Statistical Analysis of Selected Feather River Coordinated Resource Management Stream Flow Data

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Executive Summary

Streamflow data collected by the Feather River CRM since 1998 was analyzed to see if a change in summer base flow could be detected and to provide basic descriptive statistics of base flow hydrology at these sites. Data used in this analysis came from stream gauging sites on Cottonwood Creek (Big Flat), Doyle Crossing (Last Chance), Notson (Red Clover), Flournoy Bridge (Indian Creek), and the DWR weir on Indian Creek above Genesee Valley.

Most published research on the linkage between stream restoration and base flow augmentation is either anecdotal or based entirely on theoretical analysis under hypothetical conditions (Ponce, et al., 1990). Climate and aquifer properties appear to be key variables governing the potential for base flow augmentation.

This analysis is exploratory, looking for apparent trends in the data that might suggest directions for future data collection efforts. In part, this was necessitated by the type, abundance, and quality of the data. The fundamental question centers on the hydrologic effect of stream restoration and its hypothesized increase in aquifer storage. Increased aquifer storage, in turn, might feed increased base flows. This is really a research question best answered by intensive and tightly controlled, site-level data. This data does not meet that description and was not originally conceived to answer this type of question. Many of the flow monitoring sites used in this analysis were originally established to support regional-scale efforts to define flow and sediment regimes in the upper North Fork Feather River as part of a partnership between the Feather River CRM and Pacific Gas and Electric Company. Additionally, problems with data gaps and shifting stage-discharge rating curves further limited some opportunities for more intensive data analysis.

More recently, some stakeholders and interest groups have challenged those assumptions, asking if it is not possible that restoration projects could have the opposite effect. They offer the possibility that less water may appear as base flow as more water is transpired by enlarged and invigorated riparian plant communities or lost to deep seepage. This analysis looks for any trend or change in the base flow regime in either direction.

Since these data comprise that largest database available on the watershed's hydrology, this effort was initiated to see exactly what it might suggest about base flow changes and stream restoration. From the outset, it must be understood that the best this data can do is suggest where trends and linkages may be present and how we might choose to proceed in the future to address the question more definitively.

Not surprisingly, the results are mixed. At Big Flat, years of above and below monitoring did reveal an apparent positive shift in the amount base flow at the downstream station per unit of flow at the upstream station supported by statistical testing of differences. The glaring weakness is that we cannot necessarily assert a cause-and-effect relationship. Nonetheless, the difference is statistically significant.

At Flournoy, Notson Bridge, and Doyle Crossing, above and below data were not available. Instead, the time trend of normalized base flow was examined against the timeline of restoration projects in the watershed above. Moving average trend lines were superimposed on the restoration timeline to make time trends more visually apparent.

Although not statistically testable, any consistent shift in the trend line could be evidence suggesting base flow augmentation. However, these analysis yielded no apparent trend or linkage to stream restoration at any of the sites. Variation in normalized flow data from year to year appears to be more associated precipitation and snowmelt patterns dominant in any given year and not associated with the extent of stream restoration accomplishments in the watershed.

Big Flat Analysis

Extent and quality of streamflow data

The data available consists of daily averages of streamflow in Cottonwood Creek at two sites, one above and one below the restoration project at Big Flat. Data was available for water years 1998-2010. The tables below show the number of days of useable data at each site.

Number of Days of Useable Data Per Month -- Big Flat ABOVE

MONTH	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% MISSING
OCT	25	0	0	7	31	31	31	31	31	31	31	31	31	22.8%
NOV	30	0	0	30	30	30	30	30	30	30	30	30	28	15.9%
DEC	31	20	0	31	31	31	31	31	30	31	31	31	31	10.7%
JAN	31	31	0	31	31	31	31	31	31	24	31	28	16	13.9%
FEB	28	28	0	28	28	28	29	28	28	28	29	25	28	8.7%
MAR	31	31	0	31	31	31	31	31	31	31	29	31	31	8.2%
APR	30	30	0	30	30	30	30	30	30	30	30	30	30	7.7%
MAY	31	31	0	31	31	31	31	31	31	31	31	31	31	7.7%
JUNE	30	30	0	30	30	30	30	30	30	30	30	30	30	7.7%
JULY	31	7	0	31	31	31	31	31	31	31	31	31	31	13.6%
AUG	6	0	0	31	31	31	31	31	31	31	31	31	31	21.6%
SEPT	0	0	0	30	30	30	30	30	30	30	30	30	30	23.1%
% MISSING	**16.7%**	**43.0%**	**100.0%**	**6.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.3%**	**1.9%**	**0.5%**	**1.6%**	**4.7%**	**24.3%**

Number of Days of Useable Data Per Month -- Big Flat BELOW

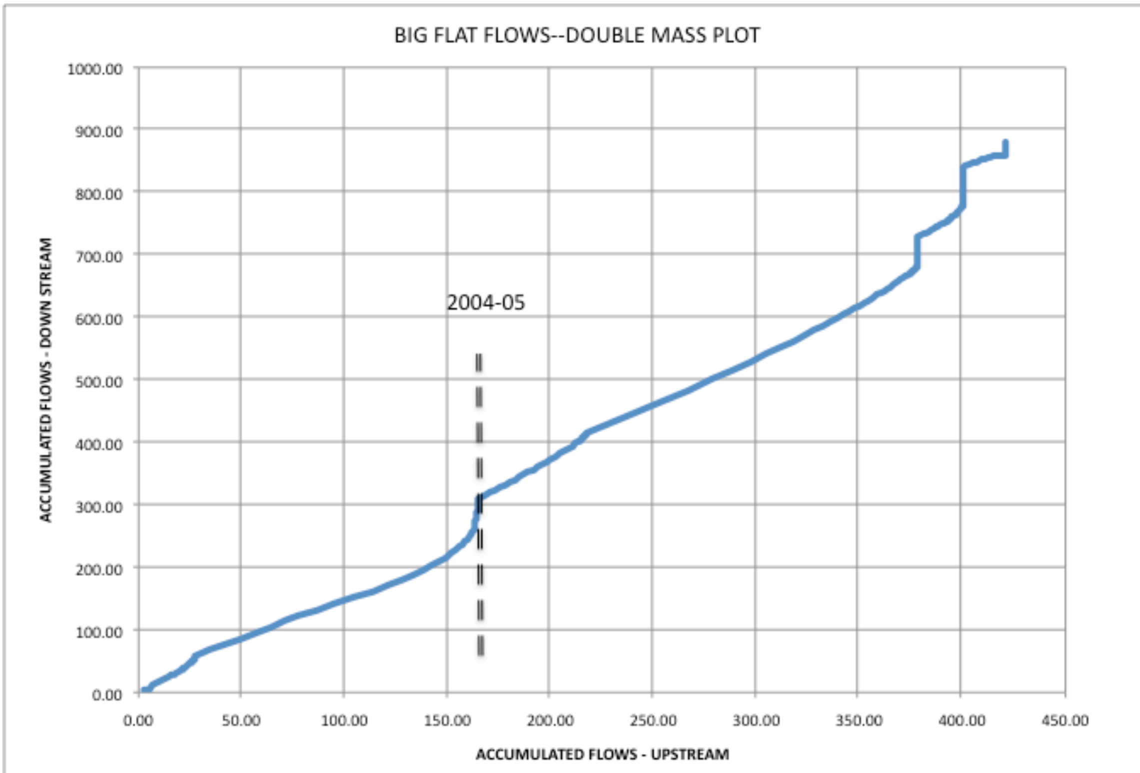
MONTH	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% MISSING
OCT	28	15	31	7	22	9	31	31	31	31	31	31	31	18.4%
NOV	11	19	30	30	30	17	30	30	30	30	30	30	30	11.0%
DEC	0	14	31	31	31	31	31	31	29	31	31	21	0	22.6%
JAN	24	31	31	31	31	31	31	31	31	31	31	0	0	17.1%
FEB	11	28	29	28	28	28	29	28	26	28	29	19	0	15.3%
MAR	31	31	31	31	31	31	31	31	31	31	29	31	0	8.2%
APR	30	30	30	30	30	30	30	30	30	22	30	30	0	9.7%
MAY	26	31	31	31	31	31	31	31	31	0	31	31	0	16.6%
JUNE	23	30	30	30	30	30	30	30	30	0	30	30	0	17.2%
JULY	31	8	31	31	23	31	31	31	31	0	31	31	0	23.1%
AUG	17	12	12	31	0	31	31	31	31	0	31	31	0	36.0%
SEPT	21	30	0	30	0	30	30	30	30	0	30	30	0	33.1%
% MISSING	**30.7%**	**23.6%**	**13.4%**	**6.6%**	**21.4%**	**9.6%**	**0.0%**	**0.0%**	**1.1%**	**44.1%**	**0.5%**	**13.7%**	**83.3%**	**30.3%**

Major gaps in the low flow period are present in WY 1998, 1999, 2000, 2002, 2007, and 2010. Because of data gaps, summation of daily flows to arrive at annual totals is not possible for all years and somewhat weakens the data set. However, there is a large data set of “same day” synoptic observations that does allow an examination of the flow relationship between the two stations.

Using the data to look for low flow augmentation from the restoration work is hampered by the lack of pre-project data. The original restoration was completed in 1995 but was modified in 2004 to reduce channel cross sectional area and possibly raising water table levels. In the analysis, data was partitioned into pre- and post-2005 subsets to see if the latter work on the project changed the relationship between the upstream and downstream stations.

Same-day Double Mass Plot of Streamflow Data for the May-Sept Low Flow Period

A double mass plot is an analytical tool where sequential observation from two stations are summed incrementally and plotted against each other. A fundamental change in the relationship between the two stations would appear as a significant change in the slope of the trend line. Only low-flow period (May 1-Sept 30) data were used in this analysis.



The data was partitioned into "pre-2005" and "post-2005" data sets. Each set was analyzed by linear regression producing two predictive equations of the form:

$$\text{DOWNSTREAM} = a + b * \text{UPSTREAM}$$

Where *a* and *b* are the regression coefficients. A statistical test was then applied to determine if the pre- and post- *b* coefficients were significantly different. This involves calculation of the Z-score as follows:

$$Z = \frac{b_1 - b_2}{\sqrt{se_1^2 + se_2^2}}$$

where b_1 and b_2 are the pre and post regression slopes and se_1 and se_2 are the standard errors of the *b* coefficients. Here is the result.

	PRE (1)	POST (2)
a COEFFICIENT	4.813	-6.458
b COEFFICIENT	1.736	1.978
r^2	0.97	0.98
Standard error (se)	0.015	0.014

Z = 11.606, $p \sim 0.00$

CONCLUSION: This indicates that the two slope coefficients for the pre and post periods ARE SIGNIFICANTLY DIFFERENT. The difference between the two slopes is much greater than their pooled standard error. Note also that the slope increases in the post period; suggesting greater amounts of water downstream per unit flow upstream. Whether or not this conclusion would persist with a longer or more tightly managed data collection effort is uncertain. The stability of the two stage discharge relationships at the stations or other potential sources of error were not assessed. In any event, this suggests a possible low flow augmentation around 10% for late May, June, and part of July only (zero flow at both stations after late July). This suggests the presence of low flow augmentation.

Two-Sample T-Test Of Differences Between Stations

In this analysis, each day's observations were used to calculate the daily difference in flows between the upstream and downstream stations. Actually, two t-tests were performed. The first is a "paired" test where the mean of the differences is tested against the null hypothesis that the true population mean of difference is zero. This test merely establishes that a consistent and statistically significantly difference exists between the two stations.

	PRE	POST
Mean difference	0.374	0.513
p from t-test	~0.00	~0.00

CONCLUSION: For both the pre and post time periods, differences between the daily flows at the two sites are significantly different than 0. That is exactly what you would expect. The next test will tell us if the pre and post differences are significantly different FROM EACH OTHER.

