Introduction

Precipitation in the Owens Valley is monitored at nine stations by Los Angeles Department of Water and Power (LADWP), one station by the National Oceanic and Atmospheric Administration (NOAA), and at seven stations by Inyo County Water Department (ICWD, Table 1). The ICWD program began in December 1991 to support an analysis of the vegetation database and maps suggested in the Green Book (Section V.A.1.b). This article summarizes results from all stations for the period that the Inyo program was in place.

Table 1. List of rain gauge abbreviations used in this article as well as location name and gauge operators.

Abbreviation	Name/Location	Operator
RG1	Laws 1 monitoring site	Inyo
RG2	Laws museum	Inyo
RG3	BC2 monitoring site	Inyo
RG4	BP2 monitoring site	Inyo
RG5	Goose Lake	Inyo
RG6	TS2 monitoring site	Inyo
RG7	Union Wash, NE of Lone Pine	Inyo
NOAA	Bishop airport	NOAA
BISYD	Bishop maintenance yard	DWP
BPPH	Big Pine Powerhouse	DWP
BPYD	Big Pine maintenance yard	DWP
TIN	Tinemaha Reservoir	DWP
LAAIT	Los Angeles aqueduct intake	DWP
INDYD	Independence maintenance yard	DWP
ALGT	Alabama gates	DWP
LPYD	Lone Pine maintenance yard	DWP
CWGT	Cottonwood gates	DWP

Methods

Monitoring was completed by manual reads collected daily for the LADWP/NOAA gauges. Inyo gauges were visited after known or suspected rain events and individual measurements constitute storm totals. Previously, ICWD constructed a precipitation database based on data for LADWP gauges provided in the LADWP daily aqueduct report. Those reports are produced before internal quality control procedures are completed, and the data they contain are subject to change. When discrepancies were noted in the daily report (e.g. the daily measurement and running total disagree), an estimated value was entered into the database. Data from LADWP gauges discussed in this article were provided after the quality control procedures were completed, and the earlier corrections estimated by ICWD were discarded.

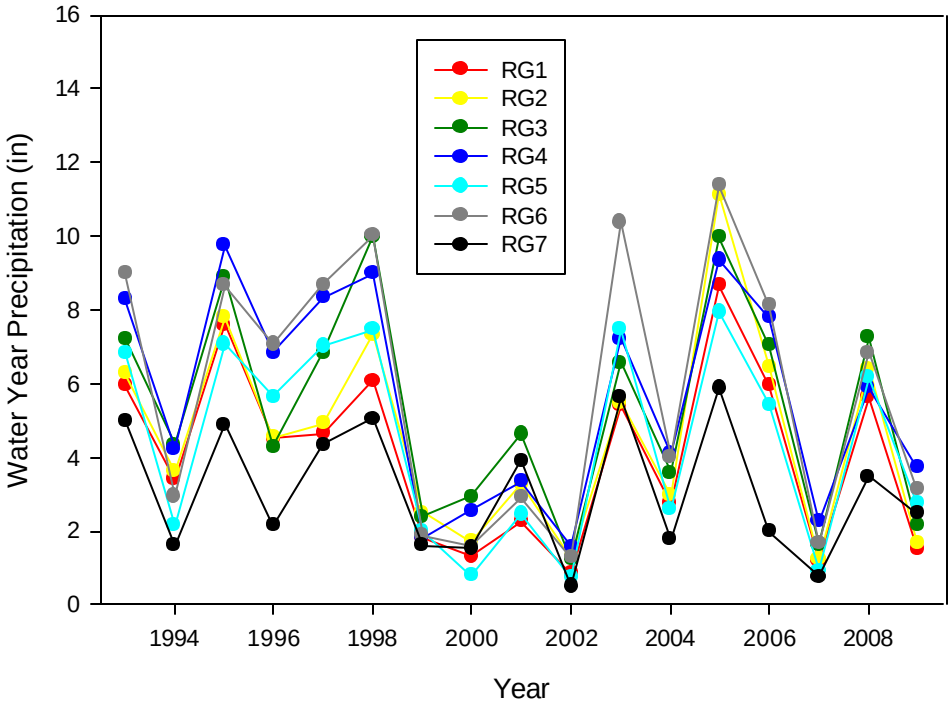

Figure 1. Water year precipitation totals for the seven Inyo County gauges for the period of record.

