Trends in Nutrient Loads to Lahontan Reservoir

A supporting document for the Carson River Report Card

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Lahontan Dam and Reservoir (photograph by U.S. Bureau of Reclamation)

Prepared by:
Randy Pahl
Nevada Division of Environmental Protection
Bureau of Water Quality Planning

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Table of Contents

List of Tables

List of Figures

Trends in Nutrient Loads to Lahontan Reservoir

Introduction

In support of its Clean Water Act responsibilities, the Nevada Division of Environmental Protection (NDEP) – Bureau of Water Quality Planning (BWQP) is developing a Carson River Watershed Assessment or Report Card. Drawing upon numerous studies and monitoring efforts, the Report Card will provide a compilation of current knowledge about the chemical, physical and biological health of the Carson River watershed with a focus on aquatic life uses from the Nevada/California stateline to Lahontan Reservoir. It is hoped that the Report Card will be a valuable tool for educating the public, agencies and decisionmakers on the state of the river system (from a Clean Water Act perspective), thereby providing direction for their future actions and decisions. The Report Card will also be a key planning tool for BWQP in possible future steps, such as standards revisions, comprehensive Total Maximum Daily Loads (TMDLs), watershed plan updates and restoration projects.

The purpose of this report is to discuss trends in nutrient loads to Lahontan Reservoir from both the Carson River and the Truckee Canal (Figure 1). A companion document, *Lahontan Reservoir: General Analysis of Water Quality Data* (NDEP, 2007), summarizes data collected during the period 2003-05 and compares to previous studies.

Trends in Lahontan Reservoir Inflows and their Nutrient Concentrations

The Carson River and the Truckee Canal provide the main sources of water and nutrients to Lahontan Reservoir. Figure 1 shows the high variability in the Lahontan Reservoir inflows from year to year, with a majority of the inflow typically coming from the Carson River. However in some years, Truckee Canal flows can account for over 50% of the reservoir inflow. Fluctuations in flow along with fluctuations in nutrient concentrations affect the overall nutrient loading to Lahontan Reservoir. Nutrient concentrations in the waters entering Lahontan Reservoir have shown a marked reduction following Truckee Meadows Water Reclamation Facility's (TMWRF) upgrade to include biological nutrient removal in the 1980s (Basham, 2006) and the removal of direct effluent discharges to the Carson River in 1987 (Kilroy et al., 1997). The following discusses trends in: 1) reservoir inflows; and 2) nutrient concentrations in the Truckee Canal and the Carson River.

<u>Truckee Canal</u>

Beginning in 1967, Operating Criteria and Procedures (OCAP) were established which placed restrictions on Truckee Canal diversions. Additional restrictions have been placed on the diversions over time (Bureau of Reclamation, 1987). As a result of OCAP, Truckee Canal annual flows have followed a downward trend since 1967. An Excel template – MAKESENS – was used to detect any statistically significant trend in the annual flow, and provide an estimate of the magnitude of the trend (Salmi, et al., 2002). MAKESENS performs two analyses: 1) tests for presence of increasing/decreasing trend using the Mann-Kendall test; and 2) estimates the slope of the linear trend using Sen's method. In the case of the Truckee Canal, the analyses indicates a decreasing trend at the 95% confidence level ($p=0.05$). The Sen's line (Figure 2) shows the magnitude of the downward trend.

