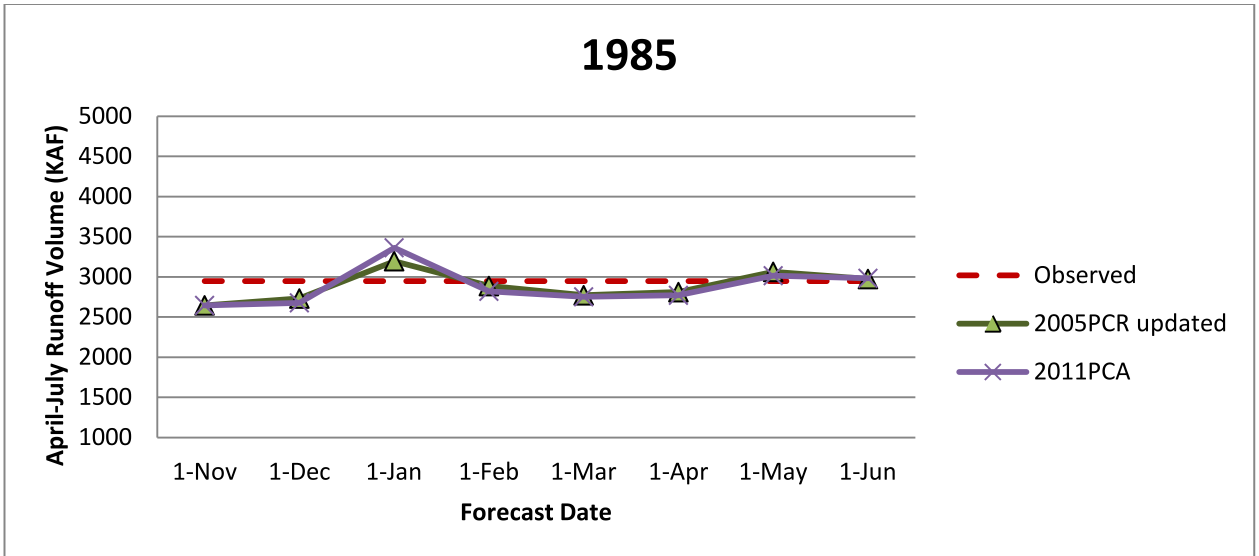
2011PCA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Forecast Date
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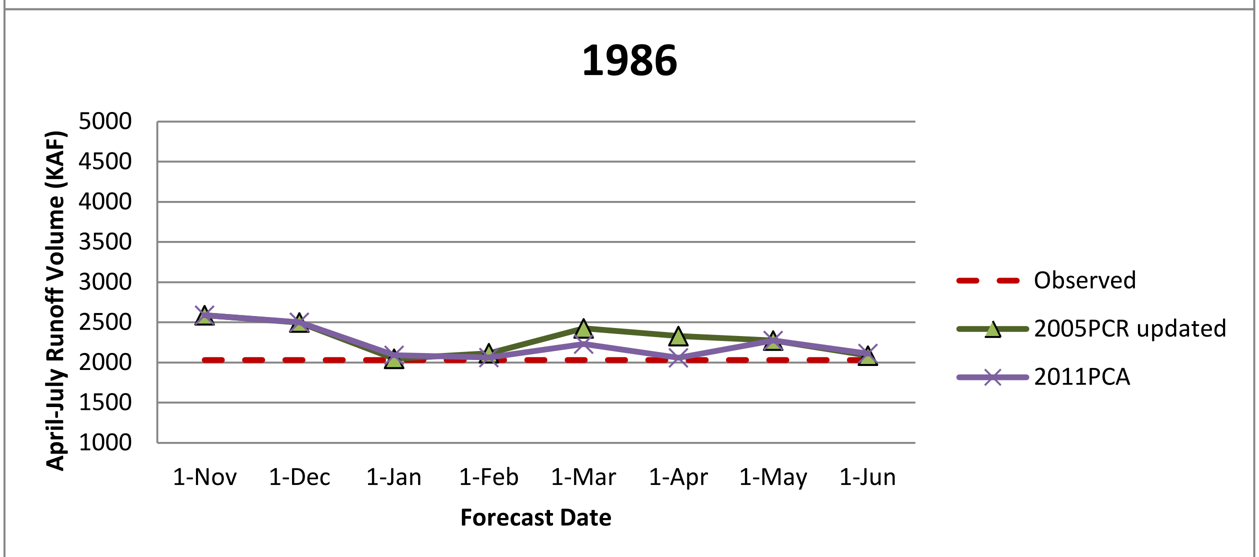
1986
April-July Runoff Volume (KAF)
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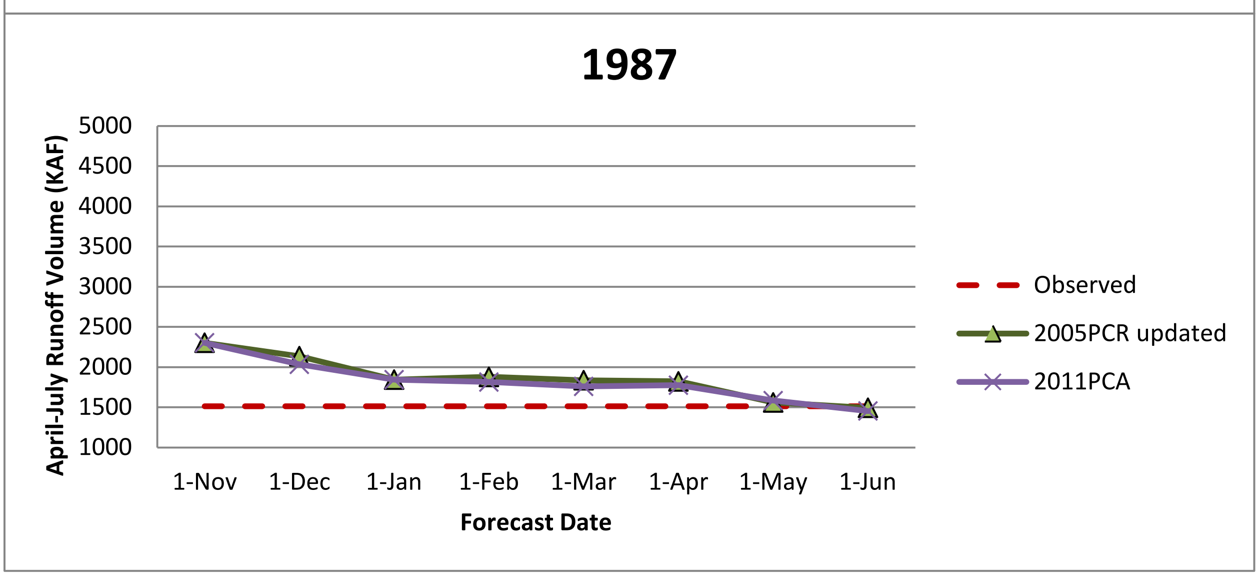
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April-July Runoff Volume (KAF)
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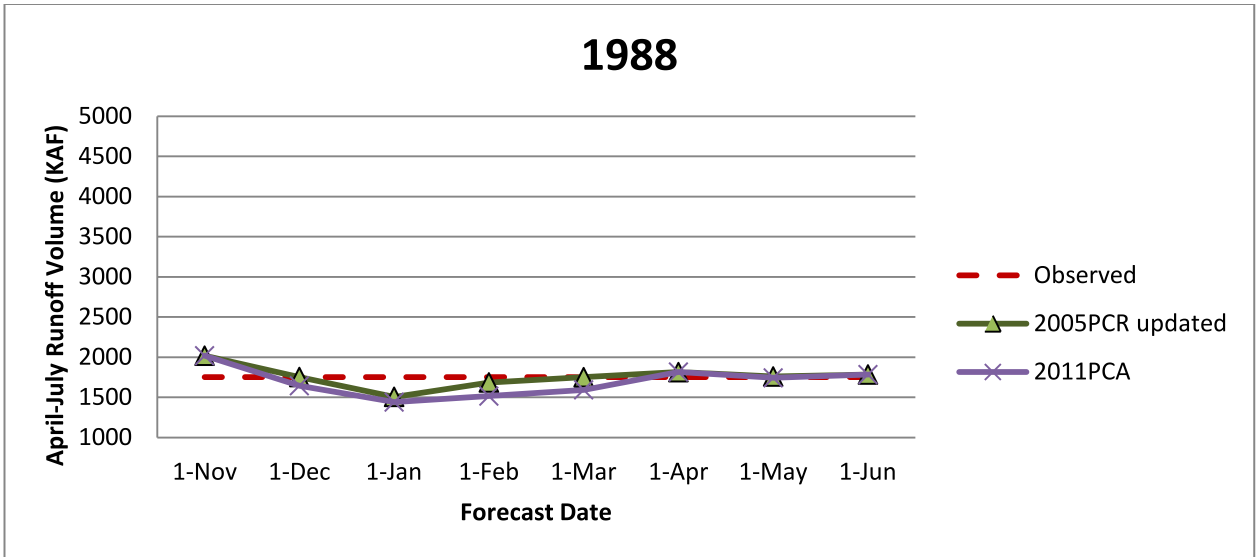
1988
April-July Runoff Volume (KAF)
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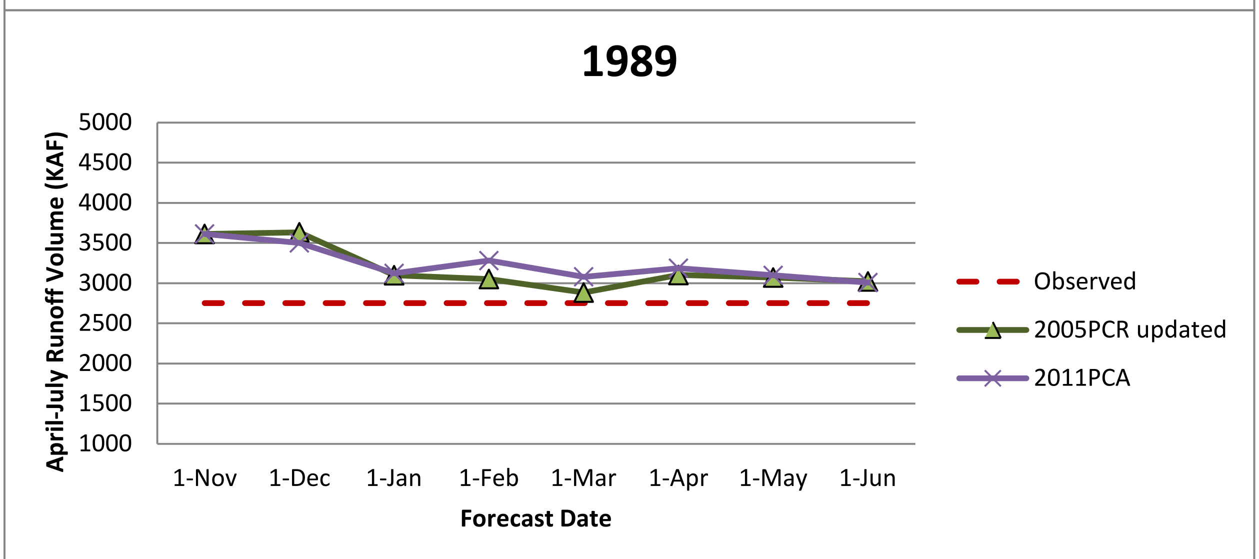
1989
April-July Runoff Volume (KAF)
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Forecast Date
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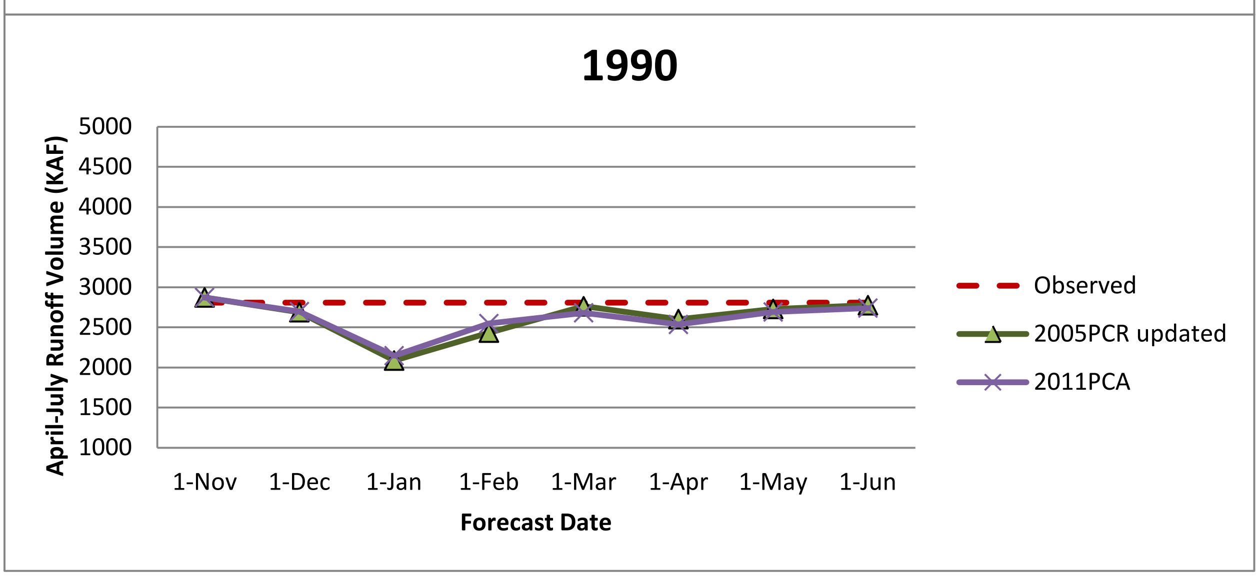
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April-July Runoff Volume (KAF)
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Forecast Date
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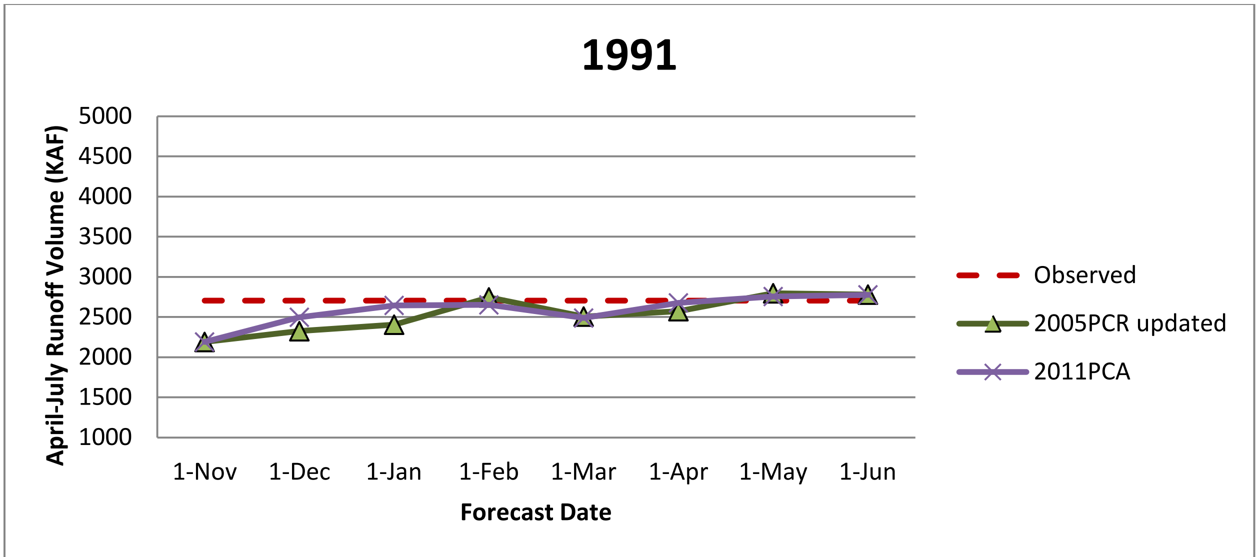
2011PCA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April-July Runoff Volume (KAF)
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Forecast Date
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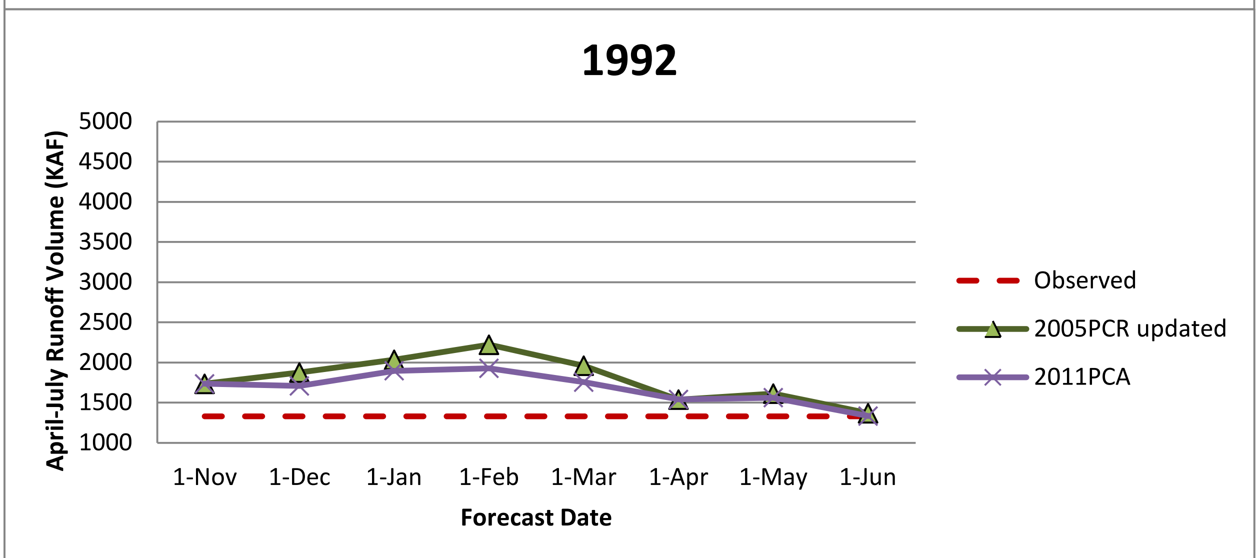
2011PCA