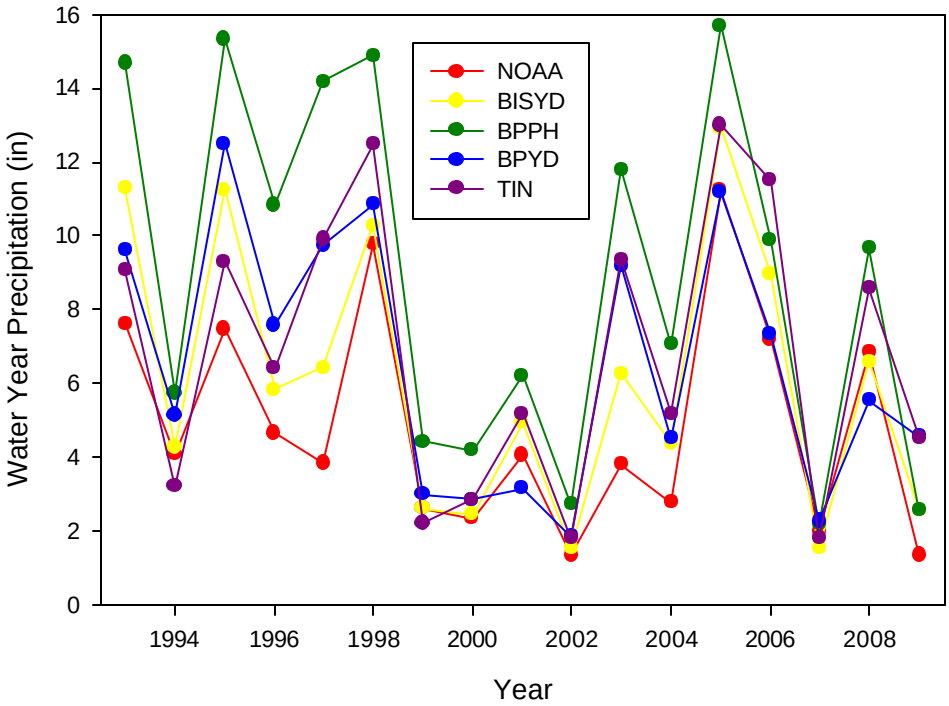

Figure 2. Water year precipitation totals for the LADWP gauges in the northern Owens Valley and the NOAA gauge at the Bishop Airport.

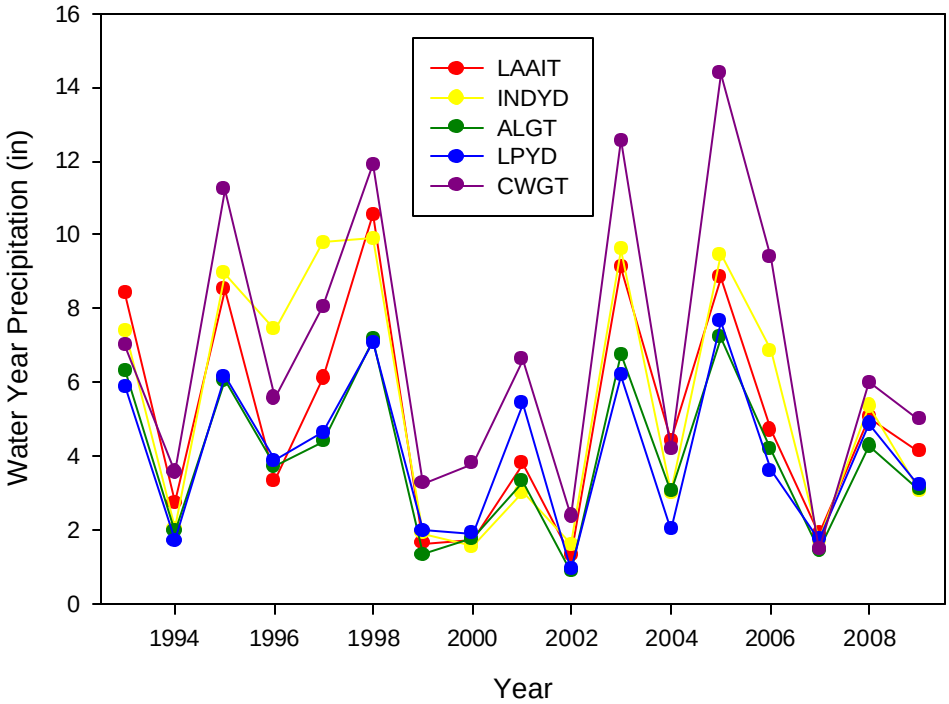

Figure 3. Water year precipitation totals for the LADWP gauges in the southern Owens Valley.