A two-sample t-test in this context is analogous to a one-way analysis of variance (ANOVA). Instead of treating the pre and post data sets separately, both are used in the analysis to compare the difference in the mean differences (sorry for the statistically wordiness!) against their pooled standard error in a manner similar to the Z test presented earlier. Here is the result:

PRE Mean difference	0.374
PRE Standard error	0.034

PRE n (sample size)	390
POST Mean difference	0.513
POST Standard error	0.041
POST n (sample size)	612

$p = 0.017$

CONCLUSION: The mean differences in daily flows for the pre vs. post periods ARE SIGNIFICANTLY DIFFERENT with an increase in the differences apparent in the post-2005 period. This is consistent with all previous analyses.

To further explore this relationship, the pre and post data sets were further partitioned by months for the low flow period (May, June, July). Remember that August and September were zero flow months for all years and sites. The same analysis used above (two-sample t-test) was applied to these monthly data sets. Here are the results without all the numbers (available in accompanying spreadsheets)

May	$p = 0.675$	No significant difference
June	$p = 0.0000055$	Differences are significant
July	$p = 0.0000018$	Differences are significant

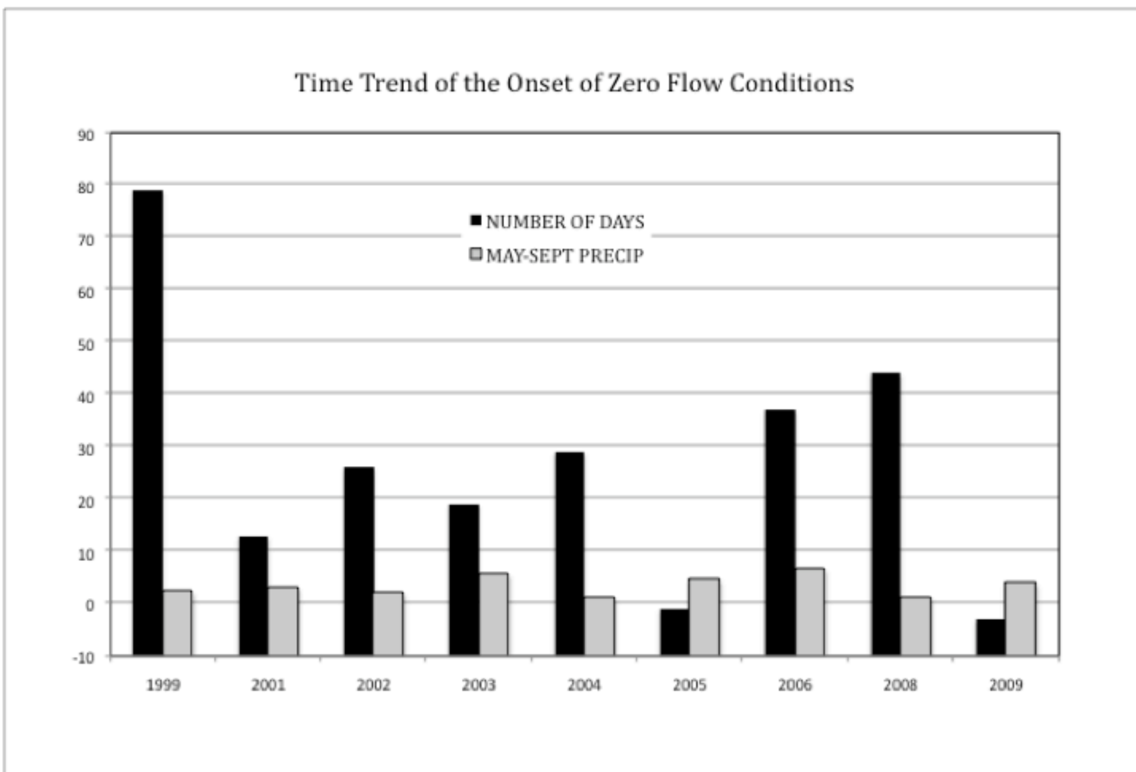
CONCLUSION: Some speculation is included here. The lack of a significant difference for May is likely due to inflows from upland sources, particularly snowmelt runoff, exerting a much greater effect and masking the groundwater contribution from Big Flat meadow. The aquifer could be recharging during this period. By June, snowmelt runoff is receding and groundwater contribution becomes more important. The July analysis shows a result consistent with June. However, the July analysis is weakened by the fact that the entire pre-2005 July data subset is all zeroes. This suggests that low flow augmentation at Big Flat, if present, is limited to late May, June, and early July.

Onset of Zero Flow Conditions

Data from both stations were examined in terms of when zero flow conditions commence. A delay in the onset of zero flow conditions at the downstream station in the post-2005 period would be another indicator of low flow augmentation. To better visualize the time trend of these data, I have included them in a plot alongside seasonal precipitation to qualitatively look for parallel trends. “NUMBER OF DAYS” refers to the number of days where flow is zero at the upstream site and non-zero at the lower site. Negative numbers indicate years where the downstream site went dry first. Data from three out of the thirteen years of record were missing (1998, 2007, 2010), precluding any of those years’ data from being included in this analysis.

Date of Onset of Zero Flow				
YEAR	BF-1 (ABOVE)	BF-2 (BELOW)	NUMBER OF DAYS*	
1999	158	237	79	PRE-Implementation Period
2001	121	134	13	
2002	153	179	26	
2003	161	180	19	
2004	138	167	29	
2005	165	164	-1	POST-Implementation Period
2006	168	205	37	
2008	153	197	44	
2009	139	136	-3	
AVERAGE	151	178	27	

* NUMBER OF DAYS defined as number of days with zero flow at BF-1 AND positive flow at BF-2. Negative values indicate the opposite condition. All dates are in Julian format.



CONCLUSION: In a nutshell, no pattern is apparent. The variability over time is unrelated either to late season precipitation (blue) or pre-post time periods. A regression analysis of precipitation against "number of days" did not yield a significant correlation. A follow-up analysis using annual precipitation had the same result.

Influent Conditions Suggesting Aquifer Recharge in Big Flat

"Influent conditions" is shorthand for a hypothesized situation where upstream discharge exceeds downstream discharge due to aquifer recharge through the channel bed. At best, these data can only hint at such conditions. A much more intensive research effort would be needed to actually establish the timing and dynamics of this process. Nonetheless, we will query the data at hand to see how strongly it does hint at this process.

Apparent influent conditions during low flow period (expanded to include April) occurred twice during the period of record.

April 30-May 26, 1999
April 3-May 18, 2009

Here is a snapshot of precipitation estimates for those water years:

PRECIP DATA FOR SUBJECT YEARS

	1999	2009	AVG FOR PERIOD
TOTAL	24.72	17.99	21.36
OCT-MAR	22.52	14.17	18.34
APR-SEPT	2.20	3.83	3.01

WY 1999 was wetter than average for the winter (OCT-MAR) period and drier than average for low flow season. Overall, WY 1999 was slightly wetter than the average for the period.

WY 2009 was the opposite--drier winter, wetter summer, below average for the year.

CONCLUSION: The data is not helping us here. It appears that the dynamics of aquifer recharge are far more complex than our data can illuminate. Addressing this question would require synoptic measurements from streamflow gauges and a network of monitoring wells, possibly dye-trace studies etc. Again, this would require a site-intensive research project, not broad scale regional flow data.

Descriptive Statistics – Big Flat Data

The following tables provide a summary of the flow and precipitation data for the period of record. Flow data has been converted to "equivalent depth" so that it may be directly compared to precipitation in units of "inches". This is accomplished as follows:

$$Q_{equivdepth} = \frac{(1.983 \times Q_{cfs} \times 12)}{WSacres}$$

Because of missing data, flows are most likely underestimated.

Big Flat ABOVE -- Runoff in Inches of Equivalent Depth

MONTH	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
OCT	0.00			0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
NOV	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEC	0.00	0.11		0.00	0.00	0.07	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.06
JAN	0.36	0.52		0.00	0.19	0.67	0.00	0.06	1.16	0.00	0.00	0.89	0.00	0.32
FEB	0.31	0.75		0.00	0.28	0.26	0.15	0.14	1.54	0.03	0.00	1.52	0.11	0.43
MAR	3.54	3.74		0.07	0.69	0.58	1.45	1.64	2.02	0.36	0.53	0.97	0.46	1.34
APR	2.63	3.21		0.01	0.37	0.83	0.15	1.08	5.07	0.07	0.34	0.41	0.52	1.22
MAY	0.84	0.72		0.00	0.10	0.52	0.00	0.20	0.59	0.00	0.08	0.08	0.25	0.28
JUNE	0.23	0.02		0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02
JULY	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AUG	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEPT				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	7.91	9.07		0.42	1.63	2.94	1.76	3.12	10.90	0.46	0.95	3.86	1.34	3.70

Big Flat BELOW -- Runoff in Inches of Equivalent Depth

MONTH	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
OCT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
NOV	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
DEC		0.20	0.00	0.00	0.00	0.02	0.00	0.00	0.63	0.00	0.00	0.00		0.23
JAN	0.46	0.50	0.00	0.00	0.15	0.58	0.00	0.06	1.61	0.00	0.00			0.17
FEB	0.44	0.69	0.25	0.00	0.30	0.34	0.18	0.05	1.36	0.12	0.00	0.82		0.15
MAR	3.61	3.95	1.94	0.06	0.73	0.64	2.74	2.17	2.52	1.37	0.62	1.25		0.08
APR	2.58	3.15	0.91	0.02	0.44	0.95	0.32	1.65	5.81	0.63	0.30	0.23		0.10
MAY	0.89	0.51	0.11	0.01	0.20	0.76	0.11	0.38	0.94		0.18	0.08		0.17
JUNE	0.43	0.17	0.03	0.00	0.02	0.05	0.02	0.01	0.16		0.09	0.07		0.17
JULY	0.18	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.07		0.14	0.00		0.23
AUG	0.01	0.01	0.00	0.00		0.00	0.00	0.00	0.00		0.00	0.00		0.36
SEPT	0.05	0.00		0.00		0.00	0.00	0.00	0.00		0.00	0.00		0.33
TOTAL	8.65	9.34	3.24	0.08	1.85	3.34	3.36	4.32	13.09		1.34	2.45		2.28

Weighted Average Precipitation Estimates for Big Flat

MONTH	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
OCT	1.06	0.58	1.16	1.36	0.42	0.01	0.00	2.49	0.24	0.35	1.37	0.58	1.69	0.87
NOV	1.98	4.03	1.61	1.23	2.68	3.41	1.30	1.28	0.84	2.17	0.54	2.18	1.37	1.89
DEC	2.55	2.51	0.46	0.62	5.10	8.00	6.74	4.21	0.79	1.46	1.73	2.63	2.67	3.04
JAN	4.87	5.69	8.10	0.69	1.51	1.86	2.75	3.67	3.68	0.44	5.87	1.02	4.74	3.45
FEB	6.95	7.47	6.47	1.81	0.50	0.84	5.43	1.20	2.87	6.52	3.31	3.41	2.94	3.82
MAR	3.78	2.24	0.77	2.02	2.54	1.88	0.57	4.07	4.33	0.90	0.30	4.34	3.18	2.38
APR	1.46	1.21	0.92	1.20	1.23	3.78	0.08	0.78	5.80	0.90	0.16	0.19	2.20	1.53
MAY	2.25	0.02	0.66	0.00	0.38	0.65	0.50	1.89	0.35	0.54	0.92	2.15	1.01	0.87
JUNE	1.17	0.14	0.08	0.03	0.11	0.07	0.26	0.98	0.31	0.55	0.00	1.20	0.14	0.39
JULY	0.29	0.19	0.00	1.65	0.15	0.10	0.02	0.00	0.01	0.01	0.00	0.05	0.40	0.22
AUG	0.02	0.49	0.00	0.00	0.00	0.88	0.01	0.00	0.00	0.00	0.00	0.23	0.08	0.13
SEPT	2.05	0.14	0.50	0.17	0.00	0.01	0.21	0.82	0.00	0.26	0.00	0.00	0.00	0.32
TOTAL	28.42	24.72	20.72	10.78	14.64	21.48	17.88	21.38	19.21	14.10	14.21	17.99	20.44	18.92

<u>Overall Conclusions Concerning Big Flat Data</u>

This is, by far, the best data set we have to address the low flow augmentation question. There is a respectable suggestion that some low flow augmentation may be occurring. The statistics suggest that it is most apparent in June and has an average magnitude of 0.14 cfs for a 4-6 week period. These are rough estimates but if they are at all close to reality, this amounts to a total augmentation of roughly 12 acre-ft/year. DON'T TAKE THAT TO THE BANK! This estimate is offered simply to help visualize the amount of water under discussion. In any event, we have no direct data linking restoration actions to this apparent "extra water". Numerous uncertainties about data quality warrant extreme caution against over-stating these conclusions. Mostly they justify closer scrutiny.