1992
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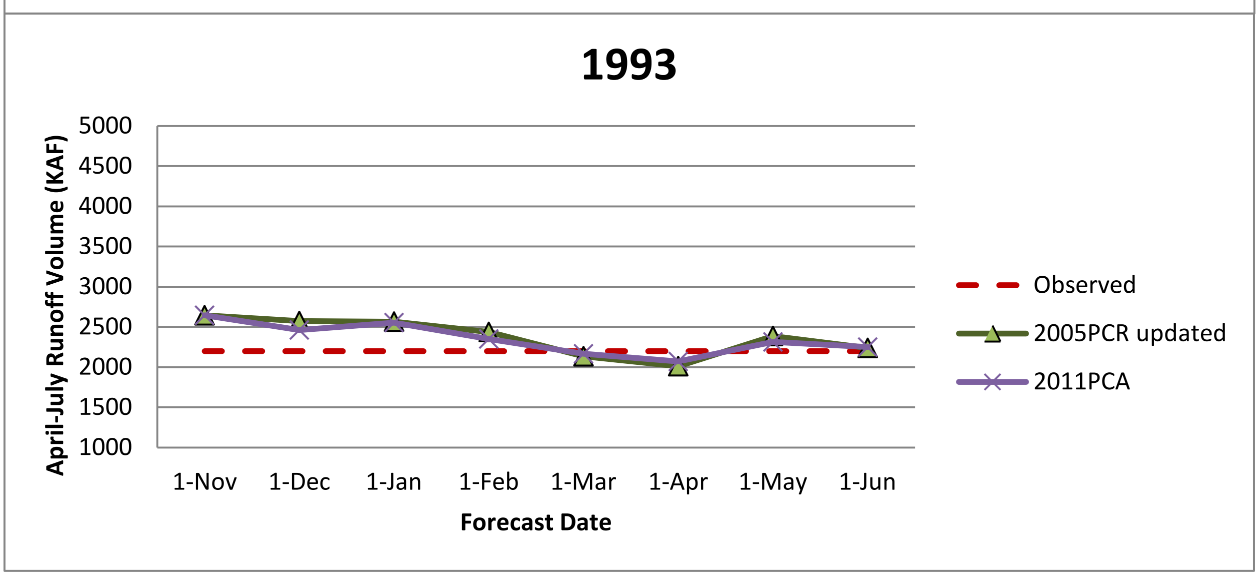
2011PCA


1993
April-July Runoff Volume (KAF)
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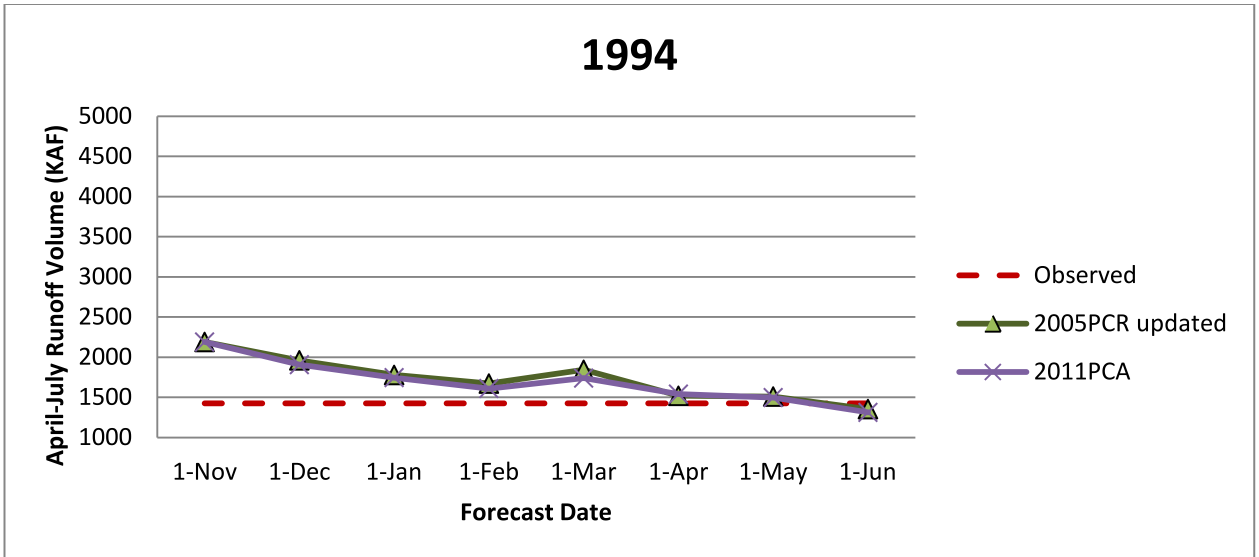
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April-July Runoff Volume (KAF)
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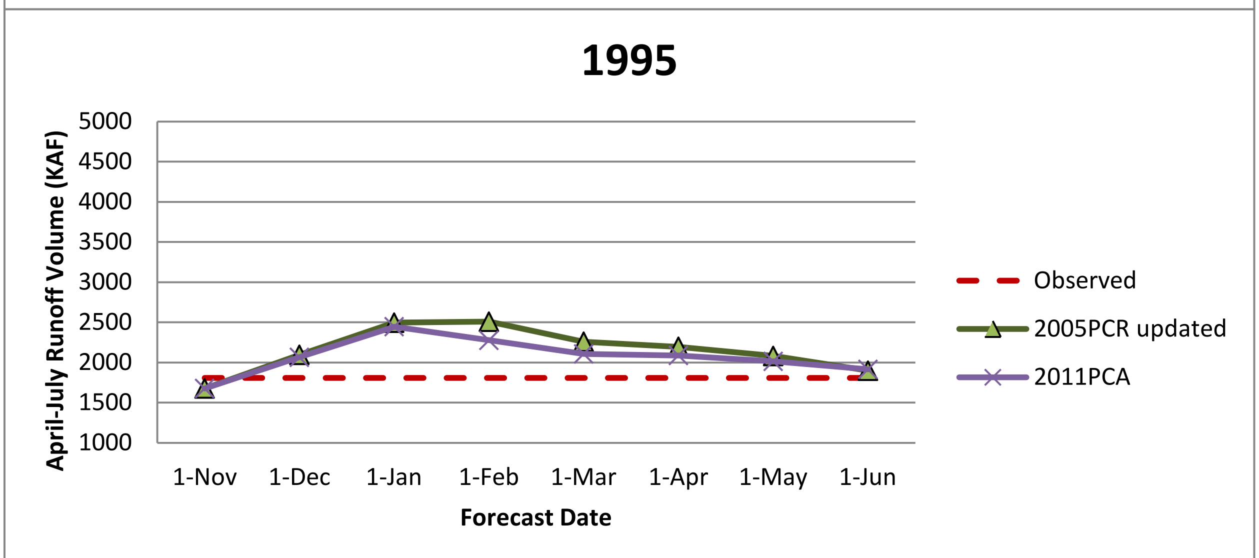
2011PCA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April-July Runoff Volume (KAF)
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Forecast Date
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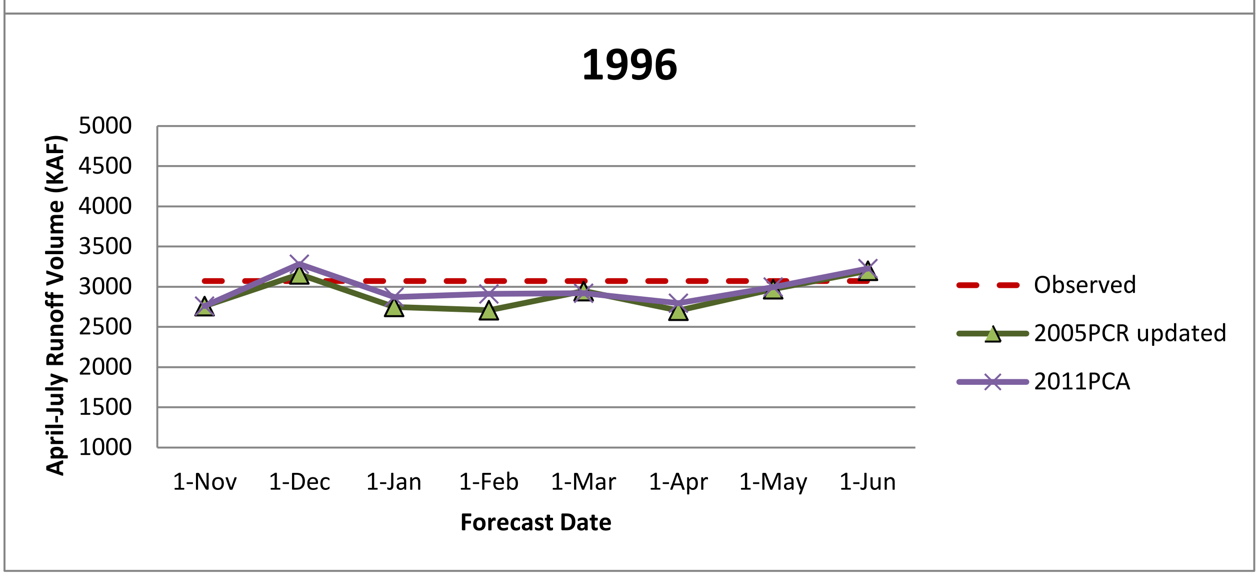
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April-July Runoff Volume (KAF)
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Forecast Date
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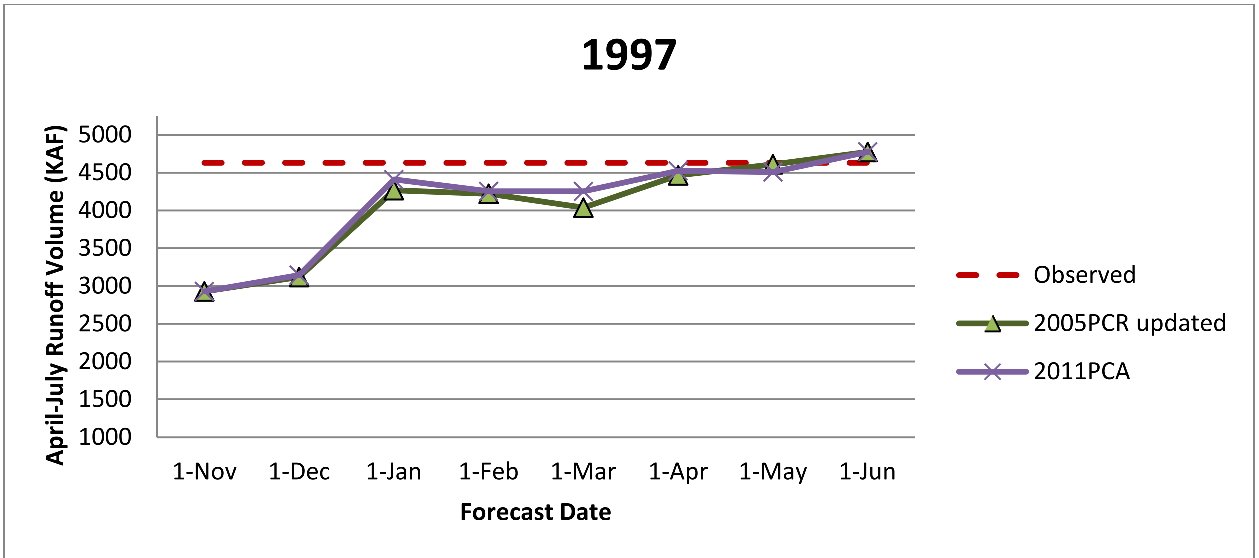
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April-July Runoff Volume (KAF)
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Forecast Date
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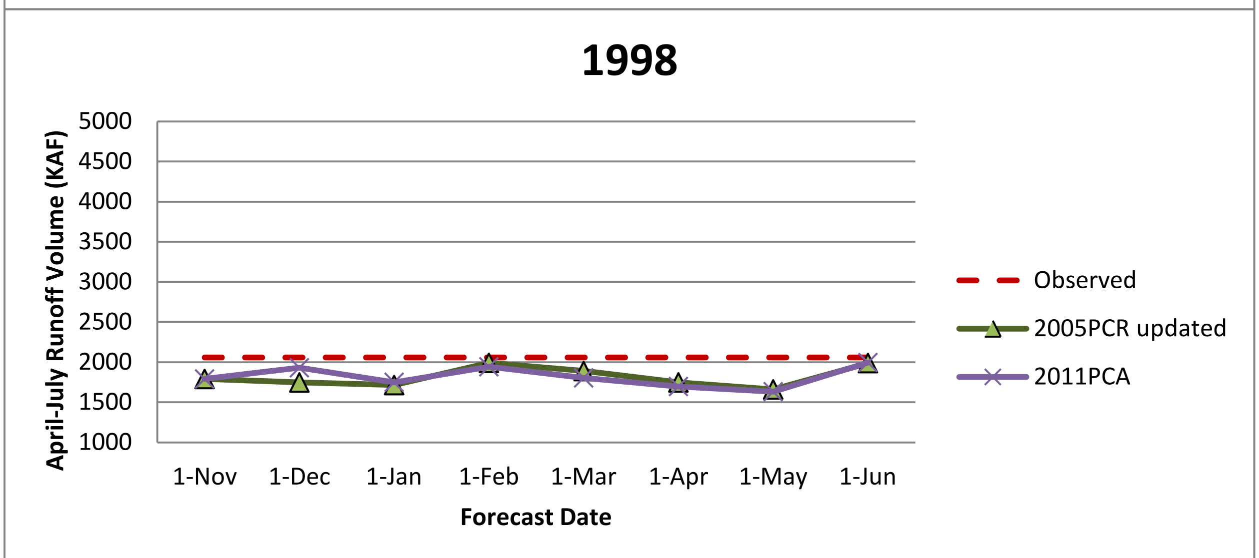
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April-July Runoff Volume (KAF)
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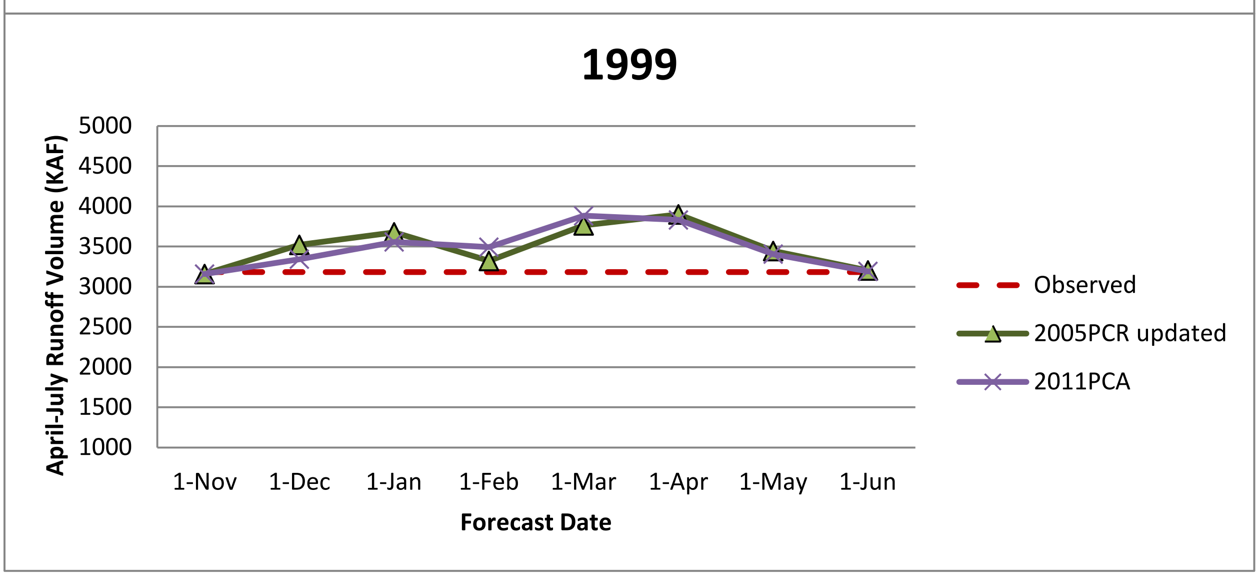
2011PCA