Precipitation measurements can be summarized several ways depending on the purpose of the analysis. Two frequently used quantities are water year and winter precipitation total. Water year is defined as the period from October 1 to September 30 and is referred to by the ending date. For example, water year 1993 encompasses the period October 1, 1992 to September 30, 1993. The Owens Valley climate is characterized by moist winters and dry summers. Approximately 80% of the annual precipitation occurs from October to April. Because the evapotranspiration demand is low during winter, much of the precipitation is stored in the soil where it is a reservoir for plant use during the growing season. For the analysis presented here, winter is defined as October 1 through March 31. Other time periods or definitions could be used to represent winter, but for the purpose of examining trends or comparing locations, the Oct.1-Mar. 31 definition is sufficient.

Discussion

Water year (October 1-September 30) totals and average for the period of record are presented in Table 2. In general, the totals for the Inyo gauges is less than that measured in nearby LADWP gauges. Most Inyo gauges were located closer to the center of the valley, and the lower values reflect the general precipitation gradients in the valley (Danskin, 1998). Simple inspection of the inter-annual trends, however, suggests that

Table 2. Water year totals and averages for Inyo and LADWP rain gauges during the period of operation of the Inyo gauges. Measurements are in inches.

Water Year	RG1	RG2	NOAA	BISYD	RG3	BPPH	BPYD	RG4	TIN	LAAIT	RG5	RG6	INDYD	RG7	ALGT	LPYD	CWGT
1993	5.94	6.29	7.63	11.29	7.21	14.68	9.61	8.29	9.07	8.41	6.83	9.00	7.41	5.00	6.34	5.89	7.01
1994	3.40	3.62	4.09	4.29	4.354	5.75	5.15	4.24	3.21	2.76	2.155	2.95	2.06	1.62	1.97	1.72	3.58
1995	7.60	7.80	7.48	11.26	8.87	15.33	12.5	9.76	9.30	8.52	7.07	8.67	8.95	4.88	6.07	6.17	11.23
1996	4.51	4.55	4.67	5.84	4.29	10.83	7.59	6.85	6.41	3.36	5.64	7.07	7.45	2.14	3.75	3.9	5.59
1997	4.66	4.91	3.85	6.44	6.85	14.18	9.76	8.33	9.92	6.13	7.02	8.68	9.79	4.35	4.42	4.65	8.06
1998	6.09	7.34	9.77	10.29	9.98	14.88	10.86	8.99	12.48	10.55	7.47	10.01	9.9	5.055	7.18	7.09	11.91
1999	1.82	2.5	2.62	2.63	2.39	4.44	3.01	1.83	2.23	1.66	1.98	1.88	1.93	1.61	1.36	2.01	3.27
2000	1.32	1.73	2.36	2.47	2.93	4.19	2.87	2.56	2.87	1.73	0.8	1.59	1.57	1.54	1.79	1.93	3.82
2001	2.26	3.27	4.07	4.96	4.63	6.22	3.16	3.34	5.20	3.82	2.46	2.91	3.02	3.91	3.33	5.44	6.63
2002	0.86	1.28	1.37	1.55	1.24	2.73	1.87	1.59	1.81	1.32	0.75	1.28	1.61	0.51	0.89	0.95	2.4
2003	5.41	5.49	3.82	6.27	6.57	11.79	9.19	7.23	9.35	9.12	7.47	10.38	9.61	5.62	6.76	6.21	12.56
2004	2.75	2.96	2.8	4.4	3.59	7.06	4.52	4.09	5.19	4.43	2.58	4.01	3.03	1.77	3.05	2.04	4.19
2005	8.65	11.13	11.24	12.94	9.96	15.7	11.19	9.35	13.00	8.86	7.94	11.38	9.47	5.88	7.24	7.66	14.37
2006	5.94	6.47	7.21	8.96	7.04	9.88	7.34	7.8	11.49	4.72	5.44	8.13	6.87	1.99	4.21	3.63	9.4
2007	1.19	1.23	2.02	1.54	1.63	2.2	2.29	2.25	1.81	1.91	0.93	1.66	1.73	0.76	1.47	1.77	1.5
2008	5.63	6.4	6.85	6.6	7.26	9.66	5.54	5.89	8.57	5.06	6.18	6.85	5.37	3.48	4.29	4.88	6.01
2009	1.52	1.69	1.37	2.6	2.16	2.57	4.57	3.72	4.55	4.14	2.75	3.12	3.09	2.49	3.11	3.23	5
Average	4.09	4.63	4.90	6.14	5.35	8.95	6.53	5.65	6.85	5.09	4.44	5.86	5.46	3.09	3.95	4.07	6.85

Table 4. Regression equations and summary statistics for estimating water year precipitation at Inyo gauge locations from LADWP gauges.