Figure 1. Lahontan Reservoir Inflows - 1967-2005

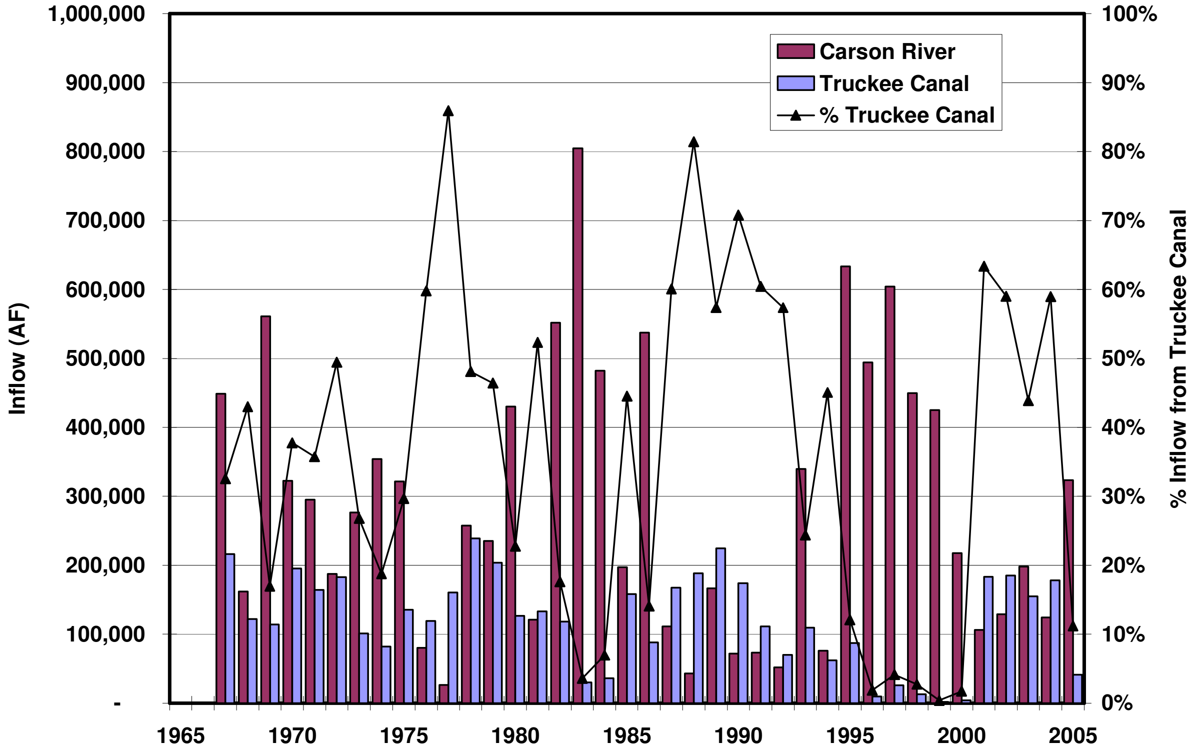
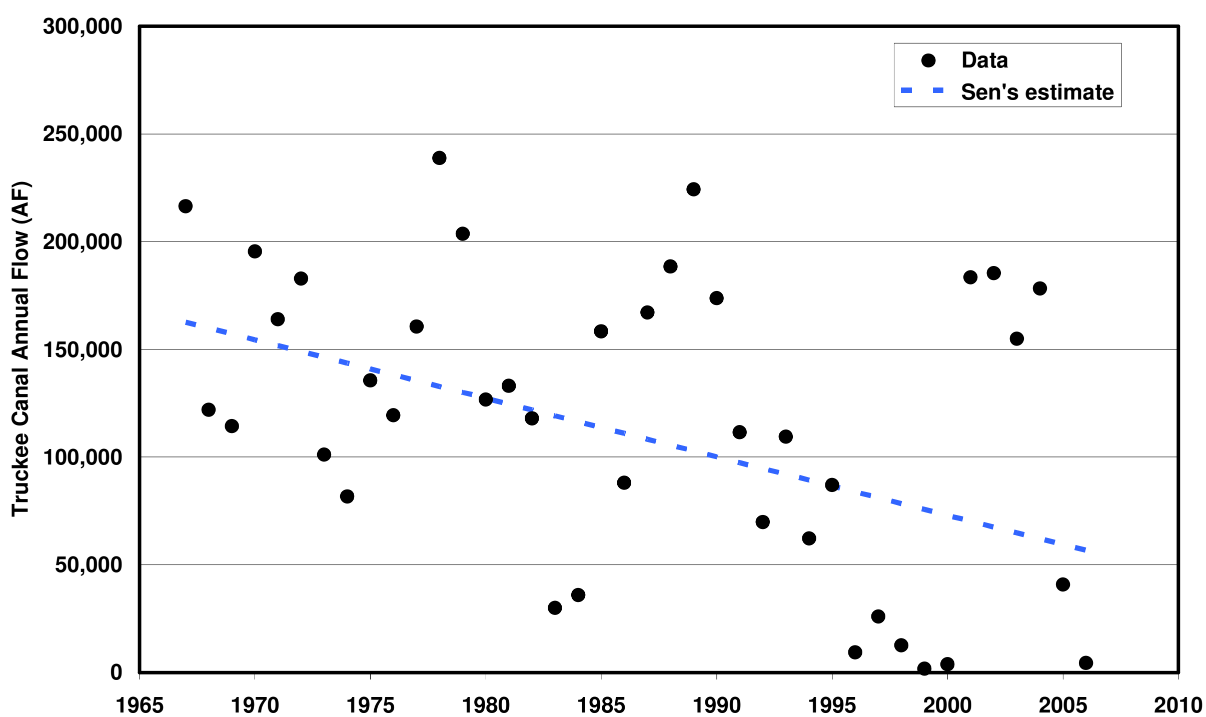