1999
April-July Runoff Volume (KAF)
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Forecast Date
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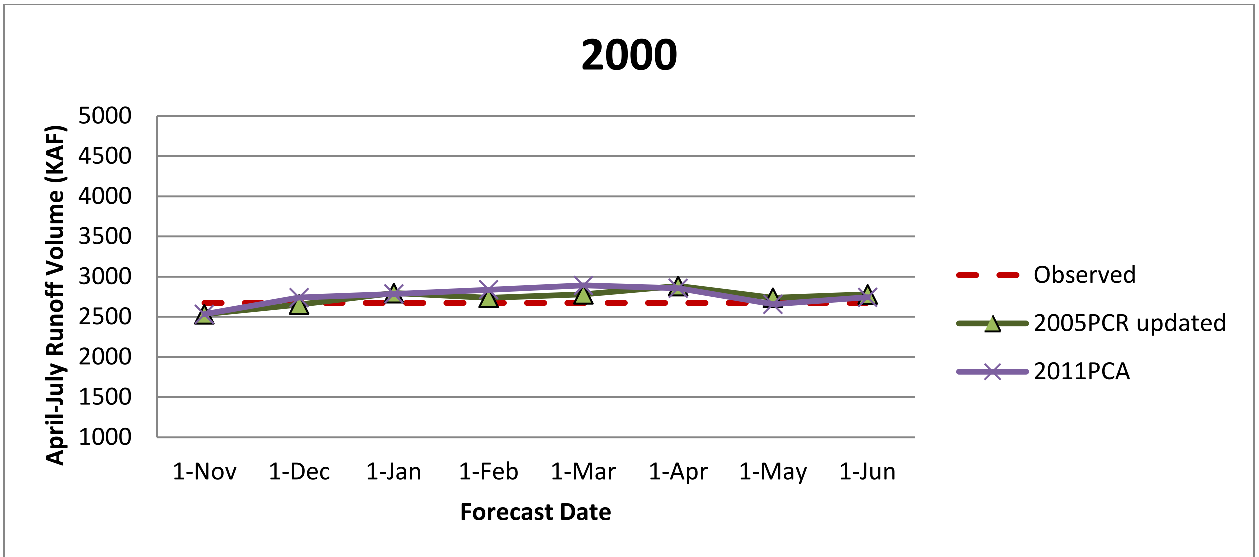
2011PCA


2000
April-July Runoff Volume (KAF)
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Forecast Date
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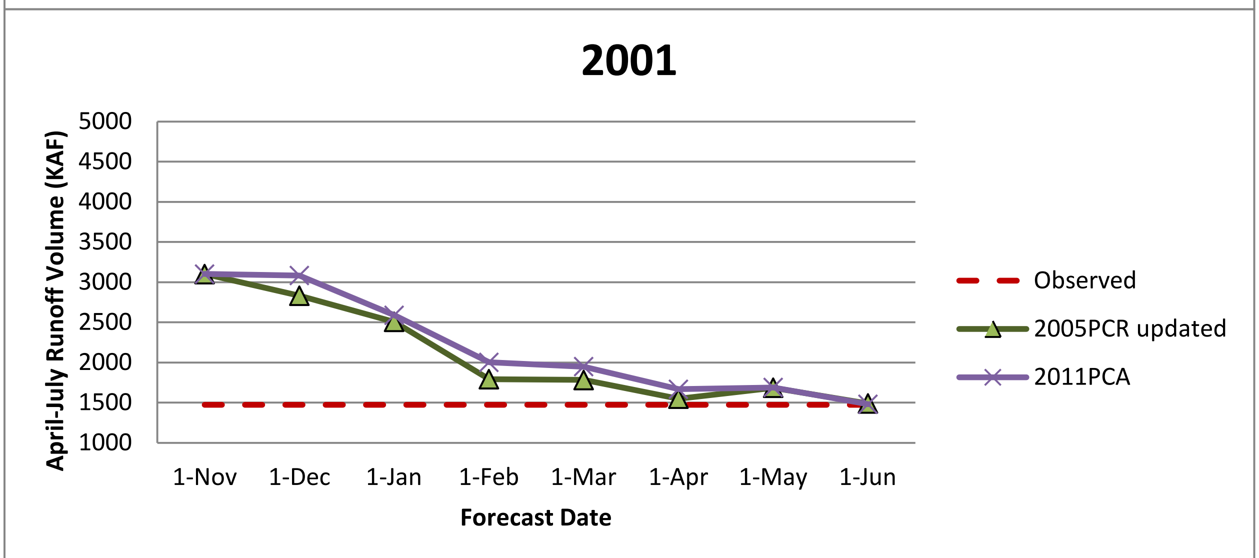
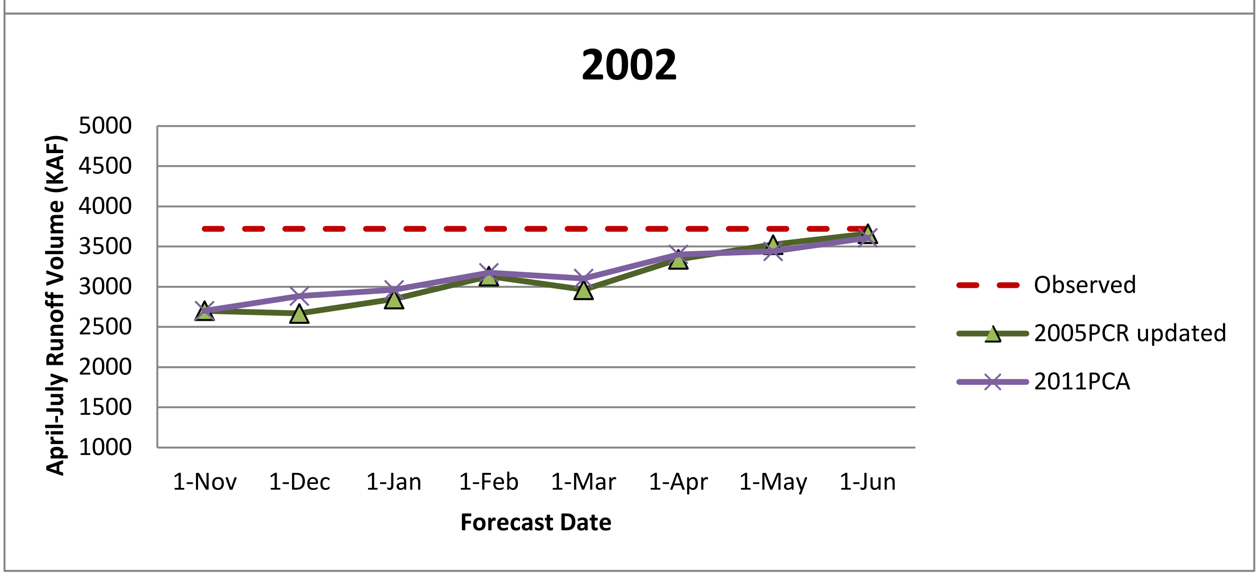
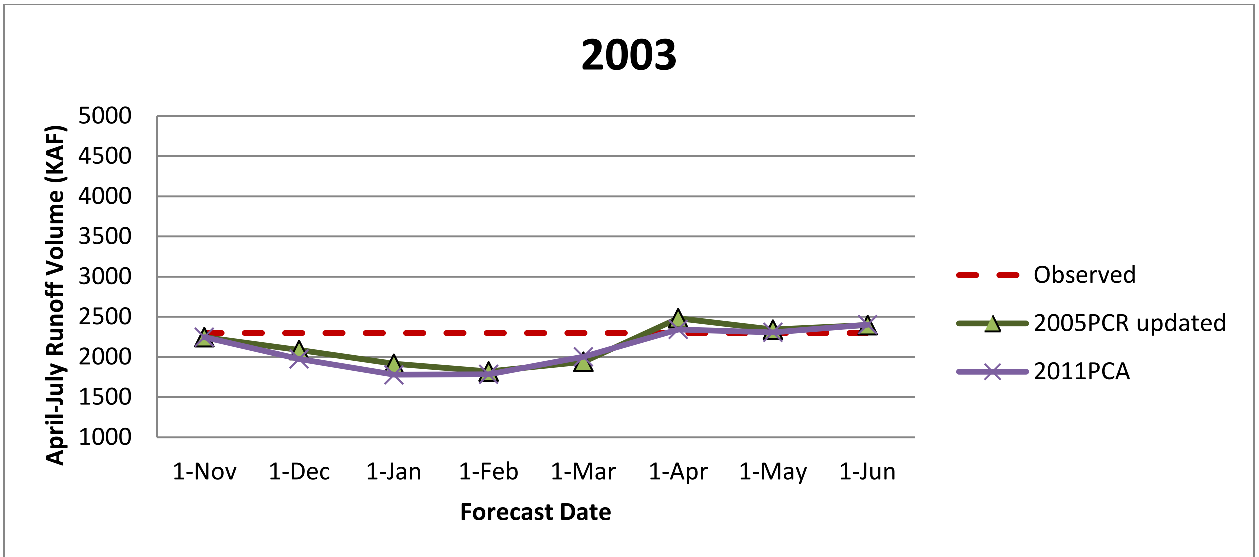
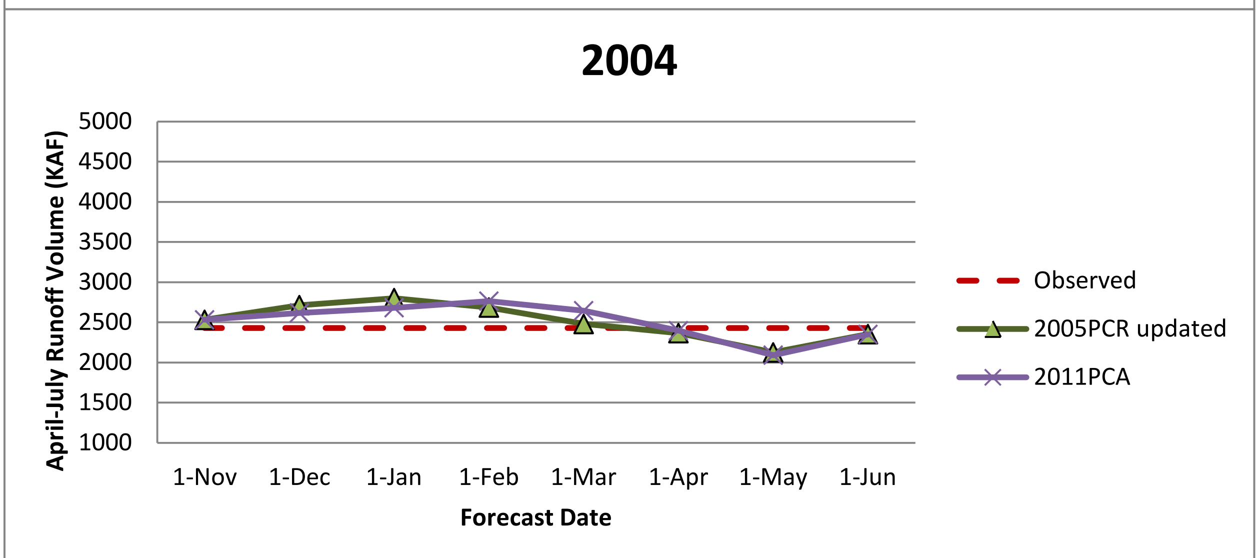
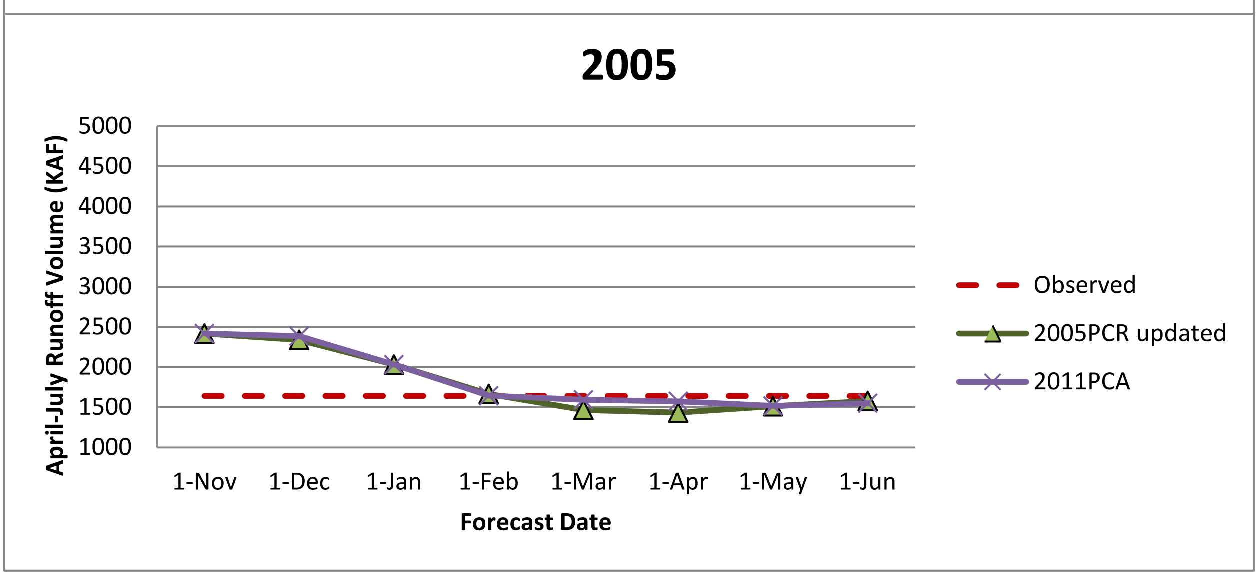
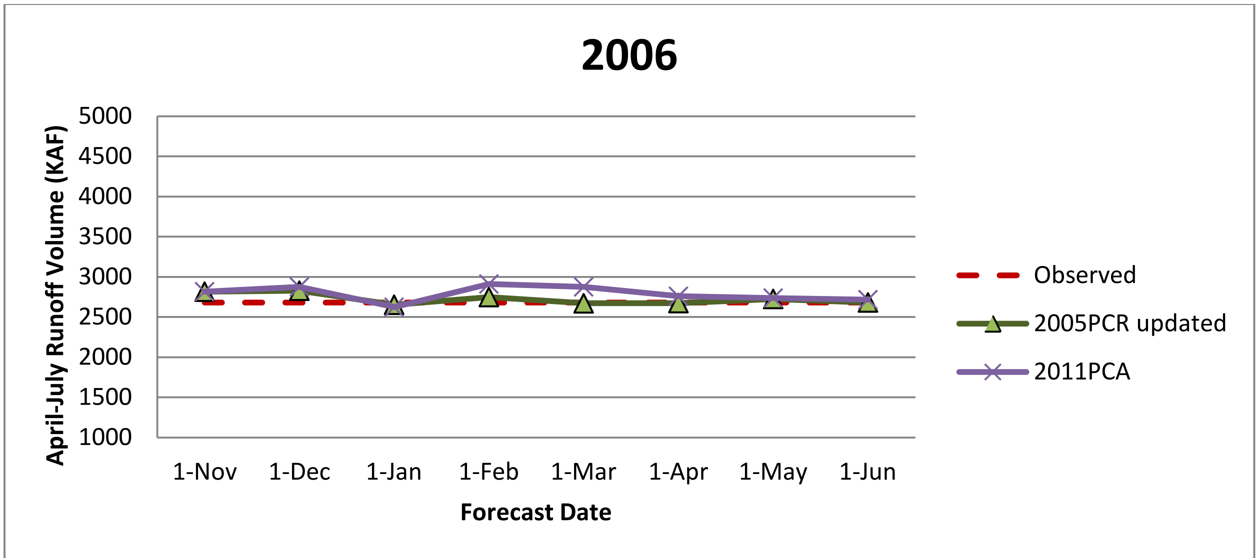