The data do not shed light on effects on timing of zero flows or influent-effluent conditions in the channel.

The project area received about 19 inches of precipitation based on a weighted average of seven nearby NOAA Climate stations (See Climate Data section of this report). Runoff from flow data is estimated around 3 inches. Missing data caused an underestimate of runoff by an unknown amount.

Flournoy Analysis

Extent and quality of streamflow data

Using data from the Flournoy gauge is beset by a number of major problems including:

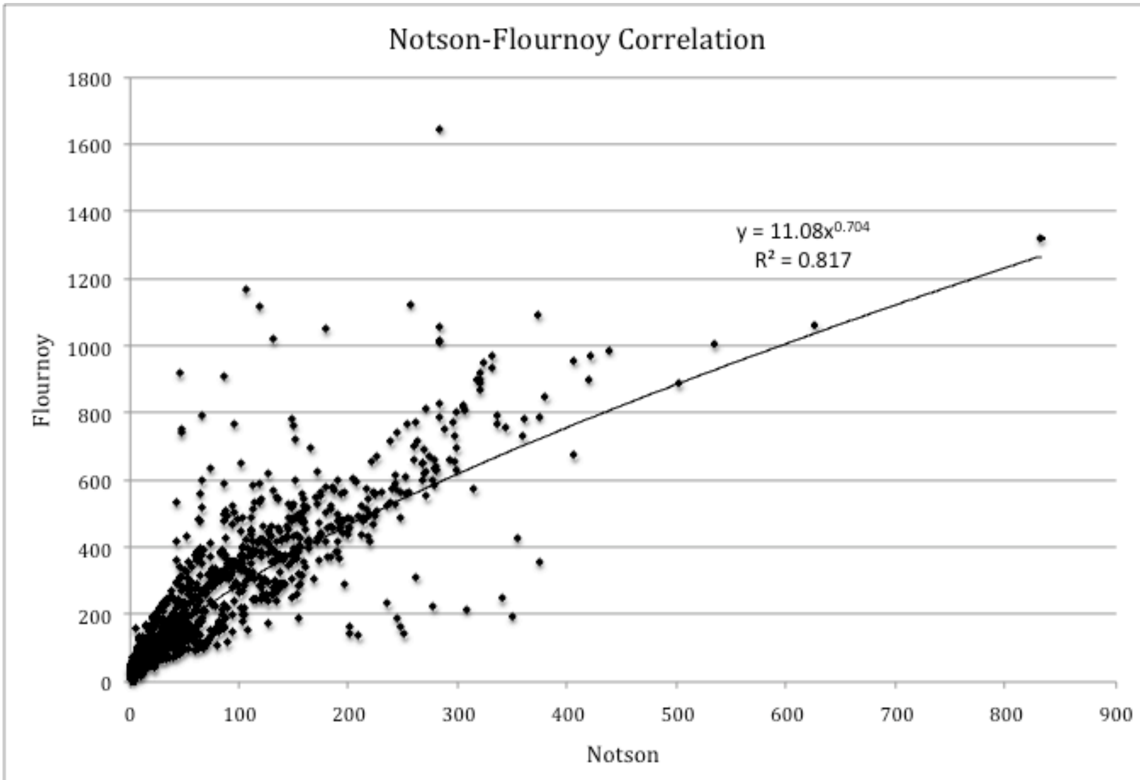
- Extensive data gaps
- Periods of unreliable data due changes in stage-discharge relationship
- Inconsistent data quality between Flournoy and the Indian/DWR gauges
- Huge watershed area relative to magnitude of restoration projects.
- Significant inflows to Red Clover between Notson and Flournoy
- Numerous restoration projects occurring in the watershed throughout the period of record making it impossible to partition data set into pre- and post-project periods

Number of Days of Useable Data per Month--Flournoy

MONTH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% MISSING
OCT	0	31	25	31	0	21	0	0	31	31	0	50%
NOV	26	30	30	30	0	30	0	0	30	30	0	38%
DEC	31	31	31	31	27	31	0	0	31	31	0	28%
JAN	31	31	31	31	31	31	0	0	31	31	0	27%
FEB	29	28	28	28	29	28	0	0	29	28	0	27%
MAR	31	31	31	31	31	31	0	0	31	31	0	27%
APR	30	30	30	30	30	30	0	0	30	30	0	27%
MAY	31	31	31	31	31	31	0	0	31	31	0	27%
JUNE	30	30	30	30	30	6	0	0	30	30	0	35%
JULY	31	31	31	31	31	0	0	0	31	31	0	36%
AUG	31	31	31	1	31	0	0	0	31	31	0	45%
SEPT	30	30	30	0	30	0	0	0	30	30	0	45%
% MISSING	10%	0%	2%	16%	18%	35%	100%	100%	0%	0%	100%	35%

For this analysis, Flournoy data was corrected by subtracting flows at the Indian-DWR site so that the resulting values represent mostly the combined flows of Last Chance and Red Clover Creeks. This also reduced the useable data set to only those dates with useable data at both sites. Also discarded were daily values where flows at Indian-DWR exceeded those at Flournoy. This was done under the assumption that this condition could only occur when the data from one of the sites was incorrect due to malfunction or change to the stage-discharge relationship.

The flow record at Notson is much more complete and reliable so an analysis was conducted to see if correlating Notson data with Flournoy could help fill critical data gaps. Overall, same-day flows at the two stations correlate fairly well as shown below.



In an effort to generate correlations with better predictive power, this data set was further partitioned by months to see how the correlations looked as the season transitioned from spring into the low flow season. Correlations for April and May are relatively good with statistically significant coefficients and r^2 values between 0.80 – 0.90. Beginning with June, the variability around the regression increases and correlations weaken. July-September data produced no statistically significant correlations at all. Since this time period is our primary interest, this approach proved not to be useful for estimating missing or questionable data and was not pursued further. Details of this analysis are included as an appendix.

Normalization of Flournoy Data

The starting point of this analysis is an edited version of the Flournoy data as mentioned in the previous section. These data are then "normalized" to control for the effects of watershed size and year-to-year variation in precipitation. Normalization allows results from different sites to be more directly comparable. It can be thought of as standardizing a data set to remove the "noise" created by extrinsic factors.

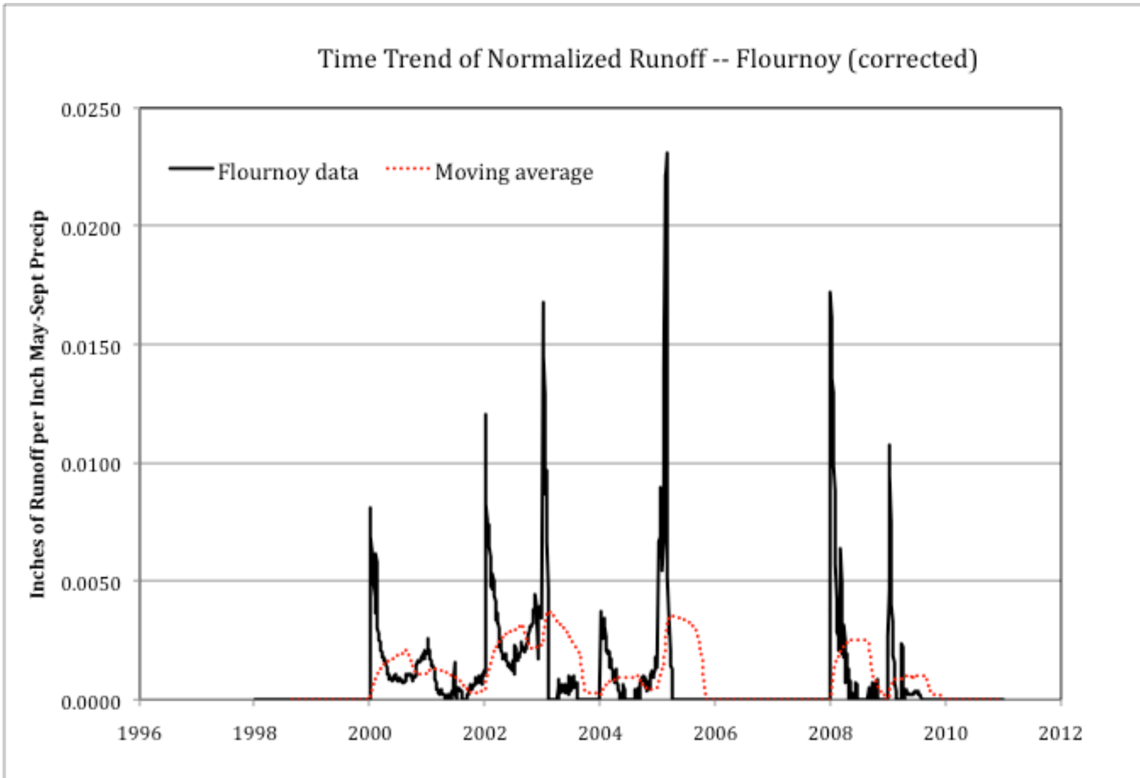
Mathematically, normalizing occurs in two steps. The first is to remove the effect of watershed size by converting daily average flows in CFS to inches of equivalent depth. (The mathematics of this step was described in the Big Flat Section). The final step is to control for year-to-year variation in precipitation. To accomplish this, the results from the first step are divided by estimates of May-Sept precipitation. The resulting values have a rather odd unit description – *inches of runoff per inch of May-Sept precipitation*. Throughout the remainder of this report, we will use the shorthand of "unit runoff" to refer to normalized flow data. This normalized data set is included electronically (on CD-ROM) with this report. Generation of precipitation estimates is discussed in the report section titled Climate Data. Here is a tabular summary of that data set.

