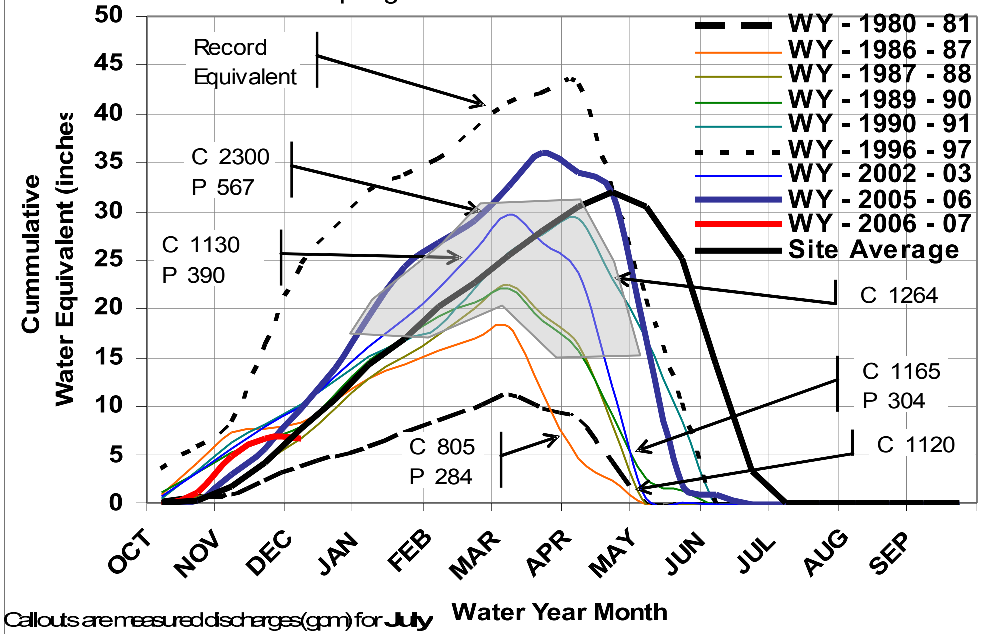
Special Report Number 1

Town of Star Valley Ranch
PREDICTING SUMMER WATER SUPPLY

December 29, 2006

Figure 1. Annual snow water equivalent curves at the Willow Creek Snotel Station for the water years with discharge data at Green and Prater Springs.



Callouts are measured discharges (gpm) for **July** for Cedar (C) and Prater (P) springs.

INTRODUCTION

This report develops visual and statistical methods to estimate summer discharges from Green and Prater Springs. They utilize snow water equivalent (SWE) data from the automated Willow Creek Snotel station (el. 8380 feet) in the Salt River Range. SWE is the amount of water (in inches) in the snow pack released upon melting; it is less than snow depth in inches.

Snow acts as a reservoir that is discharged into the ground and local rivers during the spring melt. The relationship is simple: the greater the SWE, the greater the quantity of melt water released. Forecasts are made by comparing the SWE data to measured spring discharges (data in Table 1).

Discharge data for Prater and Green springs are sparse and of uncertain accuracy. For this reason, the results from the two methods developed here are only approximations. The following paragraphs describe the methods – pattern matching and least squares regression.

CURVE MATCHING

Figure 1 (above) shows the SWE curves for the six water years with July discharge data at Green Spring and the four years with July data at Prater Spring. The discharges are monthly averages except 2006, which is a single observation. The SWE curves are separated by a shaded area that includes the maximum SWE for water years with 1000 and 1200 gpm discharges at Green Spring and 300 – 400 gpm discharges at Prater Spring. SWE curves lying below this zone are for water years with lower July discharges and above are for water years with higher July discharges. The dashed SWE curves are water years with the highest (1997) and lowest (1981) SWE of record.

Prepared by Robert Palmquist (Meandering@silverstar.com) from data at http://www.wcc.nrcs.usda.gov/snow/snotel-data.html.

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In curve matching, the SWE curve for current water year (2006 -07) is compared to curves from previous years for which July and total spring discharges are available. The maximum SWE value, which is achieved in March or April, produces the best predictions of summer discharges. The data for 2006 – 07 water year is shown by the heavy red line.