2001
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

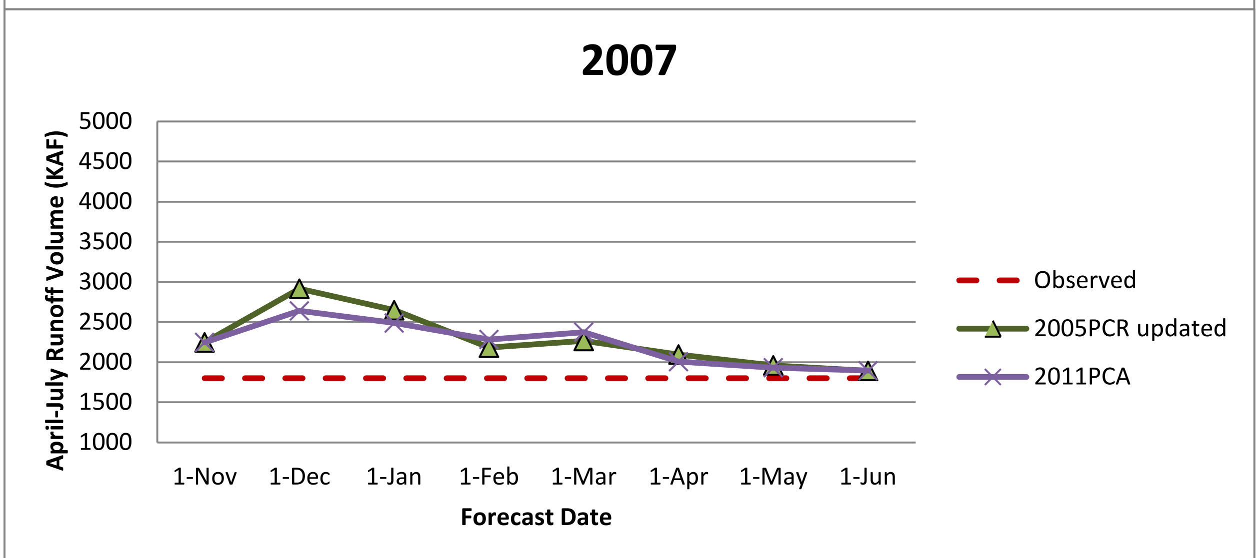

2002
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

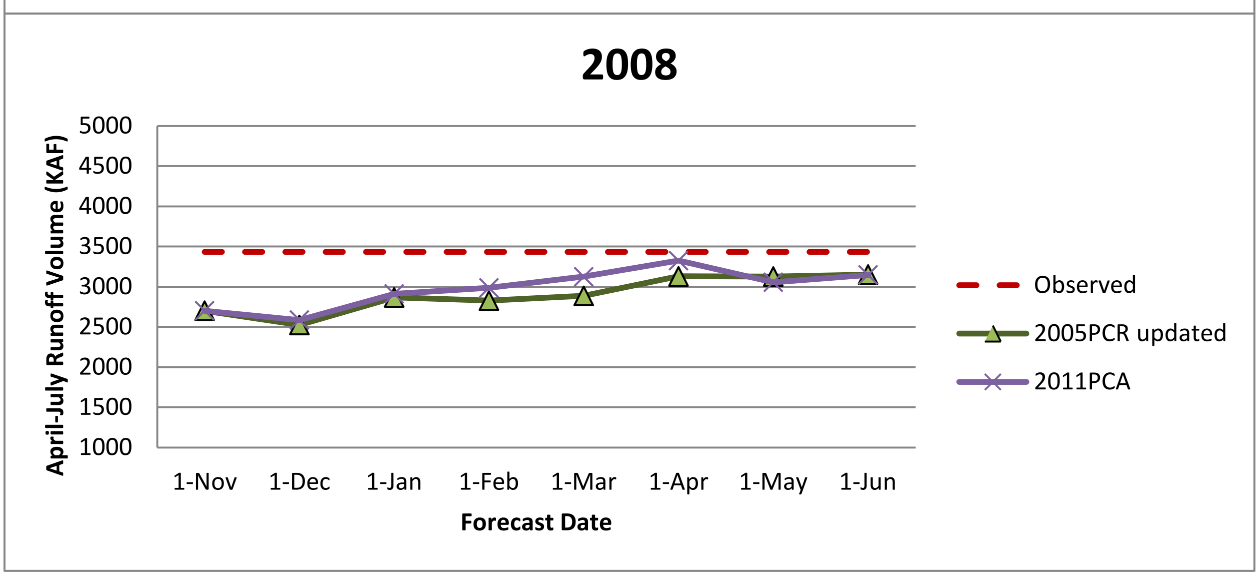

2003
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

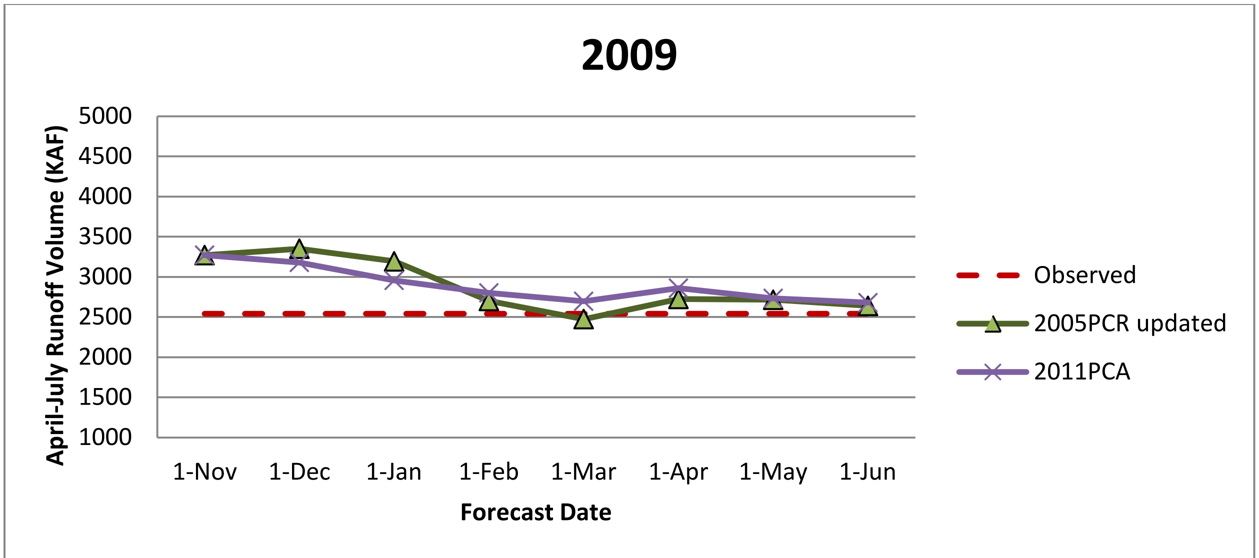

2004
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

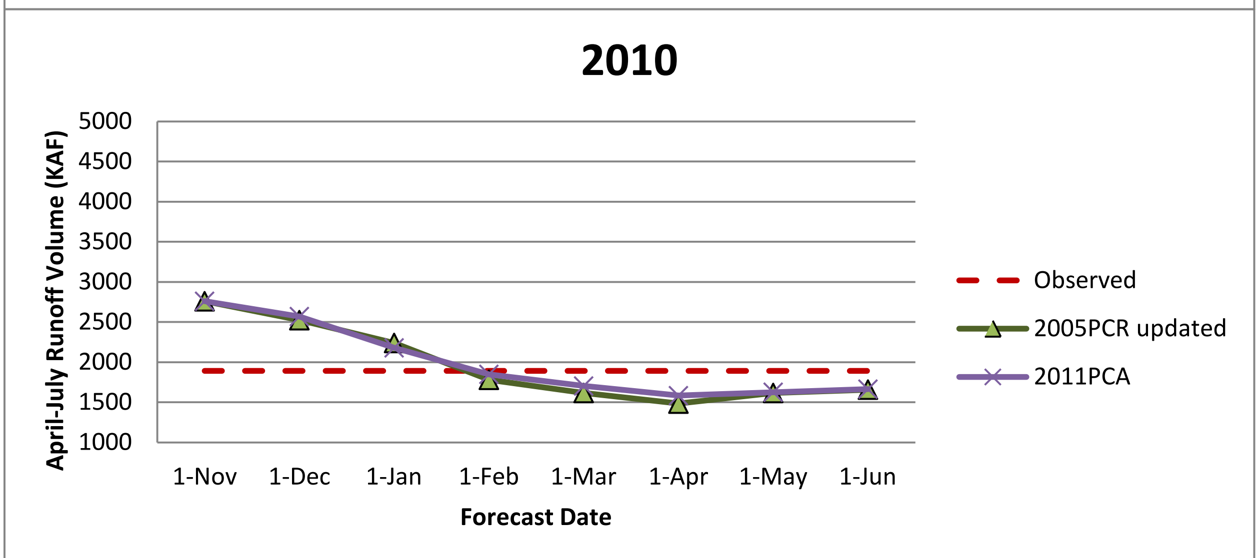

2005
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

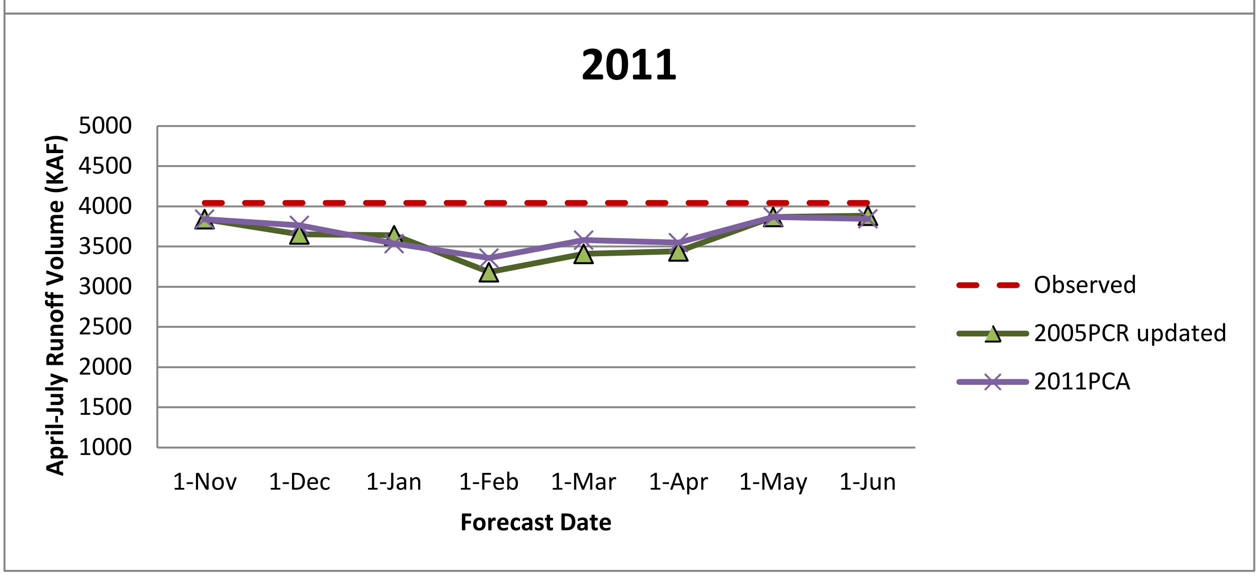

2006
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA


2007
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

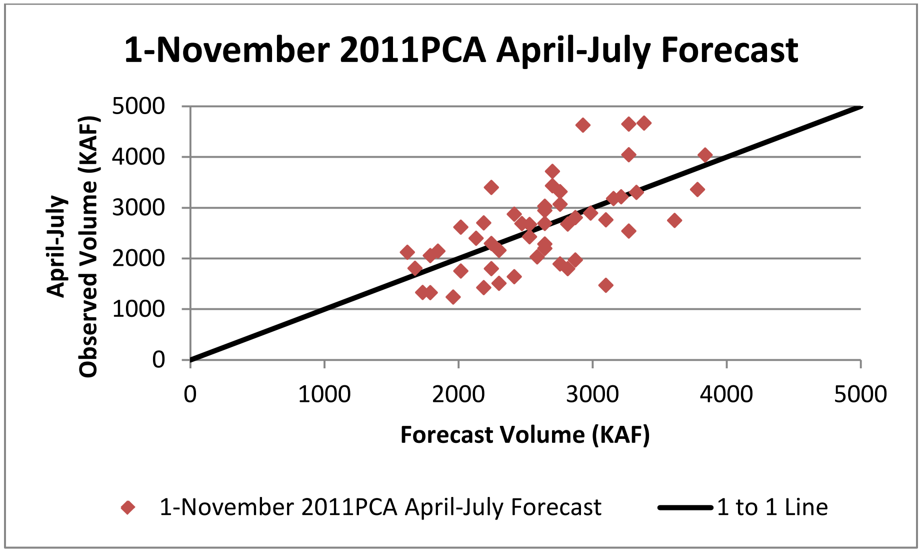

2008
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

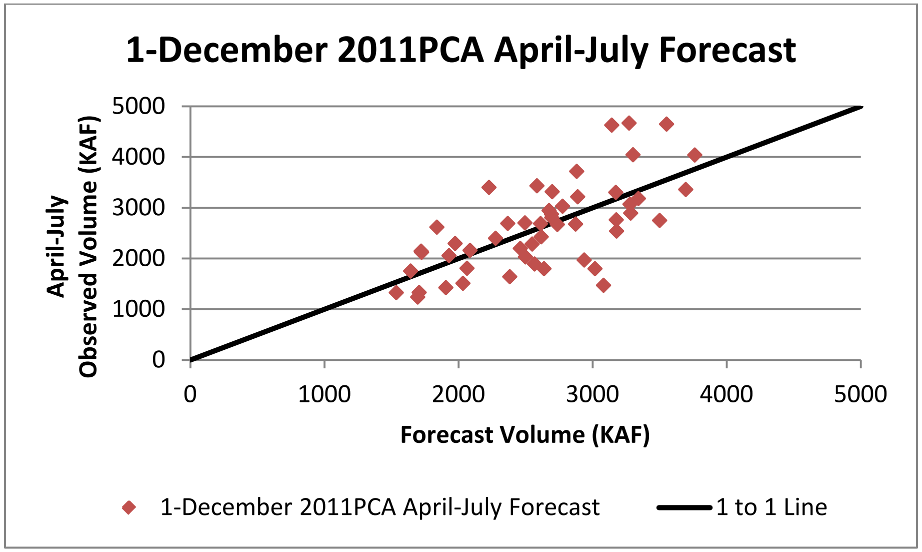

2009
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

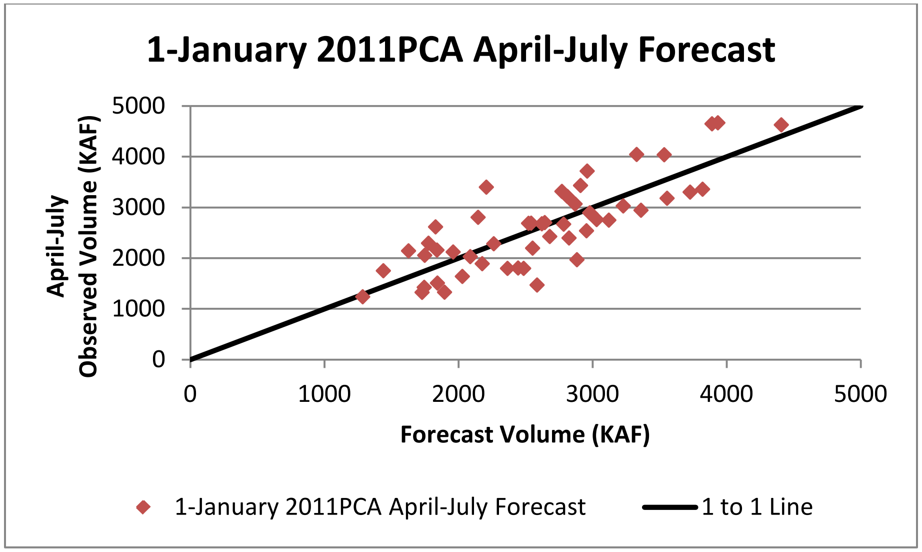

2010
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

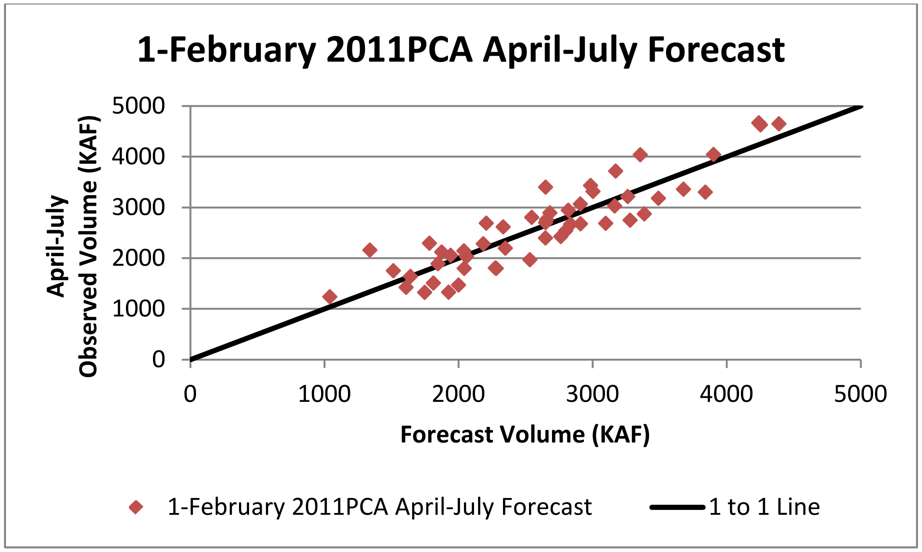