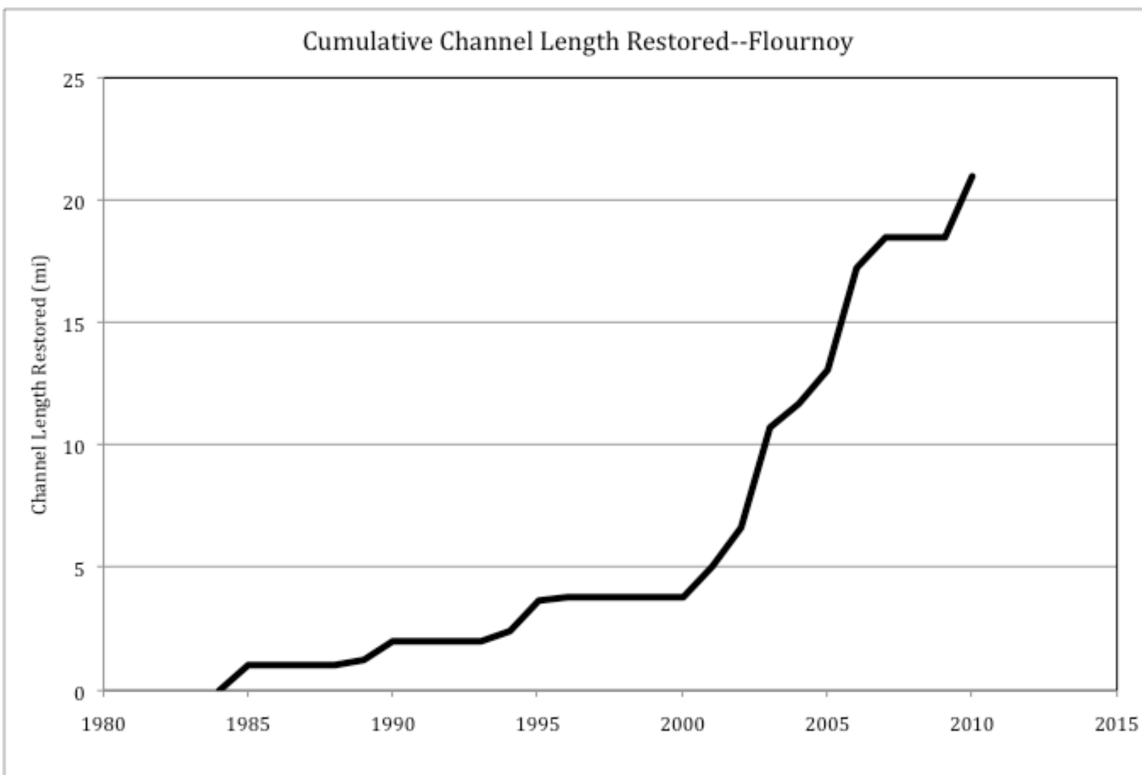
Inches of Runoff per Inch of MAY-SEPT Precipitation -- Flournoy(NORMALIZED)

MONTH	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**AVERAGE**
OCT		0.019	0.002	0.007		0.006			0.007	0.004		**0.008**
NOV	0.007	0.024	0.006	0.009		0.006			0.007	0.006		**0.009**
DEC	0.007	0.025	0.009	0.013	0.013	0.006			0.008	0.005		**0.011**
JAN	0.012	0.024	0.028	0.045	0.013	0.016			0.011	0.008		**0.020**
FEB	0.034	0.017	0.028	0.016	0.035	0.033			0.010	0.020		**0.024**
MAR	0.066	0.038	0.047	0.047	0.095	0.096			0.082	0.094		**0.071**
APR	0.061	0.023	0.044	0.068	0.037	0.068			0.062	0.059		**0.053**
MAY	0.410	0.093	0.586	0.176	0.545	0.152			0.140	0.080		**0.273**
JUNE	0.098	0.202	0.961	0.536	1.485	0.450			1.202	0.379		**0.664**
JULY	0.063	0.123	0.908	0.763	0.576	0.320			0.906	0.237		**0.487**
AUG	0.060	0.050	0.435	0.406	0.240	0.402			0.299	0.153		**0.256**
SEPT	0.082	0.012	0.128	0.073	0.073	0.120			0.090	0.045		**0.078**
TOTAL	**0.901**	**0.649**	**3.182**	**2.159**	**3.111**	**1.675**			**2.823**	**1.091**		**1.949**

The actual time trend analysis uses corrected same-day values, not the monthly totals shown in the table above. Only May-September data was used. Here is the time trend plot with a moving average trend line superimposed. Each distinct peak is that year's low-flow hydrograph and the area under each peak represents that year's volume of May-Sept flow *per inch of May-Sept precipitation*. In looking for a trend, we are looking for a consistent change over time in the area under the yearly peaks.

Following the plot of unit runoff is a plot showing the time trend of stream restoration projects. This assists in our qualitative assessment of the likelihood that any trends in unit runoff are related to stream restoration projects.


Time Trend of Normalized Runoff -- Flournoy (corrected)
Flournoy data
Moving average
Inches of Runoff per Inch May-Sept Precip
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
1996
1998
2000
2002
2004
2006
2008
2010
2012


Cumulative Channel Length Restored--Flournoy
Channel Length Restored (mi)
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015

CONCLUSION: Flournoy data does not reveal any trend over the period of record. No linkage between restoration stream miles and unit runoff is apparent. It is best to regard this data as inconclusive because of gaps and other problems with the Flournoy data.

Descriptive Statistics – Flournoy

The following tables provide monthly summaries of corrected (but not normalized) runoff data for Flournoy as well as precipitation estimates. "Corrected" refers to subtraction of Indian-DWR flows from Flournoy flows.

Runoff in Inches of Equivalent Depth - Flournoy

MONTH	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**AVERAGE**
OCT		0.17	0.03	0.14		0.10			0.09	0.06		0.10
NOV	0.13	0.22	0.08	0.18		0.11			0.09	0.08		0.13
DEC	0.14	0.22	0.12	0.26	0.22	0.11			0.10	0.07		0.16
JAN	0.23	0.21	0.39	0.91	0.21	0.27			0.14	0.11		0.31
FEB	0.67	0.16	0.39	0.31	0.58	0.56			0.13	0.28		0.38
MAR	1.28	0.34	0.64	0.95	1.57	1.66			1.09	1.31		1.11
APR	1.18	0.21	0.61	1.36	0.61	1.18			0.82	0.82		0.85
MAY	0.51	0.08	0.29	0.72	0.25	1.48			0.27	0.53		0.52
JUNE	0.12	0.02	0.09	0.13	0.08	0.44			0.08	0.16		0.14
JULY	0.08	0.03	0.07	0.07	0.04				0.05	0.07		0.06
AUG	0.07	0.02	0.09	0.08	0.06				0.04	0.06		0.06
SEPT	0.10	0.05	0.11		0.07				0.04	0.06		0.07
TOTAL	4.51	1.74	2.92	5.13	3.68	5.93			2.93	3.60		3.81

Weighted Average Precipitation Estimates--"Flournoy" watershed

MONTH	1998	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**AVERAGE**
OCT	1.13	0.59	1.21	1.34	0.45	0.02	0.01	2.50	0.29	0.34	1.35	0.58	1.73	0.89
NOV	2.05	4.16	1.64	1.21	2.73	3.46	1.26	1.27	0.95	2.08	0.52	2.12	1.30	1.90
DEC	2.49	2.48	0.47	0.61	4.94	8.00	6.46	3.96	1.58	1.48	1.76	2.48	2.63	3.03
JAN	5.09	5.47	7.93	0.75	1.56	1.96	2.61	3.62	3.58	0.42	5.84	1.01	4.50	3.41
FEB	6.95	7.28	6.34	1.92	0.56	0.88	5.56	1.20	2.99	6.18	3.23	3.26	2.76	3.78
MAR	3.68	2.16	0.80	1.99	2.42	2.03	0.57	3.94	4.18	0.85	0.35	4.23	2.93	2.32
APR	1.48	1.21	0.96	1.17	1.18	3.80	0.10	0.83	5.51	0.91	0.16	0.20	2.11	1.51
MAY	2.40	0.04	0.68	0.00	0.40	0.64	0.52	1.93	0.37	0.51	0.90	2.03	0.98	0.88
JUNE	1.33	0.21	0.09	0.04	0.13	0.08	0.27	0.99	0.29	0.51	0.00	1.15	0.12	0.40
JULY	0.29	0.18	0.00	1.43	0.15	0.11	0.04	0.00	0.01	0.03	0.01	0.07	0.35	0.21
AUG	0.04	0.47	0.01	0.00	0.00	0.91	0.02	0.00	0.00	0.01	0.00	0.21	0.09	0.13
SEPT	2.03	0.14	0.46	0.20	0.00	0.03	0.21	0.77	0.00	0.25	0.00	0.00	0.00	0.32
TOTAL	**28.96**	**24.39**	**20.60**	**10.68**	**14.51**	**21.91**	**17.64**	**21.01**	**19.76**	**13.56**	**14.12**	**17.32**	**19.51**	**18.77**
OCT-APR	**22.88**	**23.35**	**19.36**	**9.00**	**13.84**	**20.13**	**16.58**	**17.31**	**19.09**	**12.25**	**13.22**	**13.87**	**17.97**	**16.83**
MAY-SEPT	**6.08**	**1.04**	**1.24**	**1.68**	**0.67**	**1.78**	**1.06**	**3.70**	**0.67**	**1.31**	**0.90**	**3.45**	**1.54**	**1.93**

Notson Analysis

<u>Extent and quality of streamflow data</u>

Notson data does have a fair amount of data gaps. Fortunately, the majority of gaps are in the months of Oct-Dec, which are not the primary focus of this analysis. Measurement notes in the original data file suggest that the stage-discharge relationship has held relatively stable over the period of record. Over the entire period of record, 9.7% of daily flow values are missing. For the May-Sept period, only 5.2% of daily flows are missing. Water years 2000, 2002, and 2009 had the most extensive gaps.

6

Number of Days of Usable Data -- Notson

MONTH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% MISSING
OCT	9	31	31	31	31	31	7	31	31	0	19	26.1%
NOV	30	30	26	30	30	30	13	30	30	0	30	15.5%
DEC	31	31	0	31	31	31	31	31	31	22	31	11.7%
JAN	31	31	0	31	31	31	31	31	31	31	31	9.1%
FEB	29	28	0	28	29	28	28	28	29	28	28	9.0%
MAR	31	31	0	31	31	31	31	31	31	31	31	9.1%
APR	30	30	0	30	30	30	30	30	30	30	30	9.1%
MAY	31	31	30	31	31	31	31	31	31	31	31	0.3%
JUNE	30	30	30	30	30	30	30	30	30	30	30	0.0%
JULY	4	31	31	31	31	31	31	31	31	31	31	7.9%
AUG	21	31	31	31	31	31	31	31	12	31	31	8.5%
SEPT	30	30	30	30	30	30	30	30	0	29	30	9.4%
% MISSING	16.1%	0.0%	42.7%	0.0%	0.0%	0.0%	11.2%	0.0%	13.4%	19.5%	3.3%	9.7%

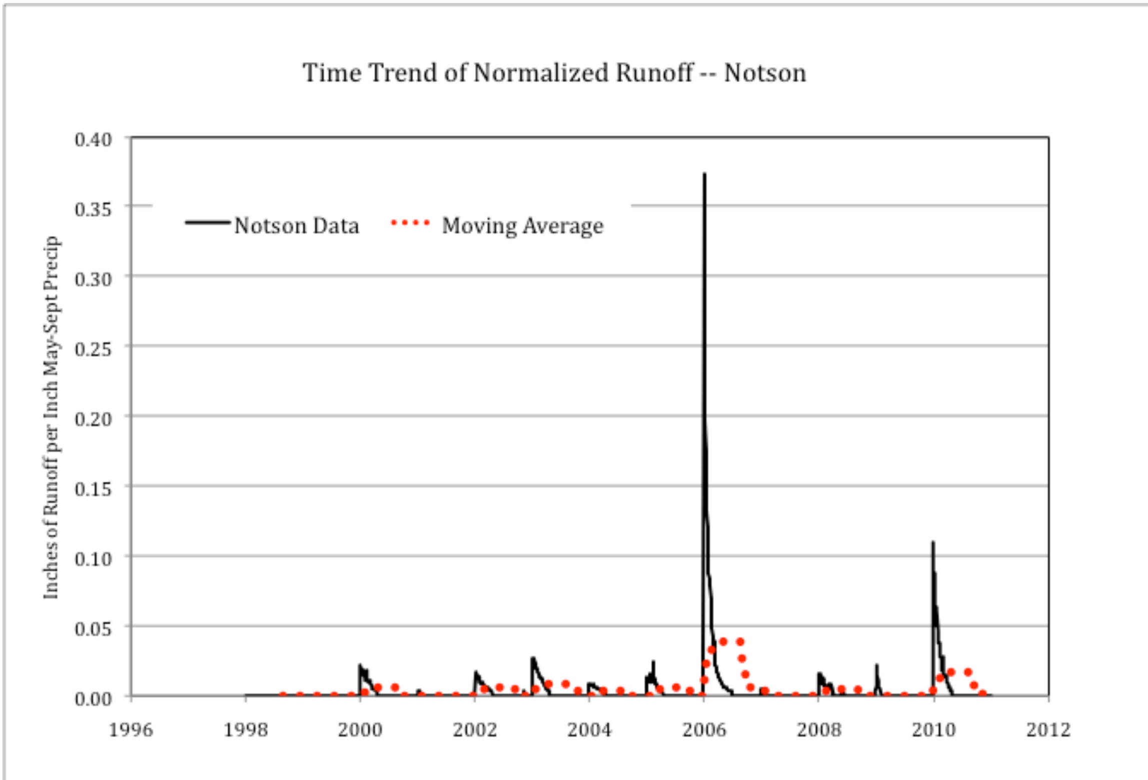
The analysis of Notson data is identical to that applied to Flournoy data (absent, the need to correct or search for correlations to replace missing data). Summaries of the analysis are presented below without the explanatory notes covered in the Flournoy analysis.