STATISTICAL PREDICTION

Statistical prediction is based on the mathematical relationships between the observed maximum SWE (usually in March or April) and the measured discharges of Green and Prater springs in July, as well as their average annual discharges. The resulting regression equations explain the observed relationships and can be used to predict spring discharges from a given maximum SWE.

Figures 2 and 3 on the right show the statistical trendline fitted to the observations, their regression equations, and the error of prediction (dotted line). The R^2 for each equation is the amount of variation in spring discharge explained by the variation in maximum SWE. The R^2 is very high for hydrological data, in part because of the apparently close relationship between stored snow water and ground water recharge and, in part, because of the few data points used to develop the regression.

The errors of prediction are based on the greatest differences between the predicted and observed discharges (Table 1). With more data, they may increase; they can not decrease.

No regression is possible for Prater Spring average annual discharge because of the lack of data (Figure 3). Only the July data for both springs are used to develop predictions.

The regression equations in Figure 2 are used to predict the July discharges for both springs and the average annual discharges for Green Spring for the interval covered by the Willow Creek Snotel record (Table 1).

Figure 2. Comparison of July discharge to maximum snow water equivalent.

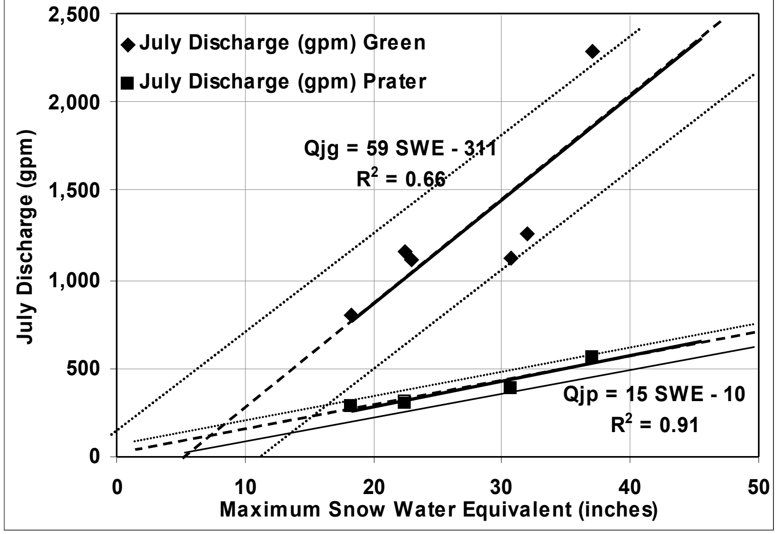

Figure 3. Comparison of average annual discharge to maximum snow water equivalent.

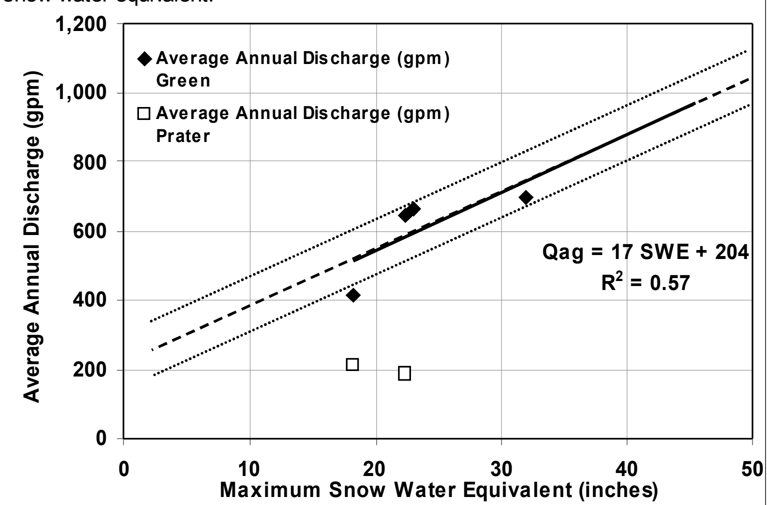

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***Table 1**. Summary of snow water equivalent (SWE) from the Willow Creek Snotel station and discharge data from springs in Green and Prater Canyons. Predicted discharges are based on the regressions in the graphs on preceding page. (2006 discharge data are single observations; others are monthly average.)*