2011
April-July Runoff Volume (KAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
Forecast Date
Observed
2005PCR updated
2011PCA

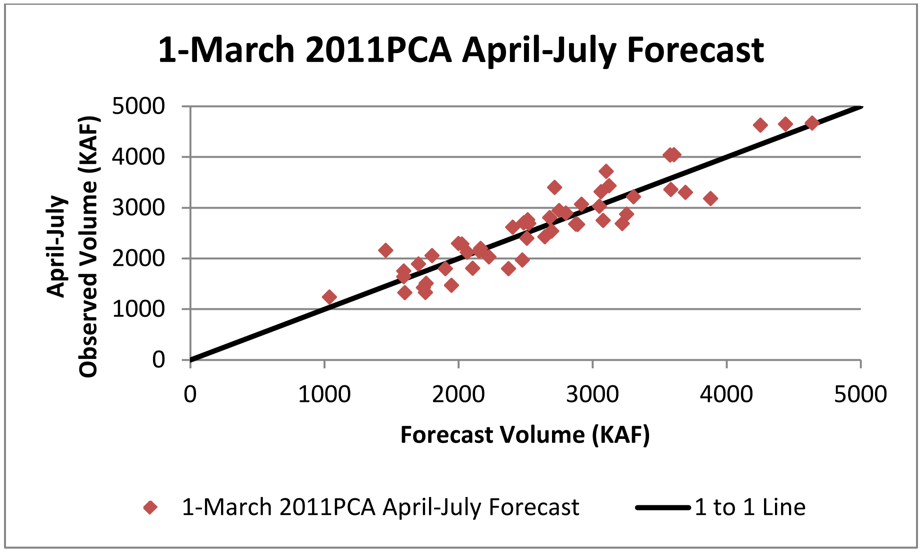
Appendix D – Forecast Comparison Plots

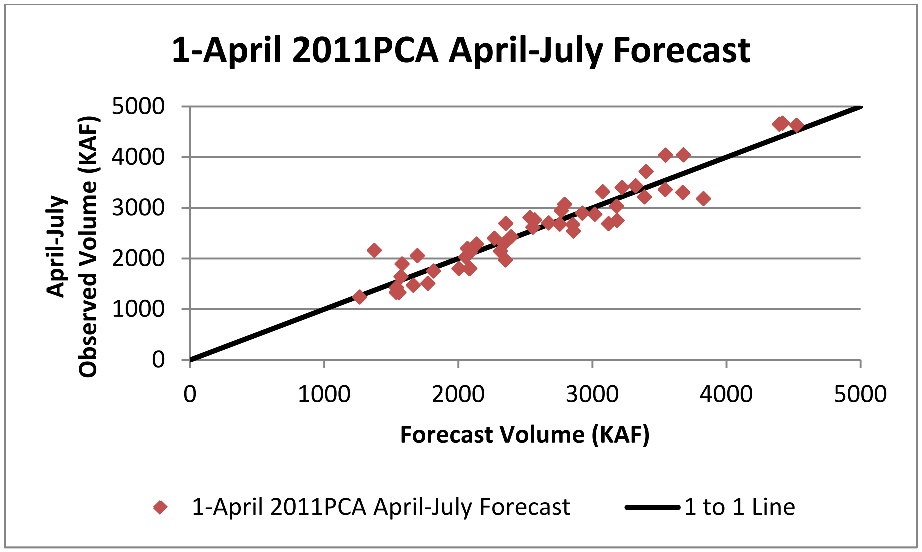

1-November 2011PCA April-July Forecast
April-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-November 2011PCA April-July Forecast
1 to 1 Line

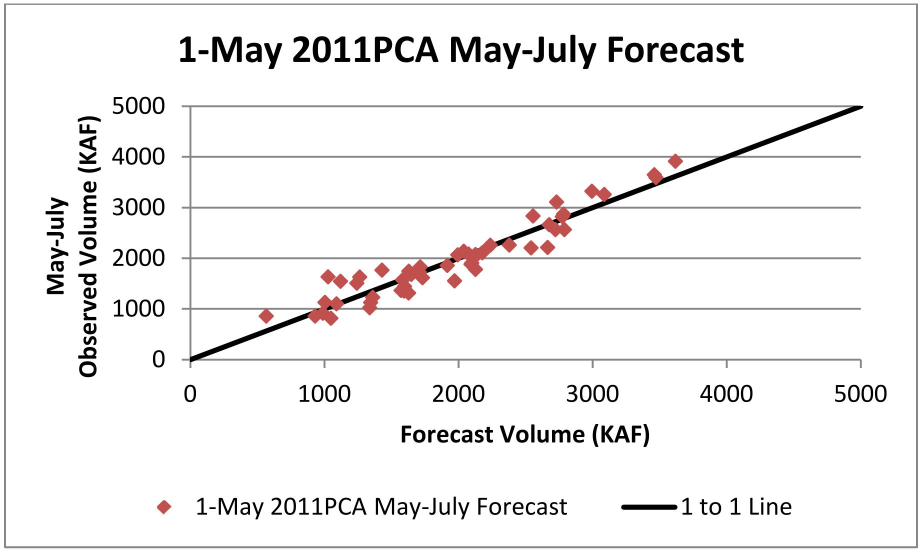

1-December 2011PCA April-July Forecast
April-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-December 2011PCA April-July Forecast
1 to 1 Line

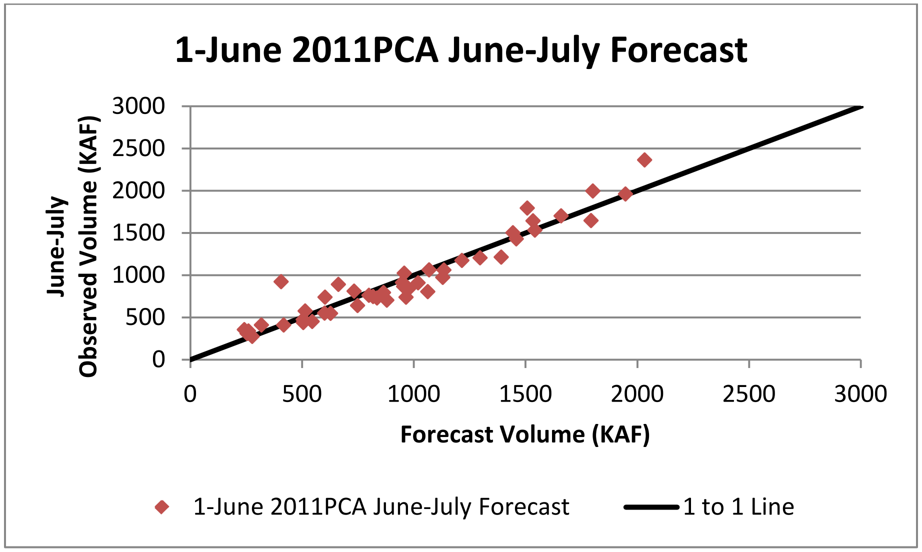

1-January 2011PCA April-July Forecast
April-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-January 2011PCA April-July Forecast
1 to 1 Line

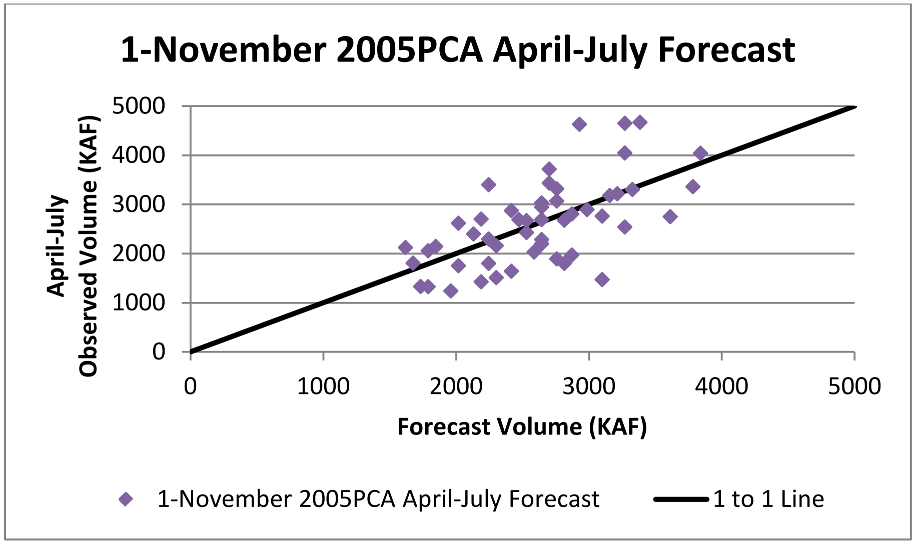

1-February 2011PCA April-July Forecast
April-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-February 2011PCA April-July Forecast
1 to 1 Line