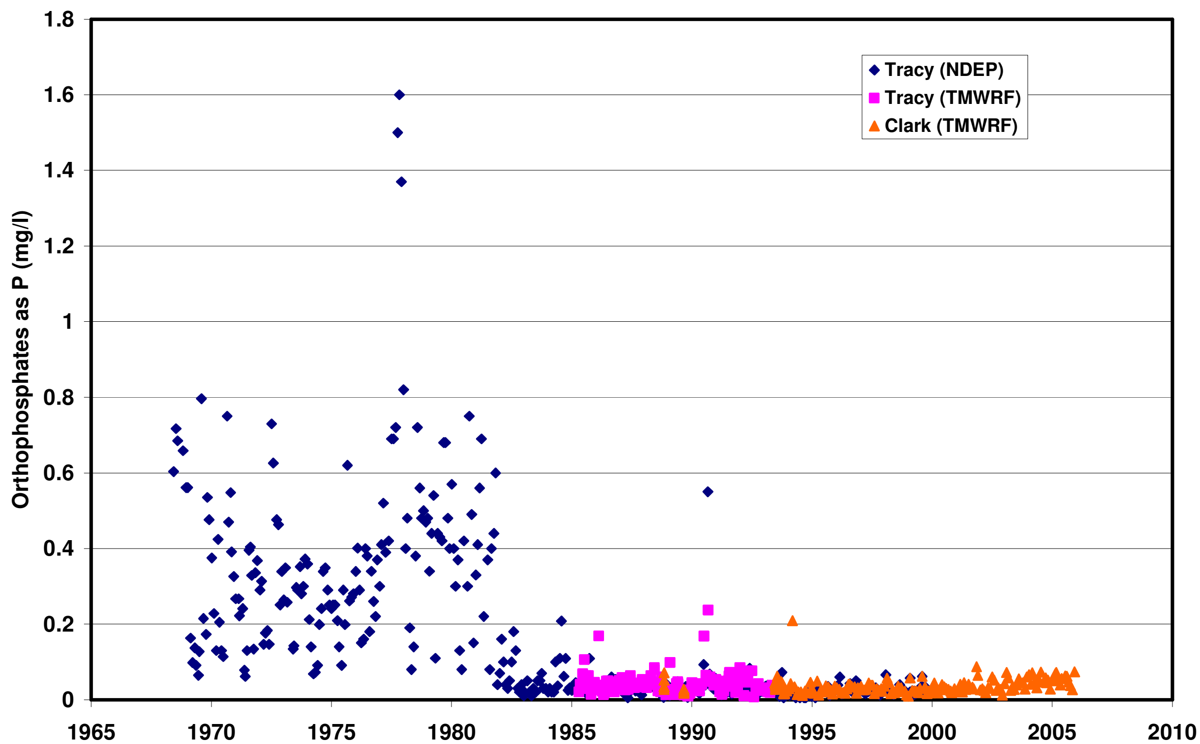
Figure 2. Trend in Annual Flows in Truckee Canal (Sta. 10351400) - 1967-2006