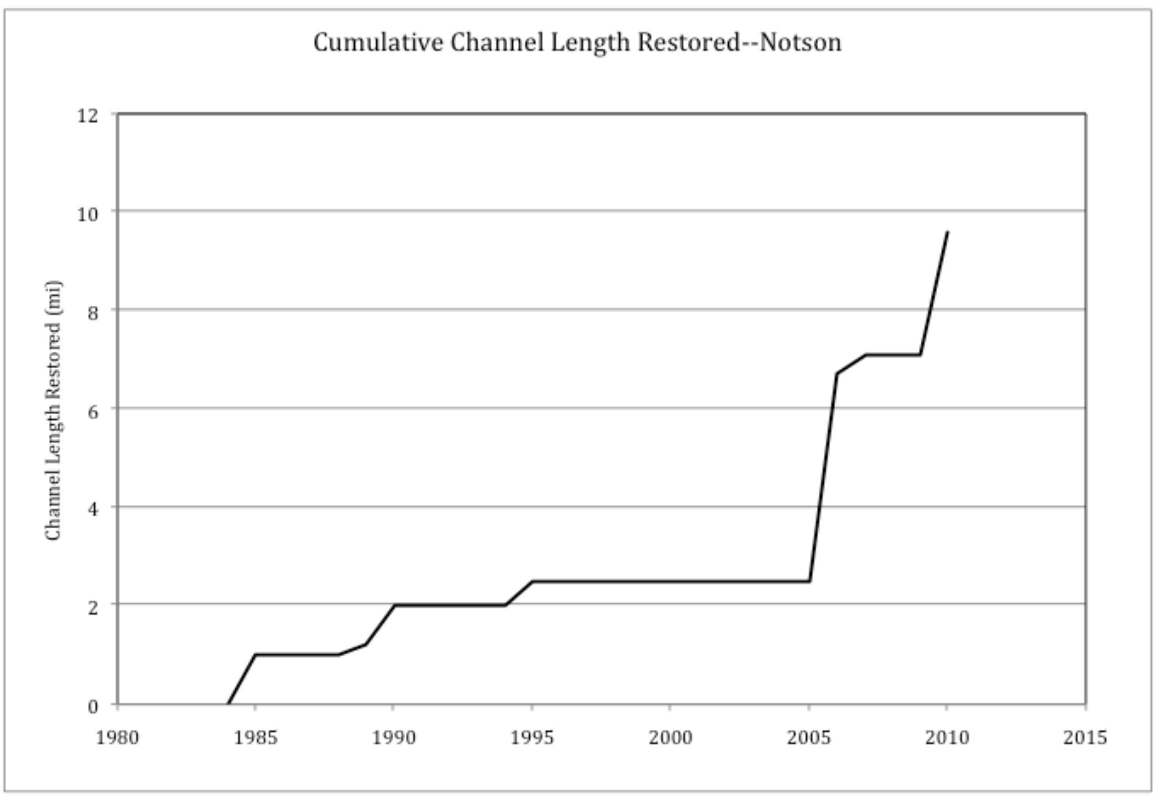
<u>Normalized Notson Data</u>

The monthly summary of normalized flow values is shown below followed by a time trend plot of the data.

Inches of Runoff per Inch of MAY-SEPT Precipitation -- Notson (NORMALIZED)

MONTH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
OCT	0.004	0.008	0.004	0.002	0.004	0.004	0.002	0.003	0.001		0.003	**0.004**
NOV	0.004	0.009	0.007	0.006	0.005	0.005	0.004	0.003	0.002		0.003	**0.005**
DEC	0.003	0.010		0.014	0.013	0.008	0.084	0.006	0.002	0.003	0.004	**0.015**
JAN	0.017	0.010		0.065	0.015	0.012	0.136	0.006	0.005	0.006	0.009	**0.028**
FEB	0.074	0.013		0.041	0.063	0.025	0.094	0.022	0.005	0.039	0.027	**0.040**
MAR	0.131	0.057		0.061	0.159	0.127	0.182	0.074	0.106	0.187	0.164	**0.125**
APR	0.092	0.029		0.075	0.049	0.118	0.383	0.023	0.073	0.062	0.220	**0.112**
MAY	0.418	0.076	0.327	0.560	0.201	0.354	3.436	0.069	0.305	0.143	1.426	**0.665**
JUNE	0.103	0.032	0.108	0.119	0.077	0.089	0.342	0.022	0.079	0.025	0.201	**0.109**
JULY	0.053	0.028	0.047	0.035	0.031	0.021	0.094	0.013	0.049	0.009	0.030	**0.037**
AUG	0.013	0.023	0.042	0.023	0.023	0.011	0.057	0.011	0.047	0.008	0.013	**0.025**
SEPT	0.027	0.029	0.052	0.021	0.027	0.015	0.058	0.012		0.010	0.019	**0.027**
TOTAL	**0.939**	**0.324**	**0.586**	**1.024**	**0.667**	**0.788**	**4.873**	**0.263**	**0.673**	**0.494**	**2.120**	**1.159**


Time Trend of Normalized Runoff -- Notson
Inches of Runoff per Inch May-Sept Precip
Notson Data
Moving Average
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1996
1998
2000
2002
2004
2006
2008
2010
2012


Cumulative Channel Length Restored--Notson
Channel Length Restored (mi)
12
10
8
6
4
2
0
1980
1985
1990
1995
2000
2005
2010
2015

The trend line of unit runoff for Notson does not display a consistent trend or any temporal pattern related stream restoration miles.

CONCLUSION: No trend is apparent for Notson despite the relatively high quality of the data set.

Descriptive Statistics – Notson

The following tables provide monthly summaries of original (not normalized) runoff data for Notson as well as precipitation estimates. Runoff values are in inches of equivalent depth.

Runoff in Inches of Equivalent Depth - Notson

MONTH	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**AVERAGE**
OCT	0.08	0.07	0.05	0.04	0.05	0.07	0.05	0.03	0.01		0.04	0.05
NOV	0.07	0.08	0.09	0.12	0.07	0.08	0.07	0.03	0.02		0.05	0.07
DEC	0.07	0.09		0.29	0.20	0.13	1.69	0.07	0.02	0.04	0.06	0.27
JAN	0.32	0.09		1.30	0.23	0.19	2.73	0.06	0.06	0.07	0.15	0.52
FEB	1.40	0.11		0.83	0.97	0.41	1.88	0.25	0.06	0.48	0.44	0.68
MAR	2.45	0.50		1.23	2.47	2.07	3.65	0.82	1.36	2.35	2.64	1.95
APR	1.73	0.25		1.51	0.76	1.92	7.67	0.25	0.94	0.78	3.54	1.93
MAY	0.54	0.10	0.26	1.12	0.26	1.28	2.30	0.08	0.27	0.44	1.96	0.78
JUNE	0.13	0.04	0.08	0.24	0.10	0.32	0.23	0.03	0.07	0.08	0.28	0.15
JULY	0.07	0.04	0.04	0.07	0.04	0.08	0.06	0.02	0.04	0.03	0.04	0.05
AUG	0.02	0.03	0.03	0.05	0.03	0.04	0.04	0.01	0.04	0.02	0.02	0.03
SEPT	0.03	0.04	0.04	0.04	0.03	0.06	0.04	0.01		0.03	0.03	0.04
TOTAL	6.90	1.44		6.84	5.23	6.64	20.41	1.66	2.90		9.24	6.81

Weighted Average Precipitation Estimates--"Notson" watershed

MONTH	1998	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**AVERAGE**
OCT	1.21	0.66	1.29	1.29	0.50	0.04	0.02	2.51	0.39	0.37	1.34	0.55	1.75	0.92
NOV	2.08	4.27	1.64	1.15	2.66	3.48	1.16	1.29	1.12	1.83	0.50	2.02	1.10	1.87
DEC	2.25	2.32	0.48	0.57	4.56	7.74	5.82	3.45	3.37	1.49	1.78	2.11	2.52	2.96
JAN	5.26	4.96	7.44	0.84	1.58	2.05	2.25	3.36	3.37	0.38	5.63	0.96	3.96	3.23
FEB	6.66	6.71	5.97	2.04	0.66	0.91	5.55	1.17	3.15	5.35	2.94	2.82	2.43	3.57
MAR	3.39	1.92	0.86	1.83	2.12	2.21	0.59	3.62	3.79	0.75	0.49	3.84	2.36	2.14
APR	1.49	1.16	1.07	1.09	1.10	3.62	0.15	0.93	4.84	0.88	0.16	0.23	1.96	1.44
MAY	2.65	0.08	0.78	0.01	0.42	0.62	0.59	1.96	0.41	0.44	0.86	1.68	0.91	0.88
JUNE	1.75	0.33	0.12	0.07	0.19	0.13	0.33	0.98	0.23	0.46	0.00	1.08	0.09	0.44
JULY	0.27	0.14	0.00	0.94	0.17	0.14	0.10	0.00	0.02	0.06	0.02	0.14	0.26	0.17
AUG	0.09	0.44	0.02	0.00	0.00	1.04	0.06	0.00	0.01	0.02	0.00	0.15	0.11	0.15
SEPT	2.08	0.14	0.38	0.25	0.00	0.07	0.20	0.68	0.00	0.24	0.00	0.00	0.00	0.31
TOTAL	**29.17**	**23.13**	**20.05**	**10.10**	**13.97**	**22.05**	**16.81**	**19.96**	**20.69**	**12.26**	**13.72**	**15.58**	**17.46**	**18.07**
OCT-APR	**22.34**	**22.00**	**18.77**	**8.83**	**13.19**	**20.05**	**15.53**	**16.33**	**20.02**	**11.05**	**12.84**	**12.52**	**16.08**	**16.12**
MAY-SEPT	**6.83**	**1.13**	**1.29**	**1.27**	**0.78**	**2.00**	**1.28**	**3.63**	**0.67**	**1.21**	**0.88**	**3.06**	**1.38**	**1.95**

Doyle Crossing Analysis

Extent and quality of streamflow data

Doyle Crossing data has a relatively complete record with only 2.7% of daily data missing over the eleven-year period. Water years 2000 and 2004 had the largest gaps. For the low flow months of May-September, only September had data gaps of note and all of those occurred in a single year (2004). The low flow period had only 1.5% of daily data missing. The original data file does not contain any notes or comments that would suggest any special problems with the data.