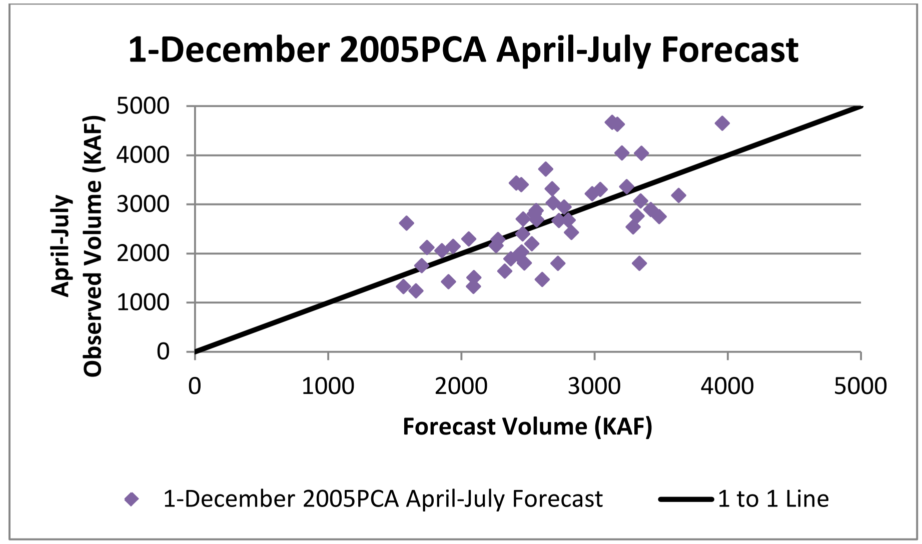

1-March 2011PCA April-July Forecast
April-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-March 2011PCA April-July Forecast
1 to 1 Line

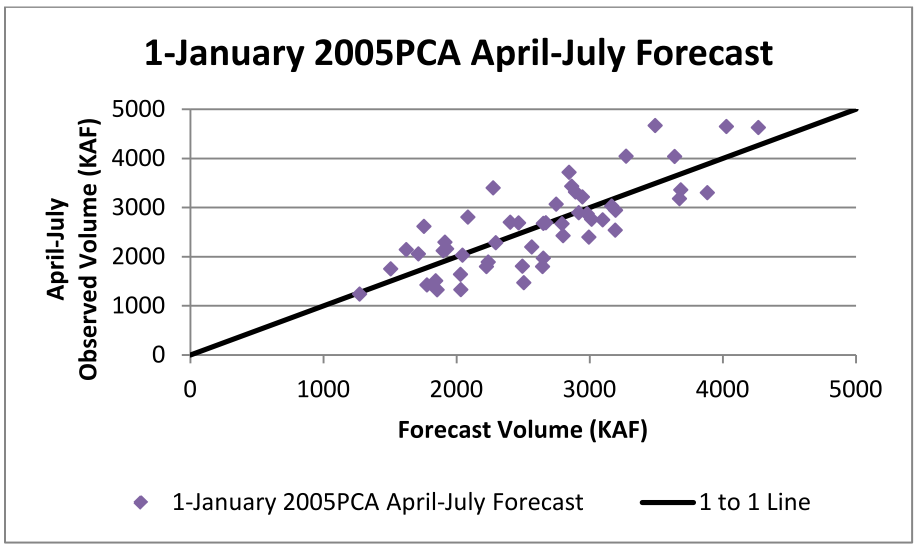

1-April 2011PCA April-July Forecast
April-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-April 2011PCA April-July Forecast
1 to 1 Line

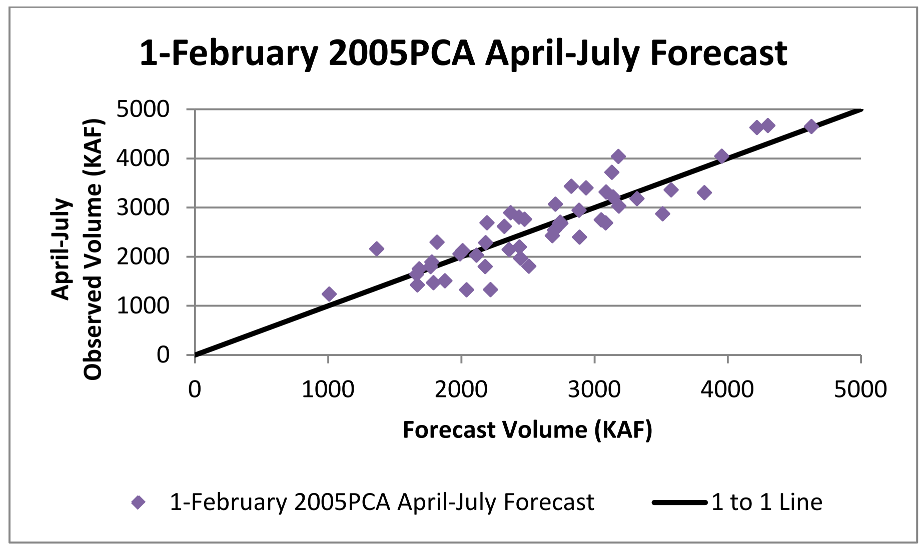

1-May 2011PCA May-July Forecast
May-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-May 2011PCA May-July Forecast
1 to 1 Line

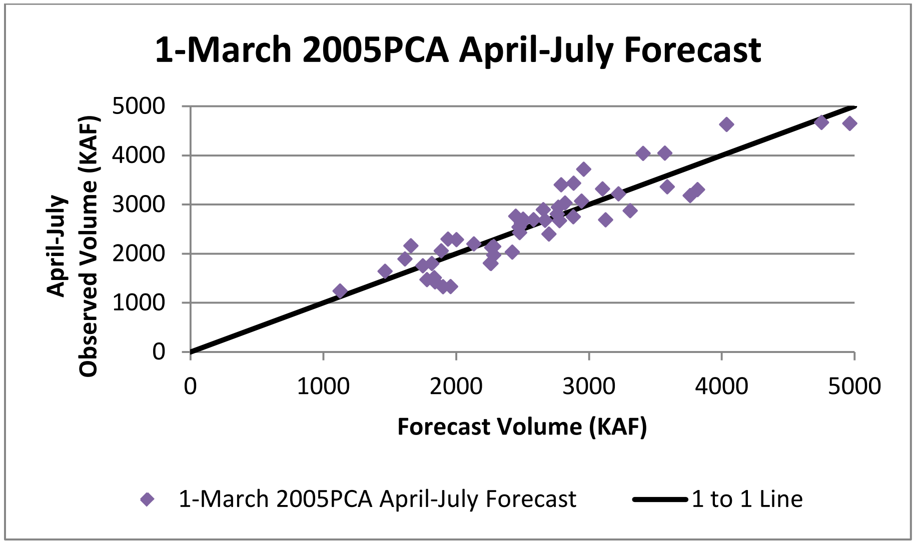

1-June 2011PCA June-July Forecast
June-July
Observed Volume (KAF)
Forecast Volume (KAF)
0
500
1000
1500
2000
2500
3000
1-June 2011PCA June-July Forecast
1 to 1 Line

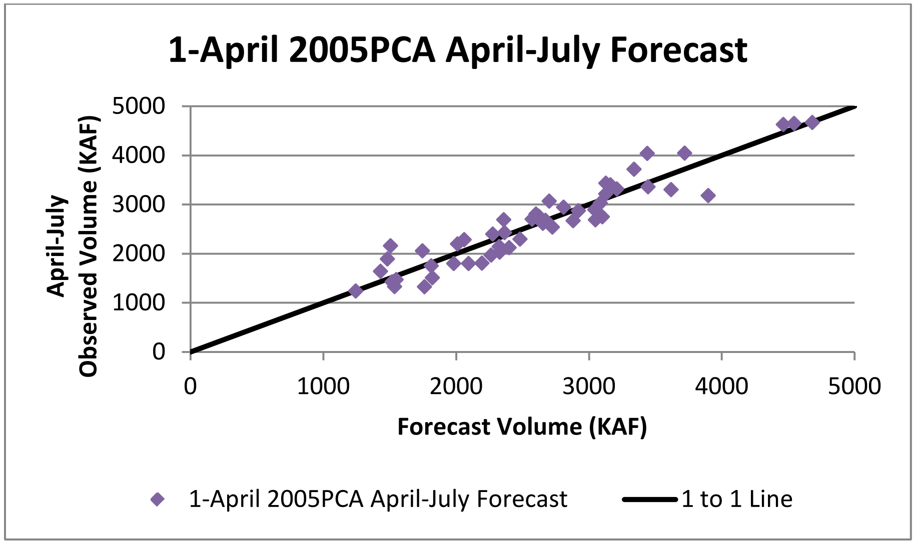

1-November 2005PCA April-July Forecast
April-July Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-November 2005PCA April-July Forecast
1 to 1 Line

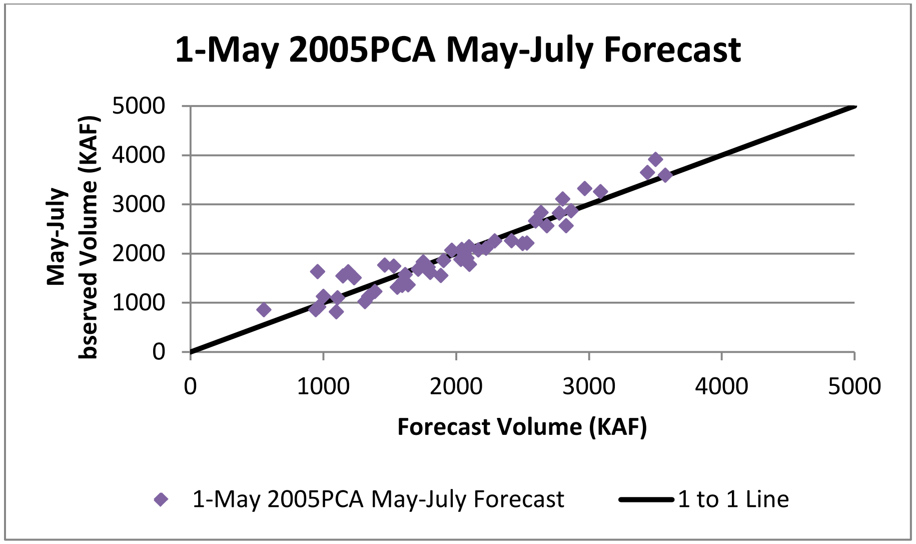

1-December 2005PCA April-July Forecast
April-July Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-December 2005PCA April-July Forecast
1 to 1 Line

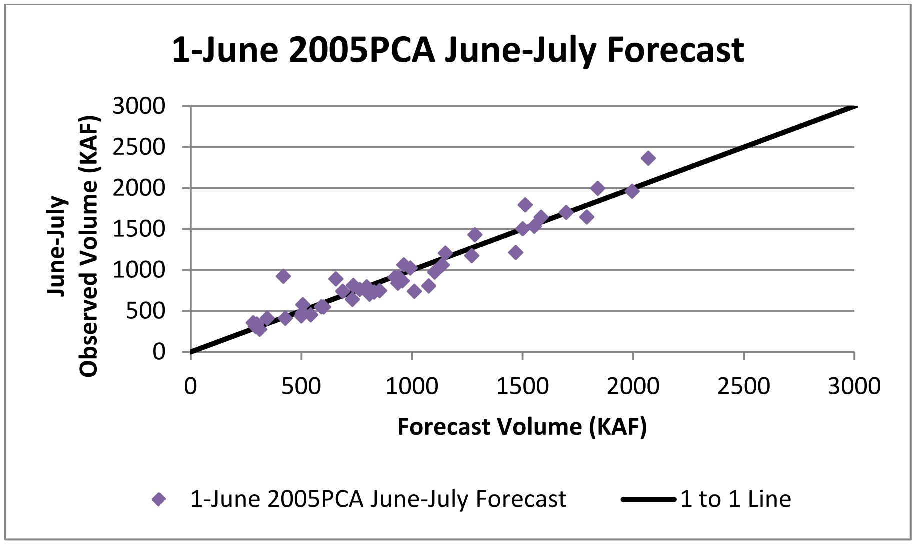

1-January 2005PCA April-July Forecast
April-July Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-January 2005PCA April-July Forecast
1 to 1 Line

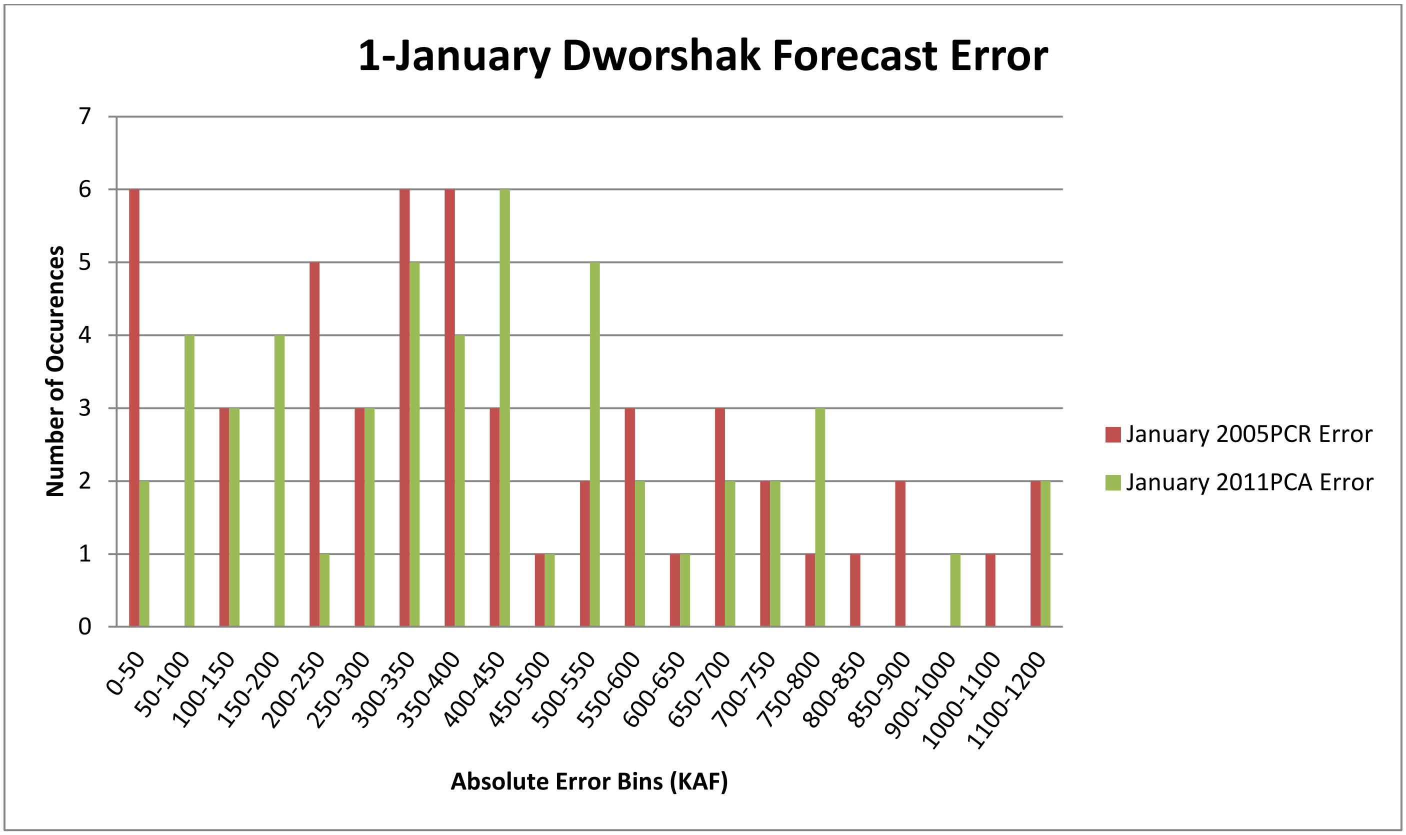

1-February 2005PCA April-July Forecast
April-July Observed Volume (KAF)
Forecast Volume (KAF)
0
1000
2000
3000
4000
5000
1-February 2005PCA April-July Forecast
1 to 1 Line