Inyo gauge	DWP gauge	regression equation	r^2
RG1	BISYD	0.63*BISYD + 0.23	0.91
RG2	BISYD	0.72*BISYD + 0.24	0.91
RG3	TIN	0.71*TIN + 0.52	0.89
RG4	BPYD^	0.80*BPYD + 0.40	0.96
RG5	INDYD	0.78*INDYD + 0.16	0.94
RG6	INDYD	1.03*INDYD + 0.21	0.95
RG7	LPYD	0.81*LPYD - 0.19	0.93

^: Correlation with INDYD was slightly better than BPYD. Either model would provide acceptable results.

precipitation totals among gauge locations is correlated (Figures 1-3). Results of a correlation analysis comparing each gauge to all others is presented in Table 3. Correlation for water year precipitation was high, and generally weakened slightly as distance between gauges increased. The high correlation between the gauges suggest that it may be possible to develop statistical models of the spatial pattern of precipitation. in the valley That analysis is beyond the scope of this work, but may be completed in the future if needed.

One important advantage of the LADWP dataset is the much longer period of record than the Inyo monitoring program. The longer record is necessary for analyses that extend to the 1984-87 period when the vegetation baseline for the Water Agreement was established. For all Inyo gauges, at least one LADWP gauge could be identified as a surrogate based on an acceptable linear regression model relating precipitation measured at the two locations (Table 4).

Examination of winter precipitation produced results similar to those from the analysis of water year totals (Figures 4-6, and Tables 5-6). The Inyo and LADWP measurements are well correlated. In fact, the correlation between gauges for winter precipitation is higher than for water year totals for most pairs. That may reflect different precipitation patterns between winter and summer storms. Winter storms tend to be frontal systems that affect a large portion of the valley. Summer showers are more isolated, weakening the correlation between pairs of stations for the water year totals. The differences in correlation are so small, however, that this interpretation is speculative.

The original goal for the expanded the rain gauge network was to improve the understanding of the precipitation patterns in the valley. That goal for Inyo County's monitoring program has been met, and the field measurements were discontinued in 2009.

Reference

Danskin, W.R., 1998. Evaluation of the hydrologic system and selected water-management alternatives in the Owens Valley. U.S. Geol. Survey Water Supply Paper 2370-H

Table 3. Coefficient of determination (r^2) matrix of water year precipitation totals. The gauges are arranged north to south.

r^2	*RG1*	*RG2*	*NOAA*	*BISYD*	*RG3*	*BPPH*	*BPYD*	*RG4*	*TIN*	*LAAIT*	*RG6*	*RG5*	*INDYD*	*RG7*	*ALGT*	*LPYD*	*CWGT*
RG1	1																
RG2	0.961	1															
NOAA	0.832	0.906	1														
BISYD	0.913	0.910	0.891	1													
RG3	0.903	0.907	0.863	0.890	1												
BPPH	0.865	0.806	0.696	0.859	0.869	1											
BPYD	0.845	0.757	0.616	0.813	0.811	0.916	1										
RG4	0.895	0.805	0.688	0.860	0.861	0.928	0.956	1									
TIN	0.836	0.830	0.745	0.817	0.891	0.817	0.778	0.877	1								
LAAIT	0.704	0.672	0.592	0.738	0.795	0.778	0.817	0.774	0.769	1							
RG6	0.872	0.813	0.659	0.795	0.835	0.897	0.882	0.922	0.913	0.827	1						
RG5	0.858	0.787	0.628	0.764	0.829	0.904	0.880	0.913	0.874	0.804	0.968	1					
INDYD	0.764	0.690	0.532	0.689	0.761	0.888	0.899	0.906	0.844	0.782	0.945	0.943	1				
RG7	0.632	0.640	0.510	0.655	0.731	0.729	0.702	0.654	0.666	0.856	0.732	0.757	0.707	1			
ALGT	0.795	0.770	0.673	0.809	0.837	0.830	0.837	0.835	0.845	0.958	0.906	0.879	0.837	0.876	1		
LPYD	0.698	0.729	0.659	0.736	0.795	0.737	0.696	0.699	0.749	0.829	0.762	0.782	0.731	0.927	0.901	1	
CWGT	0.758	0.778	0.619	0.718	0.801	0.712	0.759	0.746	0.831	0.804	0.823	0.763	0.787	0.780	0.860	0.817	1