Number of Days of Usable Data -- Doyle Xing

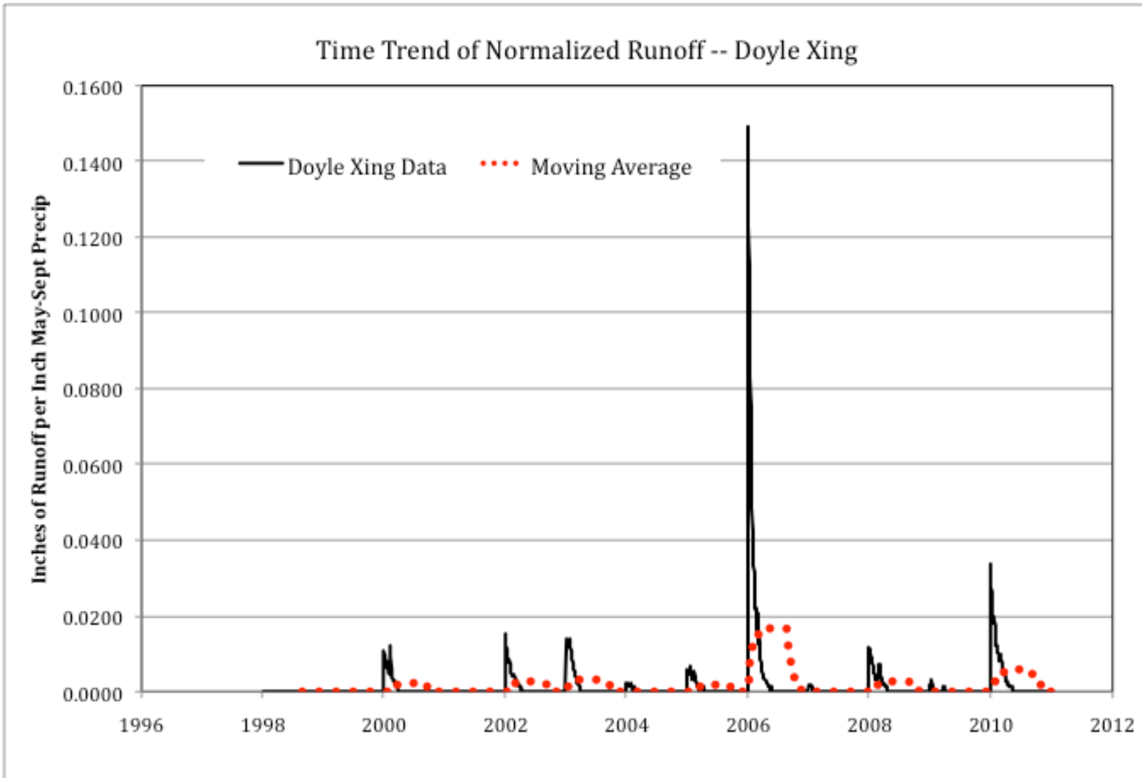
MONTH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% MISSING
OCT	31	31	31	31	31	30	31	31	31	31	31	0.3%
NOV	18	30	30	30	30	30	30	30	30	30	30	3.6%
DEC	0	31	31	31	31	31	31	31	31	31	31	9.1%
JAN	25	31	31	31	31	19	31	31	31	31	31	5.3%
FEB	24	28	28	28	29	28	28	28	29	28	28	1.6%
MAR	15	31	31	31	31	31	31	31	31	31	31	4.7%
APR	30	30	30	30	30	30	30	30	30	30	30	0.0%
MAY	31	31	31	31	31	31	31	31	31	31	31	0.0%
JUNE	30	30	30	30	30	30	30	30	30	30	30	0.0%
JULY	31	31	31	31	31	31	31	31	31	31	31	0.0%
AUG	31	31	31	31	31	31	31	31	31	31	31	0.0%
SEPT	30	30	30	30	4	30	30	30	30	30	30	7.9%
% MISSING	19.1%	0.0%	0.0%	0.0%	7.1%	3.6%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%

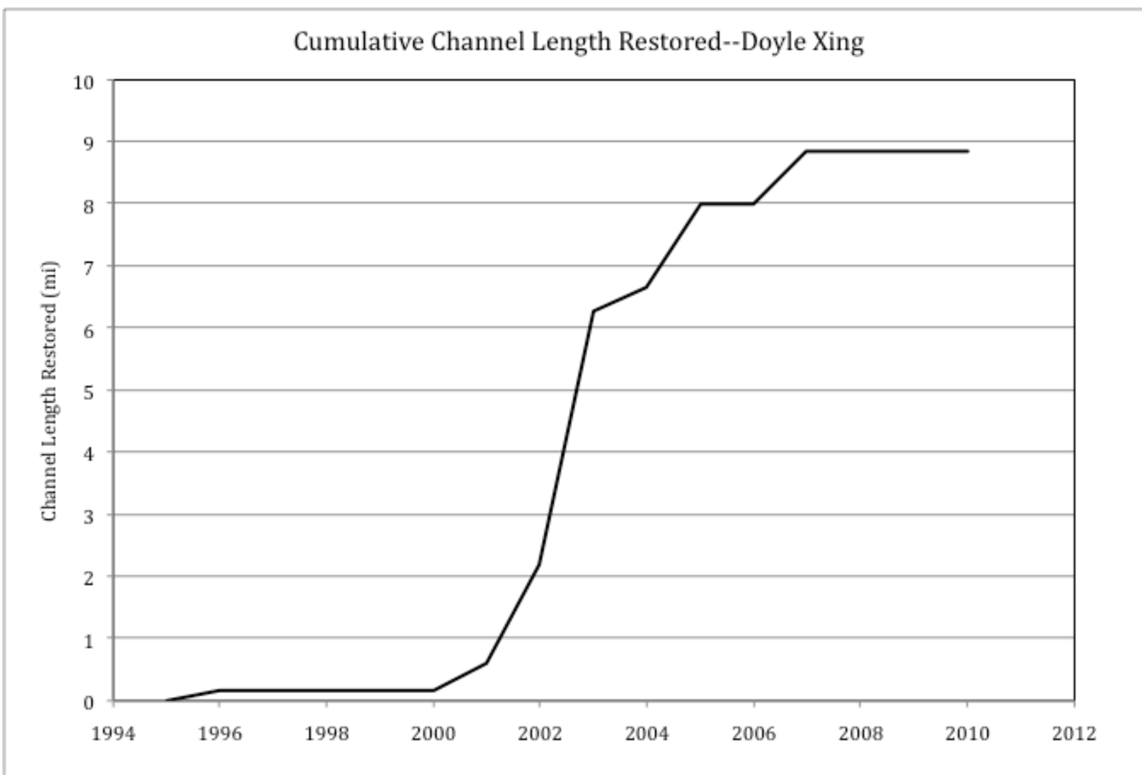
Normalized Doyle Crossing Data

The monthly summary of normalized flow values is shown below followed by a time trend plot of the data.

Inches of Runoff per Inch of May-Sept Precip -- Doyle Xing (NORMALIZED)

MONTH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
OCT	0.0019	0.0013	0.0008	0.0003	0.0005	0.0006	0.0007	0.0010	0.0018	0.0023	0.0011	**0.0011**
NOV	0.0019	0.0016	0.0015	0.0010	0.0003	0.0006	0.0005	0.0008	0.0012	0.0024	0.0007	**0.0011**
DEC		0.0039	0.0047	0.0044	0.0016	0.0025	0.0266	0.0007	0.0008	0.0032	0.0010	**0.0049**
JAN	0.0103	0.0063	0.0156	0.0239	0.0081	0.0075	0.0894	0.0015	0.0059	0.0030	0.0032	**0.0159**
FEB	0.0333	0.0027	0.0193	0.0140	0.0200	0.0129	0.0460	0.0066	0.0027	0.0108	0.0099	**0.0162**
MAR	0.0854	0.0228	0.0405	0.0286	0.0908	0.0647	0.0845	0.0320	0.0719	0.0541	0.0329	**0.0553**
APR	0.0522	0.0057	0.0393	0.0379	0.0241	0.0583	0.1527	0.0129	0.0402	0.0246	0.0541	**0.0456**
MAY	0.1794	0.0141	0.2030	0.2745	0.0481	0.1239	1.5429	0.0371	0.1980	0.0336	0.4855	**0.2855**
JUNE	0.0282	0.0075	0.0348	0.0274	0.0164	0.0201	0.1088	0.0121	0.0492	0.0143	0.0826	**0.0365**
JULY	0.0108	0.0062	0.0061	0.0051	0.0035	0.0030	0.0176	0.0014	0.0176	0.0054	0.0211	**0.0089**
AUG	0.0052	0.0060	0.0015	0.0030	0.0011	0.0003	0.0044	0.0011	0.0066	0.0035	0.0090	**0.0038**
SEPT	0.0084	0.0068	0.0017	0.0023	0.0008	0.0012	0.0082	0.0028	0.0110	0.0033	0.0098	**0.0051**
TOTAL	**0.417**	**0.085**	**0.369**	**0.422**	**0.215**	**0.296**	**2.082**	**0.110**	**0.407**	**0.161**	**0.711**	**0.4795**


Time Trend of Normalized Runoff -- Doyle Xing
Doyle Xing Data
Moving Average
Inches of Runoff per Inch May-Sept Precip
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
1996
1998
2000
2002
2004
2006
2008
2010
2012


Cumulative Channel Length Restored--Doyle Xing
Channel Length Restored (mi)
10
9
8
7
6
5
4
3
2
1
0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

The trend line of unit runoff for Doyle Xing does not display a consistent trend or any temporal pattern related stream restoration miles.

CONCLUSION: No trend is apparent for Doyle Xing despite the relatively high quality of the data set.

Descriptive Statistics – Doyle Crossing

The following tables provide monthly summaries of original (not normalized) runoff data for Doyle Xing as well as precipitation estimates. Runoff values are in inches of equivalent depth.

Runoff in Inches of Equivalent Depth -- Doyle Xing

MONTH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
OCT	0.036	0.012	0.010	0.006	0.007	0.009	0.015	0.011	0.023	0.028	0.017	**0.016**
NOV	0.036	0.014	0.020	0.019	0.005	0.010	0.009	0.009	0.016	0.029	0.011	**0.016**
DEC		0.034	0.061	0.088	0.025	0.040	0.537	0.008	0.011	0.039	0.015	**0.086**
JAN	0.192	0.055	0.202	0.475	0.123	0.120	1.802	0.017	0.075	0.037	0.050	**0.286**
FEB	0.618	0.024	0.250	0.278	0.304	0.208	0.928	0.072	0.034	0.132	0.155	**0.273**
MAR	1.584	0.199	0.526	0.570	1.382	1.039	1.703	0.345	0.913	0.659	0.515	**0.858**
APR	0.968	0.050	0.510	0.754	0.366	0.937	3.077	0.139	0.511	0.299	0.847	**0.769**
MAY	0.233	0.017	0.164	0.562	0.064	0.446	1.030	0.044	0.175	0.100	0.654	**0.317**
JUNE	0.037	0.009	0.028	0.056	0.022	0.072	0.073	0.014	0.043	0.043	0.111	**0.046**
JULY	0.014	0.007	0.005	0.010	0.005	0.011	0.012	0.002	0.016	0.016	0.028	**0.011**
AUG	0.007	0.007	0.001	0.006	0.001	0.001	0.003	0.001	0.006	0.010	0.012	**0.005**
SEPT	0.011	0.008	0.001	0.005	0.001	0.004	0.005	0.003	0.010	0.010	0.013	**0.007**
TOTAL	**3.736**	**0.436**	**1.778**	**2.829**	**2.305**	**2.897**	**9.194**	**0.664**	**1.832**	**1.403**	**2.429**	**2.682**

Weighted Average Precipitation Estimates--"Doyle Xing" watershed

MONTH	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
OCT	1.22	0.67	1.31	1.28	0.50	0.05	0.02	2.50	0.40	0.38	1.34	0.54	1.75	0.92
NOV	2.07	4.27	1.62	1.14	2.62	3.46	1.13	1.30	1.14	1.78	0.49	1.99	1.06	1.85
DEC	2.19	2.27	0.48	0.56	4.47	7.63	5.67	3.34	3.74	1.48	1.78	2.02	2.50	2.93
JAN	5.24	4.85	7.32	0.85	1.58	2.05	2.16	3.29	3.32	0.37	5.55	0.94	3.83	3.18
FEB	6.55	6.57	5.86	2.04	0.68	0.91	5.50	1.15	3.16	5.16	2.86	2.71	2.36	3.50
MAR	3.31	1.87	0.87	1.79	2.05	2.22	0.59	3.54	3.70	0.73	0.51	3.75	2.24	2.09
APR	1.48	1.14	1.09	1.07	1.08	3.55	0.15	0.94	4.69	0.87	0.16	0.24	1.93	1.42
MAY	2.69	0.09	0.80	0.01	0.43	0.62	0.61	1.95	0.42	0.42	0.86	1.60	0.90	0.88
JUNE	1.84	0.36	0.12	0.07	0.20	0.13	0.34	0.98	0.22	0.45	0.00	1.07	0.09	0.45
JULY	0.26	0.13	0.00	0.84	0.18	0.14	0.12	0.00	0.03	0.07	0.02	0.16	0.24	0.17
AUG	0.10	0.43	0.02	0.00	0.00	1.07	0.07	0.00	0.01	0.02	0.00	0.14	0.11	0.15
SEPT	2.10	0.14	0.36	0.27	0.00	0.08	0.20	0.67	0.00	0.23	0.00	0.00	0.00	0.31
TOTAL	**29.04**	**22.77**	**19.85**	**9.92**	**13.79**	**21.93**	**16.55**	**19.66**	**20.83**	**11.95**	**13.59**	**15.16**	**17.01**	**17.85**
OCT-APR	**22.05**	**21.63**	**18.55**	**8.73**	**12.98**	**19.89**	**15.22**	**16.06**	**20.16**	**10.77**	**12.71**	**12.19**	**15.66**	**15.89**
MAY-SEPT	**6.99**	**1.14**	**1.30**	**1.19**	**0.81**	**2.05**	**1.33**	**3.60**	**0.67**	**1.19**	**0.88**	**2.97**	**1.35**	**1.96**

Appendix A: Climate Data

Temperature and precipitation data were obtained from NOAA for seven stations surrounding the project area. These stations included

STATION	NOAA STATION ID NUMBER
Chester	041700
Greenville	043621
Quincy	047195
Portola	047085
Vinton	049351
Doyle	042504
Susanville	048702

The initial concept for this analysis was to arrive at average values for temperature and precipitation for the subject watersheds by preparing isohyetal and isothermal maps through linear interpolation of data from the NOAA stations. These values would be used to normalize runoff data to control for year-to-year variation in precipitation and evapotranspiration.