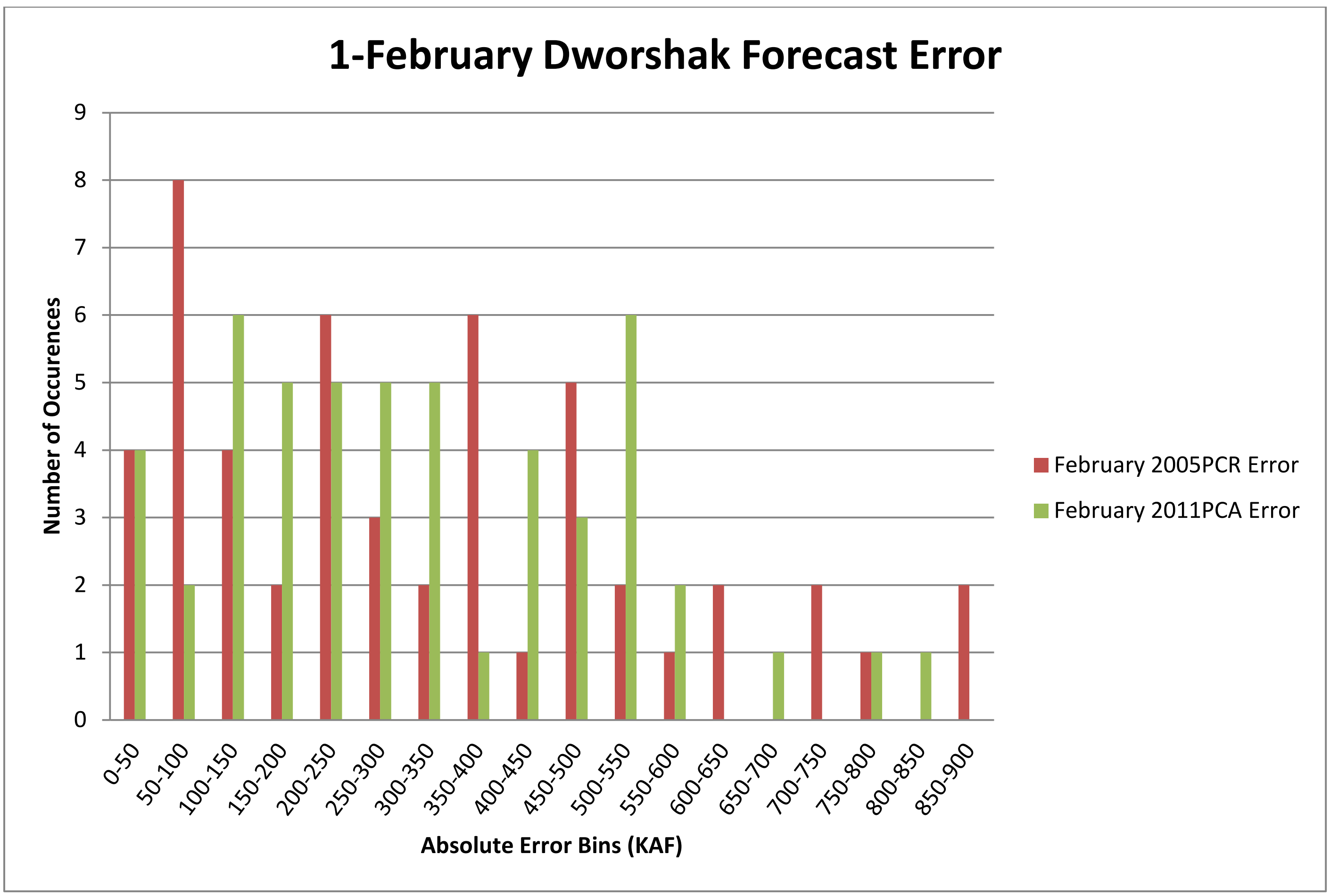

1-March 2005PCA April-July Forecast
April-July
Observed Volume (KAF)
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
Forecast Volume (KAF)
1-March 2005PCA April-July Forecast
1 to 1 Line

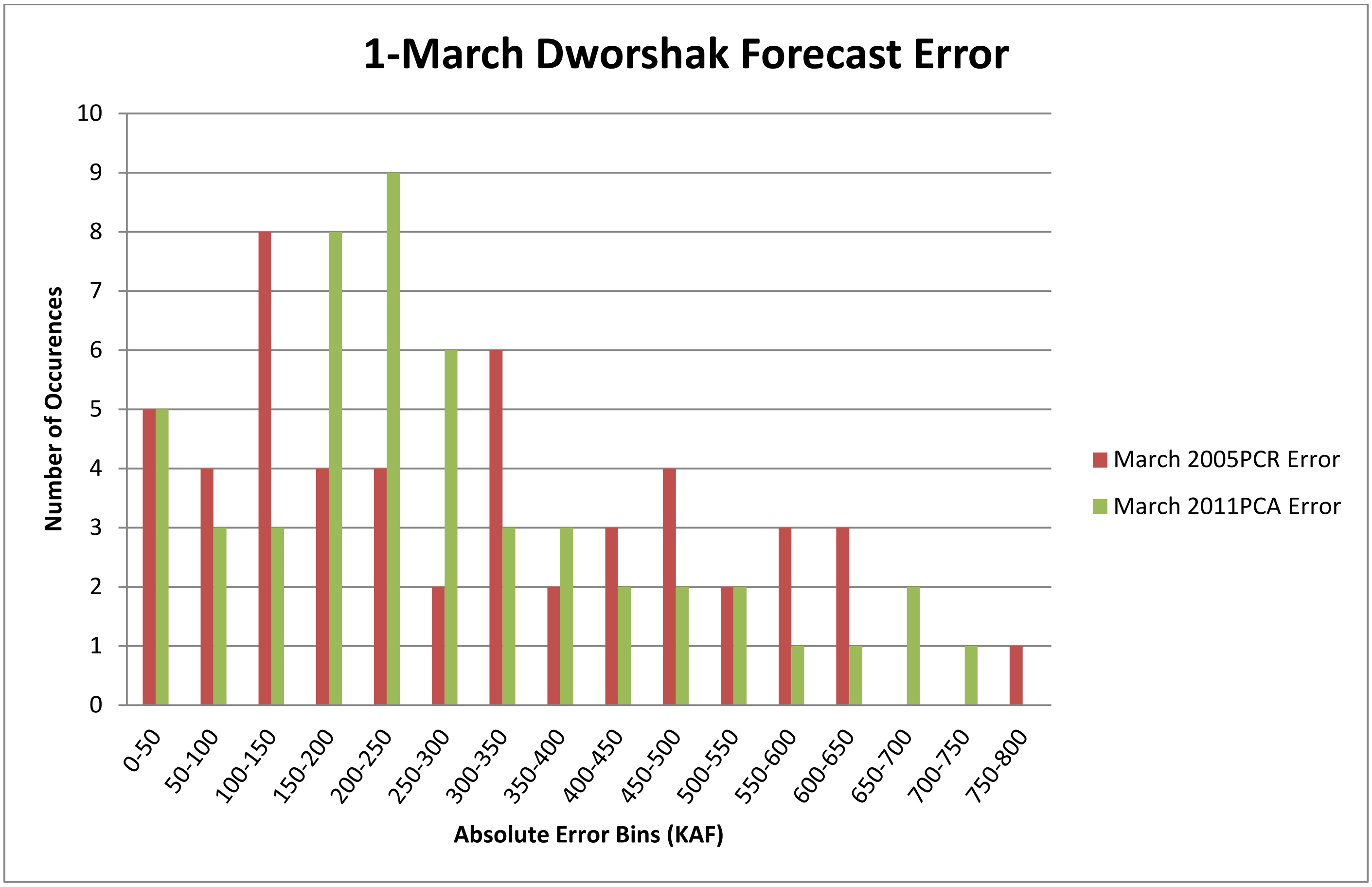

1-April 2005PCA April-July Forecast
April-July
Observed Volume (KAF)
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
Forecast Volume (KAF)
1-April 2005PCA April-July Forecast
1 to 1 Line

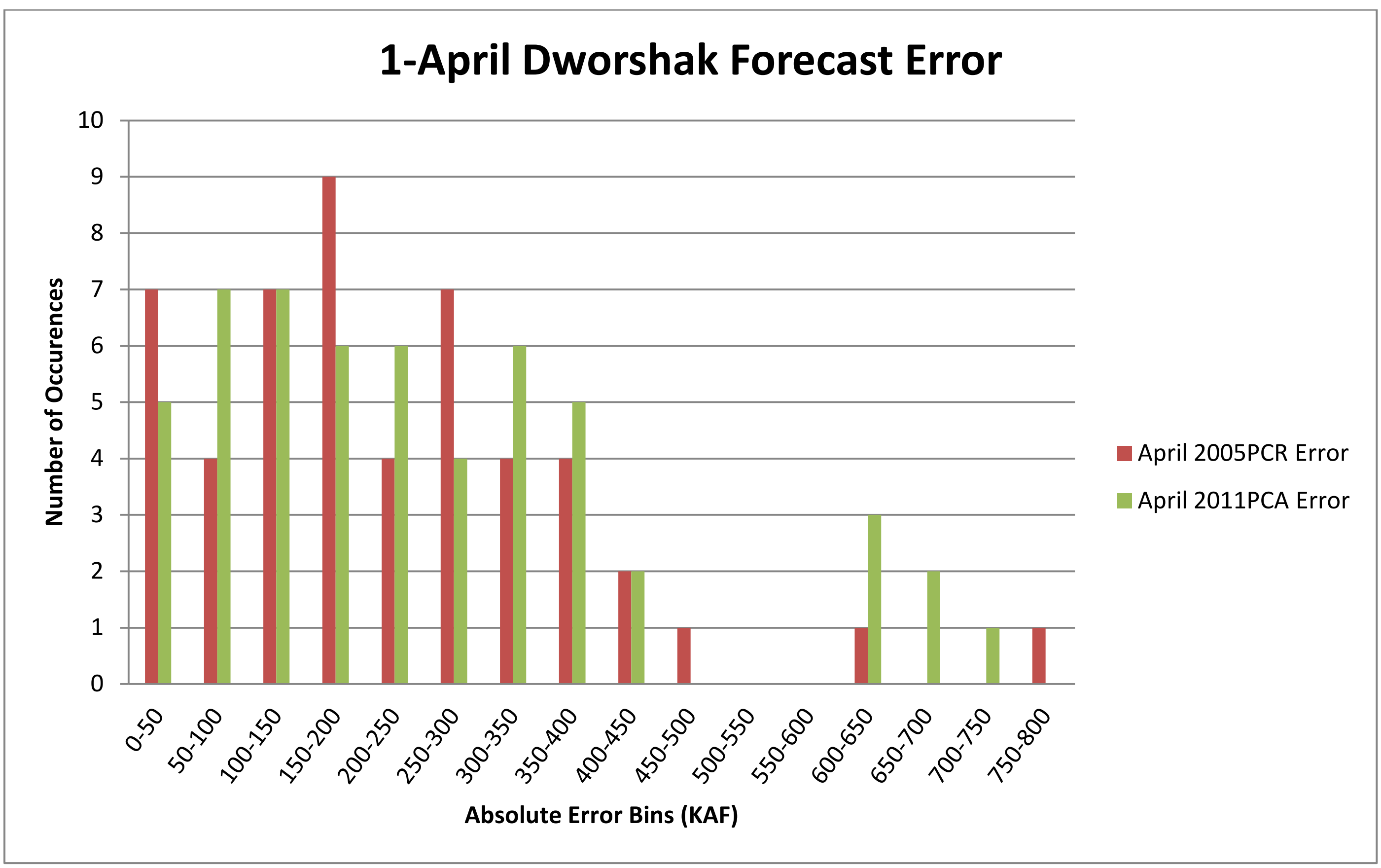

1-May 2005PCA May-July Forecast
May-July
bserved Volume (KAF)
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
Forecast Volume (KAF)
1-May 2005PCA May-July Forecast
1 to 1 Line

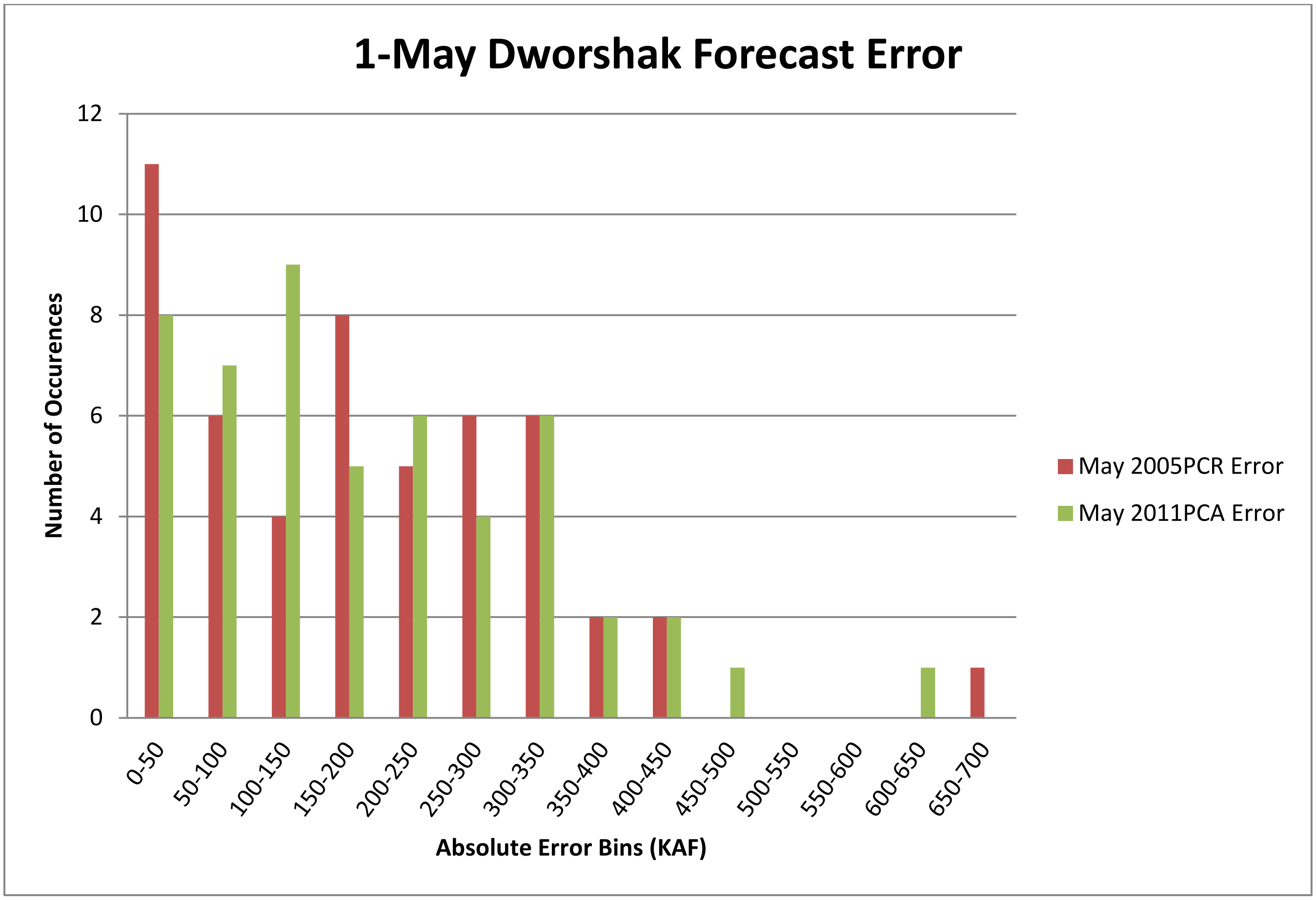

1-June 2005PCA June-July Forecast
June-July
Observed Volume (KAF)
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
Forecast Volume (KAF)
1-June 2005PCA June-July Forecast
1 to 1 Line