Water Year (ending date)	Observed					Predicted				Difference			
	Max Monthly SWE (inches)	July Discharge (gpm)		Average Annual Discharge (gpm)		July Discharge (gpm)		Average Annual Discharge (gpm)		July Discharge (gpm)		Average Annual Discharge (gpm)	
		Green	Prater	Green	Prater	Green	Prater	Green	Prater	Green	Prater	Green	Prater
1983	43					2,244	640	940					
1984	44					2,256	643	944					
1985	26					1,217	379	644					
1986	43					2,220	634	933					
1987	18	805	284	418	210	769	265	515		-36	-20	97	
1988	23	1,120		667		1,046	335	595		-74		-72	
1989	38					1,943	563	853					
1990	22	1,165	304	648	184	1,011	326	585		-154	22	-63	
1991	32	1,264		699		1,577	470	748		313		49	
1992	20					881	293	547					
1993	36					1,819	532	818					
1994	26					1,235	383	649					
1995	34					1,719	506	789					
1996	36					1,807	529	814					
1997	46					2,374	673	978					
1998	30					1,447	437	711					
1999	36					1,813	530	816					
2000	30					1,471	443	717					
2001	22					969	316	573					
2002	24					1,099	349	610					
2003	31	1,130	390			1,500	451	726		370	61		
2004	26					1,235	383	649					
2005	27					1,306	401	670					
2006	37	2,300	567			1,878	547	835		-422	-21		
Count	24	6	4	4	2	24	24	24	0	6	4	4	0
Average	31	1,297	386	608	197	1,535	459	736		-1	11	3	
Minimum	18	805	284	418	184	769	265	515		-422	-21	-72	
Maximum	46	2,300	567	699	210	2,374	673	978		370	61	97	

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The relationship between the July discharge and those of the adjacent months can be estimated from the available data. As shown in Table 2, discharges change in a systematic manner for both springs being greatest in June or July and decreasing into early spring and fall. The rate of change as shown by the monthly averages differ for the two springs. The data for Prater Spring are limited and until more data are collected, the combined monthly averages are applied to both springs.

Green Canyon Springs						
Year	April	May	June	July	August	September
1987	31%	99%	132%	100%	60%	49%
1988	49%	147%	111%	100%	91%	59%
1990	34%	71%	101%	100%	96%	87%
1991	30%	54%	96%	100%	96%	106%
2003				100%	76%	
Prater Canyon Springs						
Year	April	May	June	July	August	September
1987	65%	87%	128%	100%	72%	57%
1988						
1990	55%	83%	96%	100%	86%	63%
1991						
2003				100%	79%	
Monthly Average						
Green	36%	93%	110%	100%	84%	75%
Prater	60%	85%	112%	100%	79%	60%
Combined	44%	90%	111%	100%	82%	70%

DISCUSSION

The two methods developed here are complementary. The graphical method (Figure 1) is useful to show changes in SWE as the winter season progresses in a manner that can readily be seen by the non-mathematician. The statistical method (Figures 2 and 3) can be used to predict the July discharge within the errors of prediction once the maximum snow water equivalent has been observed at the Willow Creek Snotel station. The July prediction when combined with the summer monthly averages (Table 2) then can be used to assess the potential water availability during the critical summer months.

The predicted discharges in Table 1 define the limits of the town's spring-fed water resource during the 20 years of snotel record. The greatest SWE (46 inches) occurred in water year 1997 with a predicted July discharge for Green and Prater Springs of 2,374 and 673 gpm respectively. The lowest recorded SWE (18 inches) occurred in 1987 with a predicted July discharge for Green and Prater Springs of 769 and 265 gpm, respectively. The recorded high and low SWE result in nearly a three fold difference between the high and low July discharges. This variation in potential resource availability is a strong argument for supplementary ground water sources.

The analysis presented here applies indirectly to ground water availability because Prater, Green, and Cedar Creeks infiltrate into the alluvial fans underlying the town and ground water levels should respond directly to the quantity of infiltrated water. At this time, no data are available to these relationships.

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