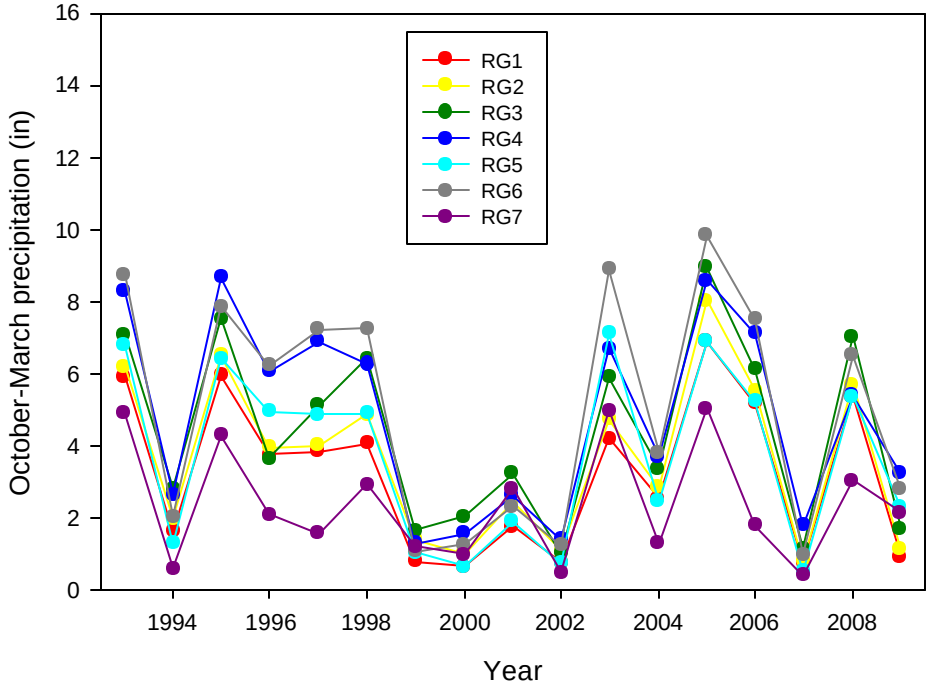

Figure 4. Winter precipitation totals for the seven Inyo County gauges for the period of record.