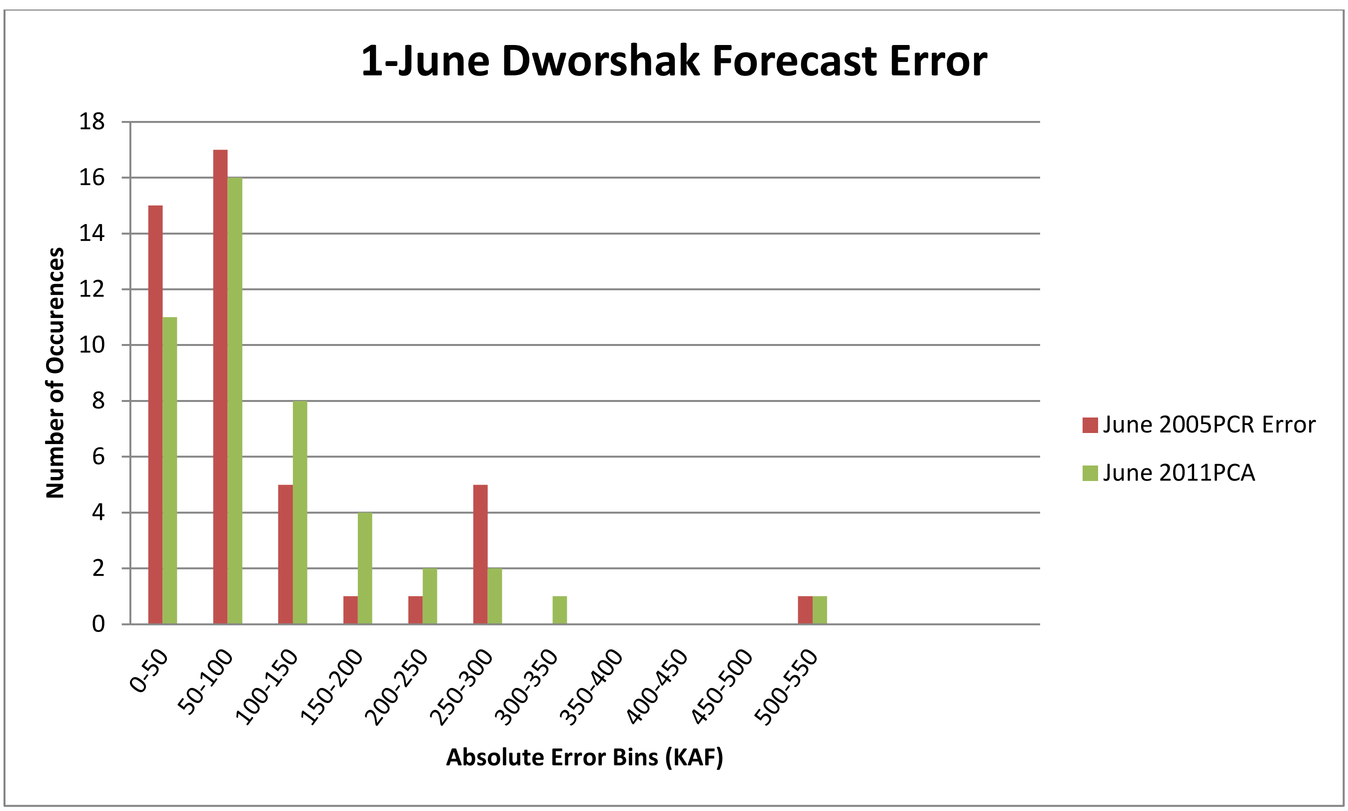

1-January Dworshak Forecast Error
Number of Occurences
Absolute Error Bins (KAF)
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600-650
650-700
700-750
750-800
800-850
850-900
900-1000
1000-1100
1100-1200
January 2005PCR Error
January 2011PCA Error


1-February Dworshak Forecast Error
Number of Occurences
Absolute Error Bins (KAF)
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600-650
650-700
700-750
750-800
800-850
850-900
February 2005PCR Error
February 2011PCA Error


1-March Dworshak Forecast Error
Number of Occurences
10
9
8
7
6
5
4
3
2
1
0
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600-650
650-700
700-750
750-800
Absolute Error Bins (KAF)
March 2005PCR Error
March 2011PCA Error


1-April Dworshak Forecast Error
Number of Occurences
10
9
8
7
6
5
4
3
2
1
0
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600-650
650-700
700-750
750-800
Absolute Error Bins (KAF)
April 2005PCR Error
April 2011PCA Error


1-May Dworshak Forecast Error
Number of Occurences
Absolute Error Bins (KAF)
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600-650
650-700
0
2
4
6
8
10
12
May 2005PCR Error
May 2011PCA Error


1-June Dworshak Forecast Error
Number of Occurences
Absolute Error Bins (KAF)
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
0
2
4
6
8
10
12
14
16
18
June 2005PCR Error
June 2011PCA

Appendix E – ATR Summary

Dworshak Runoff Volume Forecast

Agency Technical Review

May 2012

Both the 2011 Z-Score and 2011 PCR forecasts were developed by Walla Walla District and are considered technically sound methods for runoff volume forecasting. Each method is based on statistical analysis of historical volume forecasts and has been technically reviewed by experts within the region. We are asking the independent review panel to review each of these approaches along with the existing 2005 PCR and provide your ratings of each method based on the criteria provided below. We would also request that you provide a summary of your professional comments and opinions on each method.

Criteria

1. **Accurate forecast** - To provide the most accurate runoff volume forecast for the upcoming year which will allow making the best operational decisions for all project purposes. This may require real-time adjustment during unusual or abnormal conditions to minimize risk. (outstanding, good, fair, poor)
2. **Solid Historical Base** - To provide a solid statistically based forecast equation as measured with a variety of statistical metrics against the historic data. These include cross validation standard error (CVSE), Standard Error, minimizing Maximum Errors, minimizing bias, and Maximizing Correlation. The value of each of these should be appropriately balanced. (Excellent, Very Good, Good, Poor)
3. **Adequate Basin Coverage** - Selected indicator stations should offer representative basin coverage for all foreseeable geographic distributions of snowpack to the extent SWE stations are available. Such basin coverage will reduce forecast error for years beyond the historic record that may have unusual snow distribution. (Outstanding Coverage, Sufficient Coverage, Poor Coverage).
4. **Reproducible Process (intent/consistency)** - Runoff volume forecasts need to be explainable and transparent to regional interests in Dworshak operations such that independent forecasters could arrive at a similar result. Would use of each of the three forecast methods provide a consistent reproducible high quality forecast over time? (Consistently Reproduces similar, high quality results, Usually Reproduces similar/ high quality results, Seldom Reproduces similar/high quality results)
5. **Additional considerations** – Sufficient period of record, decreasing seasonal forecast error through the forecast season, use of present condition SWE values rather than prior months. (Meets all additional considerations; Meets most of additional considerations; Fails a majority of additional considerations)

Dworshak Runoff Volume Forecast

Review Summary

June 2012

Independent technical review of the Dworshak runoff volume forecast was conducted from 11 June to 27 June. Three reviewers were jointly selected by the NWD CBWM office and the NWW WM offices. These reviewers were Beth Faber of the Corps Hydrologic Engineering Center, John Roache from the USBR, and Stephen King from the National Weather Service. Reviewers were provided 5 review criteria to review and provide responses.

Written comments from reviewers were varied, but contained similar conclusions. In general reviewers indicated that the 2005 PCR forecast was not as desirable as the 2011 PCR and 2011 Z-Score forecasts. Comparisons between the 2011 PCR and 2011 Z-Score forecasts indicated advantages and disadvantages of each, with no significant conclusion that one is definitely preferable than the other. Standard Errors were found to be slightly better with the 2011 PCR, Maximum Errors were slightly better for the Z-Score. Better Broad Basin Coverage and usability for real time applications was found with the 2011 Z-Score.

The general statistical comments are consistent with the Walla Walla District development goals of the 2011 PCR and 2011 Z-Score. Broader basin coverage results in lower maximum errors in unusual years due to reflecting of a greater portion of the basin, however broader basin coverage slightly reduces the standard error (average error).

The following table summarizes the criteria responses. Note that Faber responded separately to both components of the Accurate forecast criteria and Reproducible process criteria as noted.

Comment	Reviewer	2005 PCR	2011 PCR	2011 Z-Score
Accurate Forecast	Faber (ability to make real-time adjustment/accuracy otherwise)		Poorer than Z-Score/Better than Z-Score	Outstanding/Good
	King	Outstanding	Outstanding	Outstanding
	Roache	Good	Good	Good
Solid Historical Base	Faber		Fair	Good
	King	Very Good	Excellent	Very Good
	Roache	Good	Very Good	Very Good
Adequate Basin Coverage	Faber		Fair	Outstanding
	King	Sufficient	Sufficient	Outstanding
	Roache	Sufficient	Sufficient	Outstanding
Reproducible Process	Faber (transparent/reproducible)		Fair/Outstanding	Outstanding/Fair
	King	Consistently Reproduces Similar, high quality results	Consistently Reproduces Similar, high quality results	Consistently Reproduces Similar, high quality results
	Roache	Consistently Reproduces Similar, high quality results	Consistently Reproduces Similar, high quality results	Consistently Reproduces Similar, high quality results
Additional Considerations	Faber		Meets all	Meets all
	King	Meets all	Meets all	Meets all
	Roache	Meets most	Meets all	Meets all

Note: Faber did not see the 2005 PCR as a desirable forecast because it was only a data extension omitting the PCR optimization of the cross-validation standard error and therefore did not rate it.

Following are summary comments:

King – "From a statistical standpoint, none of the three stands out as being definitively better than the others."…" Given the similar results, other non-statistical factors may be more important in the selection process such as operational efficiencies, user acceptance, or acceptable risk (e.g., is it more important to select a model that does well during extreme years)."

Faber – "PCA regression has the benefit of ensuring the assumptions of OLS regression are met, meaning resulting variables are orthogonal (uncorrelated), and each contain more information than any singular independent variable. However, Z-score regression also achieves a similar benefit by combining variables and their information prior to regression.
If one cares about real-time clarity and flexibility of the forecast procedure, Z-score seems to provide both better. I'm told the tools allow the user more ability to study the real-time data and trends within it. However, PC could provide more clarity if tools were made to do so. With Z-score, while I like the ability to adjust input in

real-time to capture the watershed better, I'd like to see the result of using that flexibility year by year, to determine if using the flexibility gave better results in the important years, or led the forecaster astray. (Note, a standard error of "user adjusted" forecasts could be computed. Would it be better or worse than the unadjusted standard error?)
Overall, I feel the Z-score method is more appropriate to the needs of real-time forecasting, but there are variations that do not seem to have been explored (such as not combining indices of different variable types), and so I cannot be certain this method is the best possible of its type.

Standard errors of the PCR equations are better than those of the Z-score equations. However, there are some examples of larger maximum errors with PCR, generally as underestimates. If one wants to minimize the maximum error, PCR would be a poorer choice. I don't know enough about the operation of the reservoir to know whether underestimates or overestimates are more of a problem. Both PCR and Z-score share a trend in the errors to overestimate the lows and underestimate the highs. This makes both procedures somewhat violate the base assumptions of linear regression. However, the results are still useful. The usability of the Z-score equations seems better. Not being a user, and not seeing the result of making use of the flexibility and clarity, I cannot tell if the trade-off toward usability is worth it."

Roache – "In our opinion it is hard to say which technique is better than the other for "official water supply forecast." For producing an operating forecast for Dworshak, we would recommend running both the 2011 PCR forecast and the 2011 Z-score forecast and compare the results from both forecasts to determine the "official operating forecast". This may mean choosing one result over another or averaging the results from both forecasts based on judgment on current basin conditions (i.e. comparing to analog years, snow-flight verification, and base flow conditions etc). However if only one technique can be deemed the "official" forecast, we would recommend the 2011 PCR forecasts since the PCR forecasts are a more proven method for producing water supply forecasts and have been used in many basins for many years. We would still recommend running the 2011 Z-score for comparison purposes or if the PCR forecast was producing unreliable forecasts. We also recommend running the 2011 Z-score forecast in between the official forecasts to gain insight into forecast trends or to educate an operational change, such as final fill or verification during low years. "

Appendix F – Hedges for Variable Energy Content Curves (VECC)

Hedges were developed for use in the Variable Energy Content Curves (VECC) for power modeling. The VECC utilize a different forecast period then is utilized for flood risk management. Flood risk management utilizes an April-July forecast for the November-April period and a Date-July forecast for May and June. The VECC utilizes a Jan-July forecast for November and December, and Date-July for the remaining season. Correspondence from Northwestern Division 14 November 2011 indicated that VECC's are no longer utilized for Dworshak project. At the request of the Columbia River Treaty Hydromet Committee the following VECC forecasts and associated hedges were developed.

KAF

Dworshak	Statistic	Aug-Oct	1-Nov	1-Dec	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun
Jan-Jul 71-yr Volume	71-year Median	3445								
Jan-Jul 71-yr Volume	Standard Error about the Median	1019								
Jan-July Forecast	adj. CVSE		895	830						
Date-July Forecast	adj. CVSE				683	519	374	294	250	159
April-July Forecast	CVSE		705	679	534	405	354	294	250	159
Hedge (Jan-Jul/Date-Jul)	t(95%) x CVSE	1699	1501	1391	1146	871	627	494	420	267

ksfd

Dworshak	Statistic	Aug-Oct	1-Nov	1-Dec	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun
Jan-Jul 71-yr Volume	71-year Median	1737								
Jan-Jul 71-yr Volume	Standard Error about the Median	514								
Jan-July Forecast	adj. CVSE		451	418						
Date-July Forecast	adj. CVSE				344	262	188	148	126	80
April-July Forecast	CVSE		355	342	269	204	178	148	126	80
Hedge (Jan-Jul/Date-Jul)	t(95%) x CVSE	856	757	701	578	439	316	249	212	134