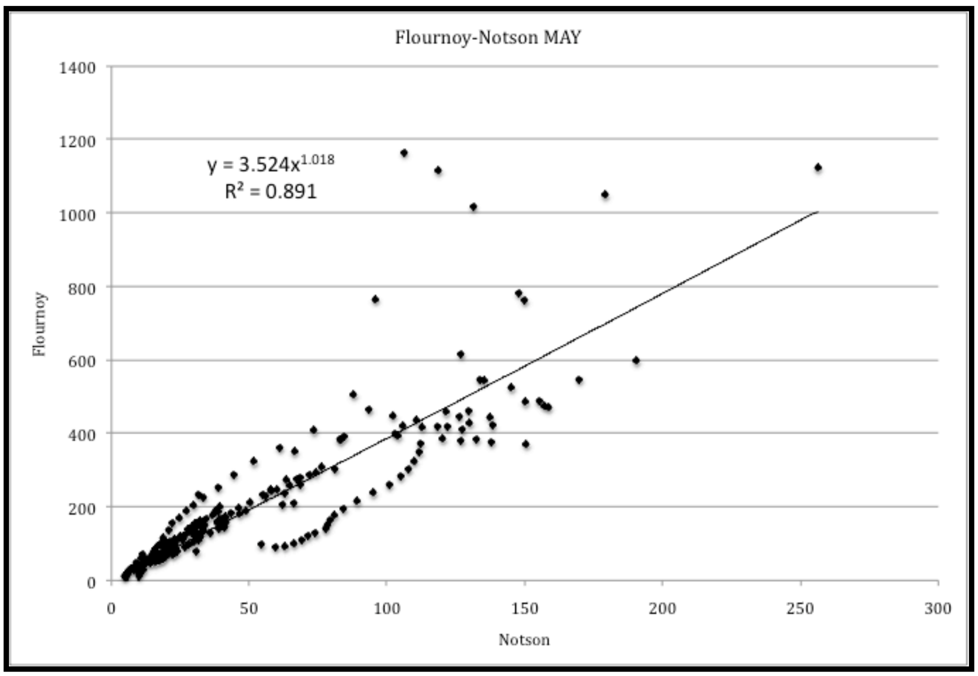
As the first maps were prepared, two things became clear.

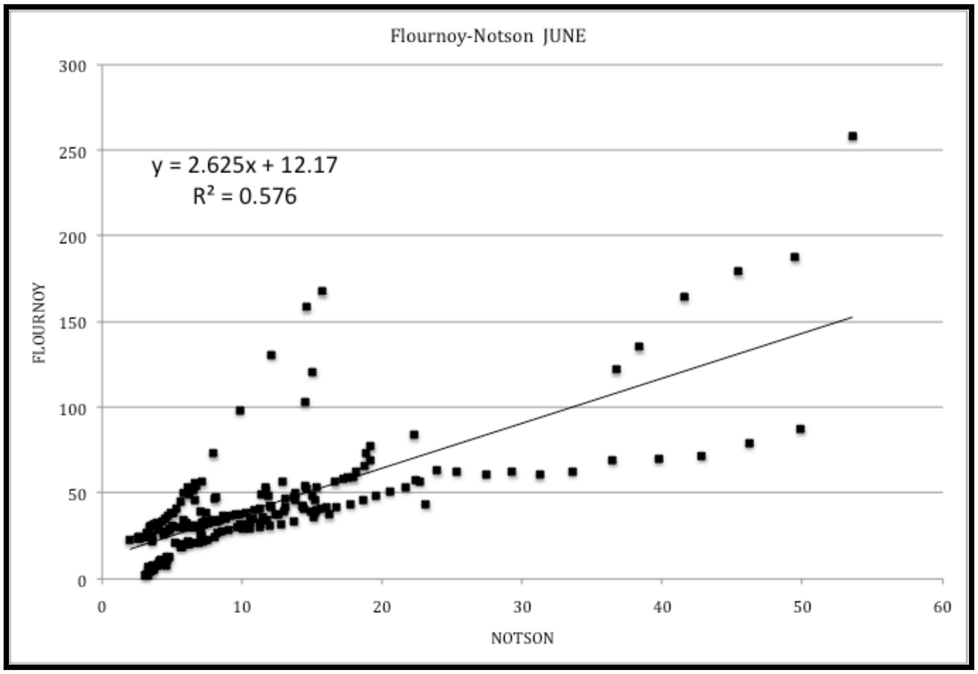
First, temperature data was used to generate potential evapotranspiration (PET). The resulting PET values did not vary enough from year to year to warrant including it in the data normalization process. PET estimates using the Thornthwaite method were generated but not used in this analysis.

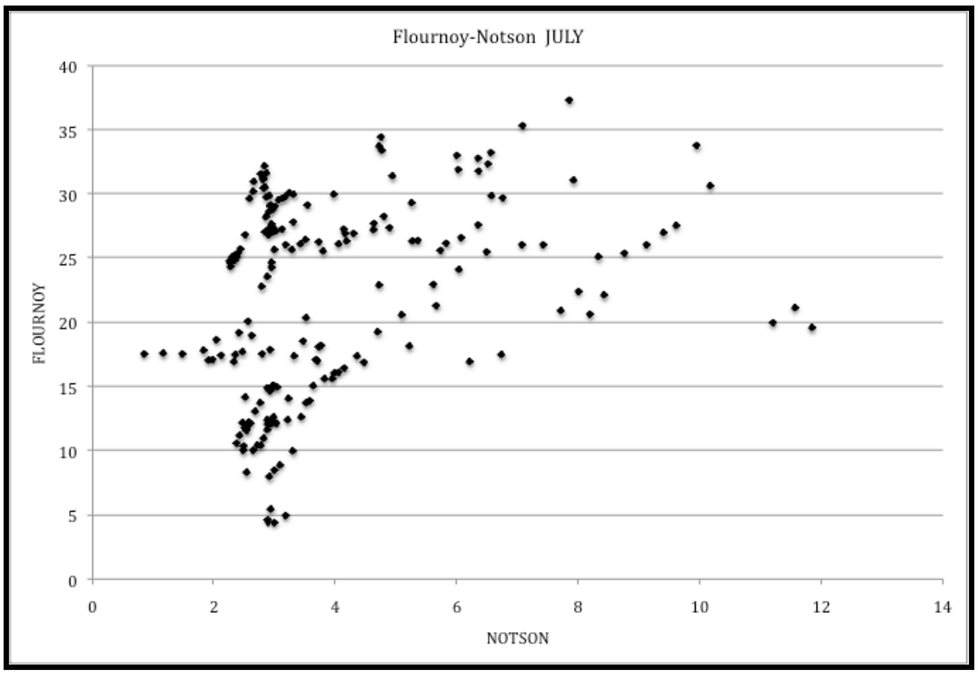
Second, initial isohyetal lines drawn from the NOAA data were oriented strongly in a north-south direction, indicating a strong east-west gradient. Since the generation of these maps was a time-consuming process, a mathematical method of weighting each station's precipitation was developed. The reciprocal of the east-west distance between a NOAA station and the watershed centroid was used as a weighting factor applied against that station's precipitation estimate. For each watershed area in this analysis, a table of "weighted average precipitation" was generated. These tables are included under the "Descriptive Statistics" heading for each watershed area's analysis section of the report. The averages presented in these tables are for the period 1998-2010 and are not the same as long-term averages commonly reported.

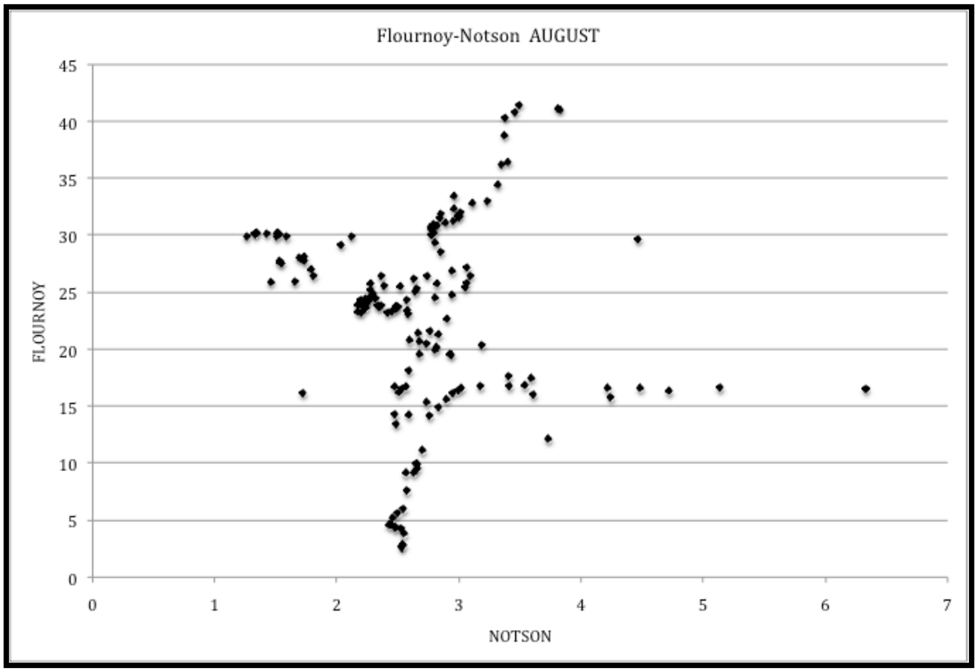
Appendix B: MONTHLY CORRELATION OF FLOURNOY FLOWS (Corrected) WITH NOTSON FLOWS