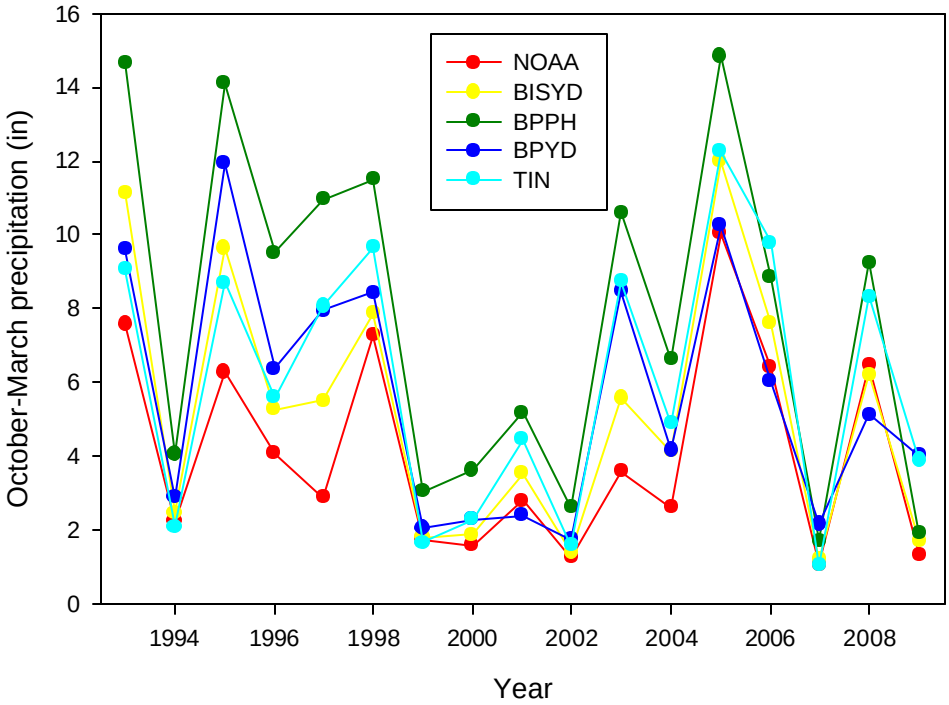

Figure 5. Winter precipitation totals for the LADWP gauges in the northern Owens Valley and the NOAA gauge at the Bishop Airport.

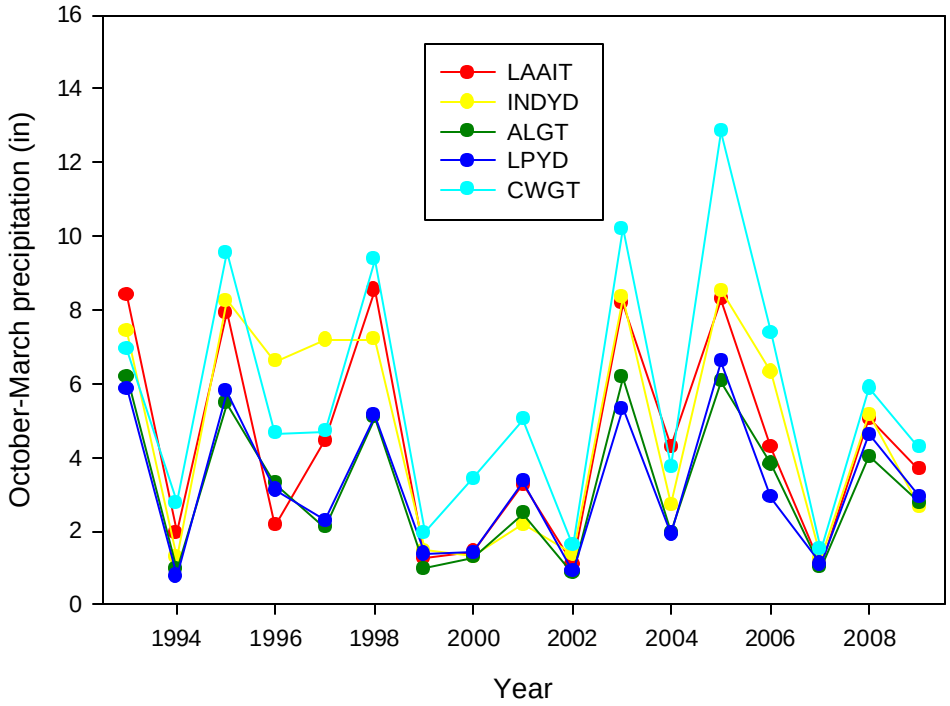

Figure 6. Winter precipitation totals for the LADWP gauges in the southern Owens Valley.

Table 5. Winter (October 1-March 31) totals and averages for Inyo and LADWP rain gauges during the period of operation of the Inyo gauges. Measurements are in inches.