Orthophosphate and total phosphorus concentrations in the Truckee River (and subsequently Truckee Canal) experienced a decrease around 1982 due to the startup of the PhoStrip process for the biological removal of phosphorus (Gray, 2006) (Figures 3 through 6)[1]. There also appears to have been a decrease in the OP:TP ratio (see Figure 7) at that same time.

Nitrate and total nitrogen concentrations in the Truckee River and Truckee Canal have dropped since 1989 with addition of biological nutrient removal (Figures 8 through 11)[1]. The data also show a drop in the Nitrate:TN ratio (Figure 12). Note that during the period from 1994 until early 1998, TMWRF had not been able to consistently meet the waste load allocation (WLA) for total nitrogen due to a snail infestation of the plant's nitrification towers. By early 1998, the snail problem had been solved and the plant was once again in compliance with the WLA (NDEP, 1998). Also in the spring of 2001, elevated nitrogen discharges from TMWRF were allowed during a brief period while plant plumbing improvements were completed (Holmgren, 2006).

Figure 3. Truckee River at Tracy and Clark - Orthophosphates



[1] To demonstrate long-term changes, TMWRF's Tracy and Clark monitoring sites on the Truckee River upstream of Derby Dam were selected due to their longer period of record. Between these 2 sites, data exists for 1967-2005 while the Truckee River at Derby Dam site only dates back to 1985; and NDEP's Truckee Canal site only goes back to 1991.