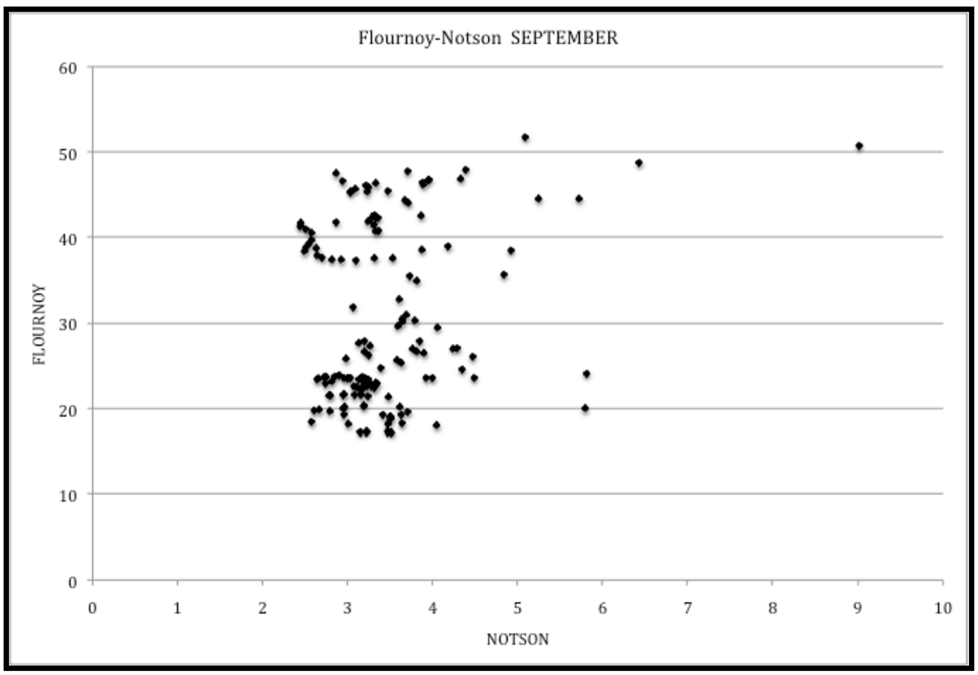
Monthly flows at Flournoy, corrected by removing flows from the Indian Creek DWR weir, were subject to regression analysis using Notson data as the independent variable. As the plots below show, the significance and predictive power of the regression are fairly strong for May, weaker for June, and completely lacking for July-September. Allowing some speculation, this probably indicates that flows originating above Notson Bridge are a much more significant proportion of the flows measured at Flournoy during the winter months. As the season transitions into summer, inflows from the “Mt. Ingalls reach” below Notson Bridge become more significant and the correlations breakdown. For this reason, the analysis was taken no further.




Flournoy-Notson JUNE
y = 2.625x + 12.17
R² = 0.576
FLOURNOY
NOTSON
300
250
200
150
100
50
0
0
10
20
30
40
50
60

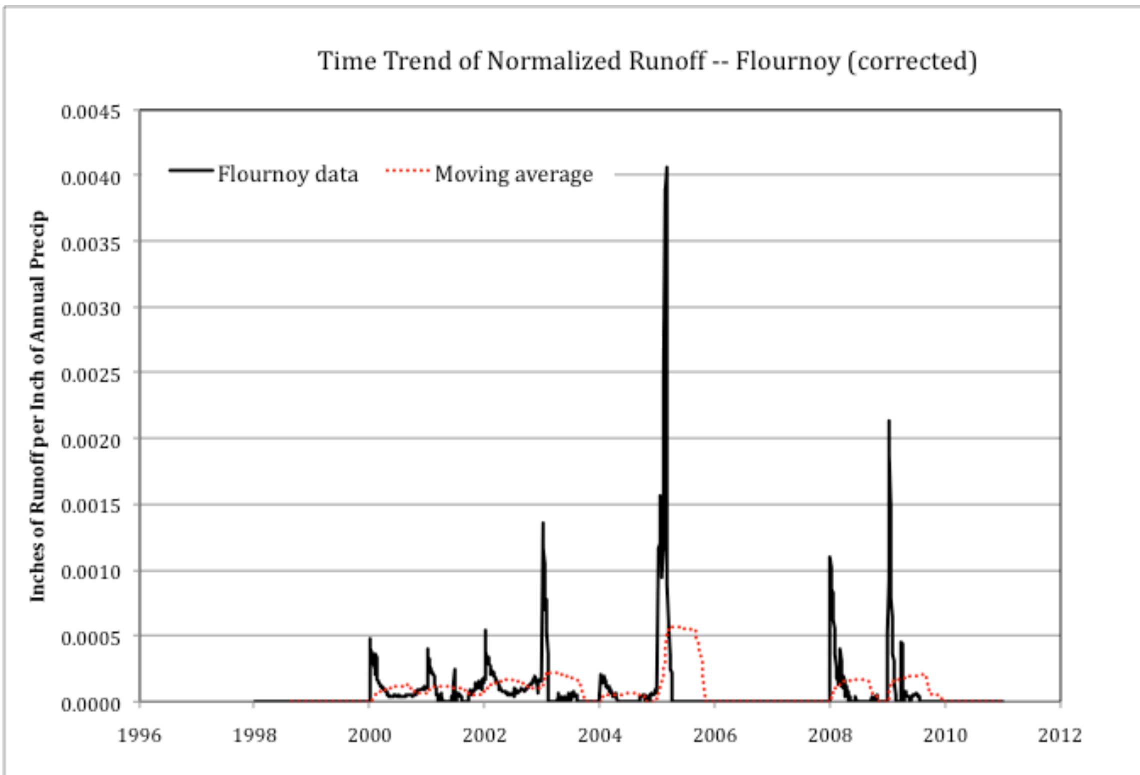

Flournoy-Notson JULY
FLOURNOY
NOTSON
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14

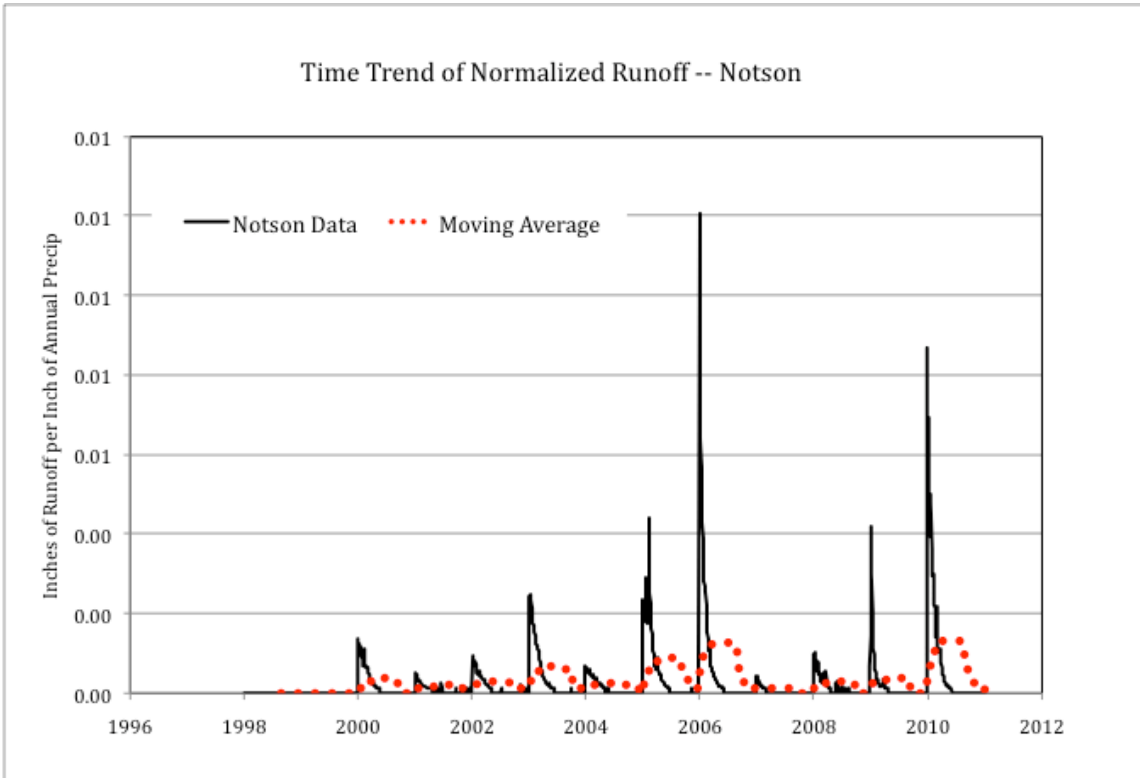

Flournoy-Notson AUGUST
FLOURNOY
NOTSON
0
5
10
15
20
25
30
35
40
45
0
1
2
3
4
5
6
7

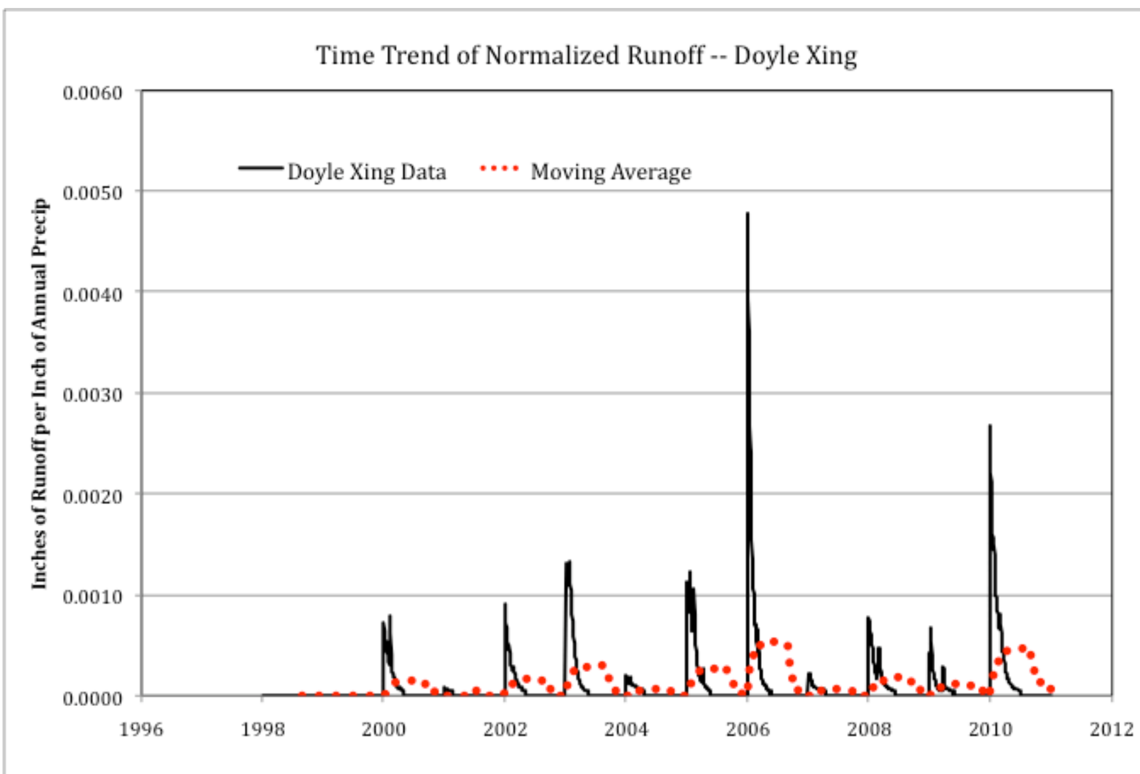

Flournoy-Notson SEPTEMBER
FLOURNOY
NOTSON
0
10
20
30
40
50
60
0
1
2
3
4
5
6
7
8
9
10

Appendix C: TIME TREND ANALYSIS USING ANNUAL PRECIPITATION FOR DATA NORMALIZATION

A number of commenters expressed concern about the use of late season (May-Sept) precipitation to normalize runoff data for the low flow period. To address this concern, the time trend analysis presented for the Flournoy, Notson, and Doyle Crossing sites is repeated here using full water year precipitation data for normalization. The time trend graphs with moving averages are presented below using data normalized with annual precipitation.




Time Trend of Normalized Runoff -- Notson
Notson Data
Moving Average
Inches of Runoff per Inch of Annual Precip
0.01
0.01
0.01
0.01
0.01
0.00
0.00
0.00
1996
1998
2000
2002
2004
2006
2008
2010
2012


Time Trend of Normalized Runoff -- Doyle Xing
Doyle Xing Data
Moving Average
Inches of Runoff per Inch of Annual Precip
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
1996
1998
2000
2002
2004
2006
2008
2010
2012

CONCLUSION: No time trend is apparent at any of the three sites. Year to year variability in base flow appears dominated more by patterns of precipitation and snowmelt than by restoration effects.