Water Year	RG1	RG2	NOAA	BISYD	RG3	BPPH	BPYD	RG4	TIN	LAAIT	RG5	RG6	INDYD	RG7	ALGT	LPYD	CWGT
1993	5.92	6.21	7.59	11.14	7.08	14.67	9.61	8.27	9.07	8.39	6.78	8.75	7.41	4.9	6.19	5.86	6.92
1994	1.64	1.98	2.24	2.49	2.81	4.07	2.89	2.66	2.11	1.96	1.29	2.05	1.28	0.59	0.96	0.78	2.77
1995	5.96	6.52	6.29	9.65	7.53	14.11	11.94	8.66	8.71	7.92	6.41	7.87	8.26	4.29	5.47	5.78	9.56
1996	3.75	3.95	4.1	5.28	3.64	9.53	6.38	6.08	5.61	2.15	4.96	6.23	6.6	2.11	3.3	3.11	4.66
1997	3.85	4.02	2.9	5.51	5.11	10.96	7.95	6.89	8.07	4.45	4.88	7.22	7.18	1.56	2.11	2.29	4.7
1998	4.075	4.87	7.29	7.87	6.425	11.51	8.43	6.27	9.67	8.54	4.89	7.25	7.19	2.92	5.07	5.14	9.37
1999	0.79	1.4	1.76	1.81	1.65	3.06	2.07	1.29	1.68	1.27	1.04	1.07	1.48	1.2	0.98	1.38	1.97
2000	0.65	1.01	1.59	1.9	2.05	3.64	2.31	1.56	2.3	1.43	0.65	1.27	1.31	0.98	1.29	1.41	3.43
2001	1.77	2.43	2.81	3.54	3.25	5.19	2.41	2.63	4.47	3.26	1.9	2.33	2.18	2.81	2.47	3.36	5.03
2002	0.78	1.1	1.27	1.42	1.03	2.62	1.76	1.4	1.6	1.11	0.75	1.24	1.38	0.49	0.85	0.91	1.62
2003	4.2	4.74	3.61	5.59	5.91	10.6	8.48	6.7	8.74	8.17	7.1	8.88	8.34	4.98	6.17	5.32	10.2
2004	2.54	2.84	2.62	4.15	3.38	6.62	4.18	3.7	4.9	4.29	2.46	3.83	2.72	1.31	1.95	1.92	3.75
2005	6.89	8.03	10.03	11.99	8.94	14.84	10.26	8.59	12.26	8.27	6.89	9.82	8.52	5.04	6.07	6.61	12.83
2006	5.17	5.53	6.42	7.61	6.12	8.84	6.03	7.13	9.8	4.26	5.24	7.49	6.31	1.81	3.82	2.92	7.39
2007	0.77	0.79	1.07	1.22	1.17	1.73	2.18	1.79	1.05	1.06	0.51	1	1.25	0.41	1.02	1.11	1.5
2008	5.37	5.71	6.47	6.22	7.04	9.26	5.13	5.41	8.33	5.06	5.38	6.51	5.17	3.04	4.02	4.62	5.88
2009	0.94	1.14	1.35	1.72	1.71	1.93	4.04	3.23	3.91	3.67	2.29	2.8	2.67	2.15	2.78	2.94	4.26
average	3.24	3.66	4.08	5.24	4.40	7.83	5.65	4.84	6.02	4.43	3.73	5.04	4.66	2.39	3.21	3.26	5.64

Table 6. Coefficient of determination (r^2) matrix of winter precipitation totals. The gauges are arranged north to south.

r^2	*RG1*	*RG2*	*NOAA*	*BISYD*	*RG3*	*BPPH*	*BPYD*	*RG4*	*TIN*	*LAAIT*	*RG6*	*RG5*	*INDYD*	*RG7*	*ALGT*	*LPYD*	*CWGT*
RG1	1																
RG2	0.988	1															
NOAA	0.860	0.898	1														
BISYD	0.921	0.937	0.912	1													
RG3	0.952	0.970	0.880	0.907	1												
BPPH	0.903	0.905	0.770	0.919	0.890	1											
BPYD	0.793	0.790	0.629	0.817	0.784	0.899	1										
RG4	0.915	0.889	0.715	0.872	0.855	0.916	0.922	1									
TIN	0.890	0.906	0.816	0.850	0.921	0.842	0.773	0.881	1								
LAAIT	0.684	0.714	0.648	0.748	0.783	0.761	0.802	0.722	0.781	1							
RG6	0.904	0.892	0.722	0.833	0.875	0.902	0.866	0.954	0.932	0.771	1						
RG5	0.895	0.877	0.683	0.798	0.854	0.879	0.856	0.933	0.880	0.761	0.976	1					
INDYD	0.828	0.818	0.636	0.770	0.795	0.888	0.910	0.939	0.864	0.730	0.960	0.949	1				
RG7	0.634	0.671	0.576	0.673	0.685	0.672	0.674	0.626	0.644	0.801	0.679	0.748	0.653	1			
ALGT	0.760	0.779	0.711	0.780	0.788	0.765	0.786	0.777	0.793	0.881	0.831	0.868	0.800	0.908	1		
LPYD	0.735	0.774	0.737	0.775	0.795	0.748	0.746	0.707	0.761	0.860	0.745	0.789	0.725	0.935	0.945	1	
CWGT	0.709	0.772	0.718	0.737	0.806	0.711	0.742	0.716	0.834	0.820	0.775	0.752	0.754	0.773	0.853	0.840	1