Figure 4. Truckee River at Tracy & Clark - Total Phosphorus

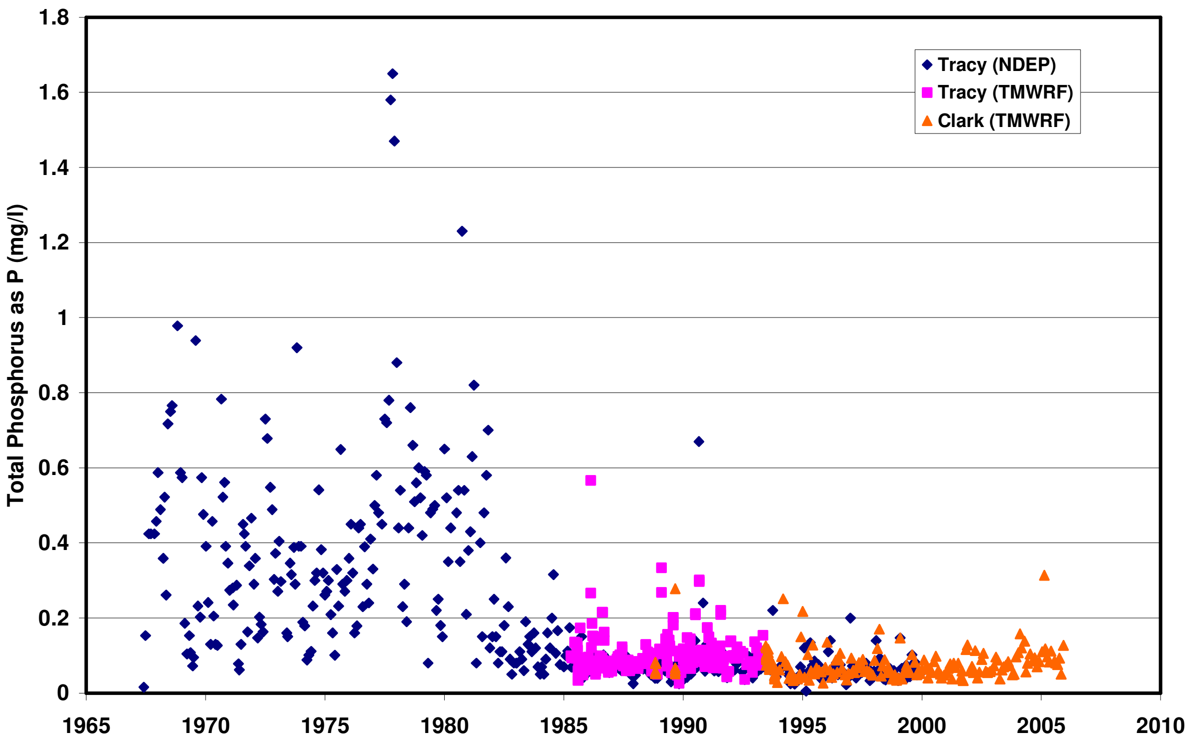
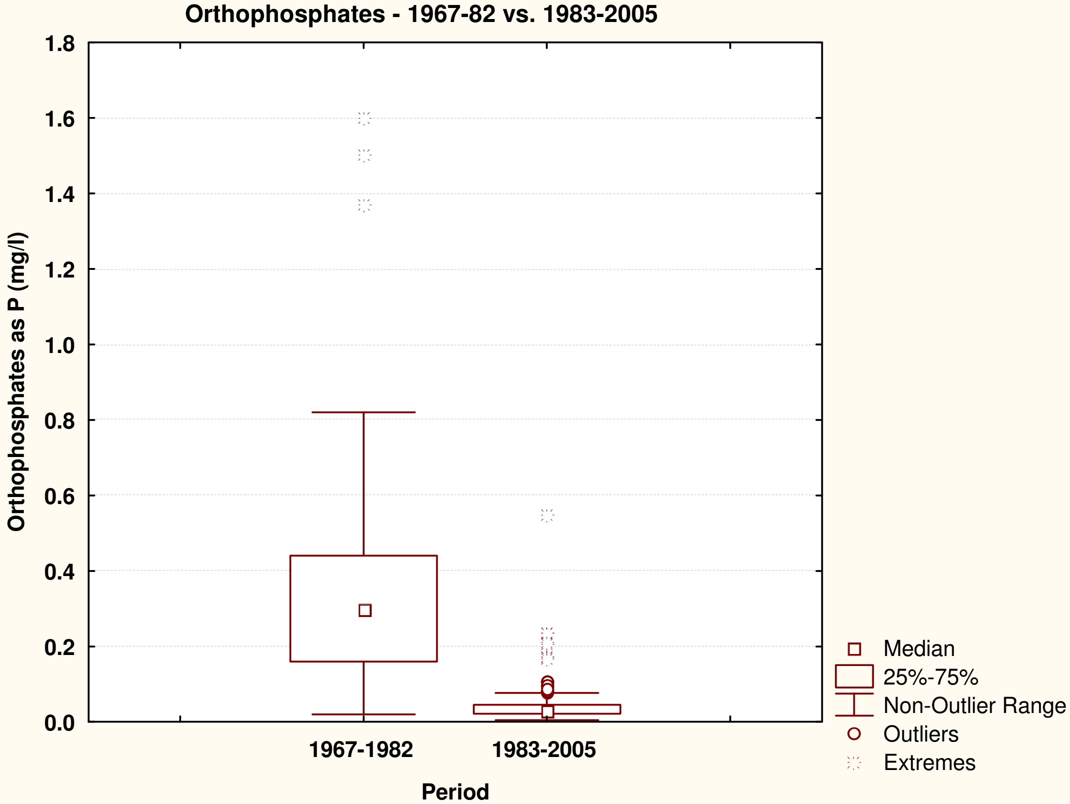


Figure 5. Truckee River at Clark and Tracy -
Orthophosphates - 1967-82 vs. 1983-2005



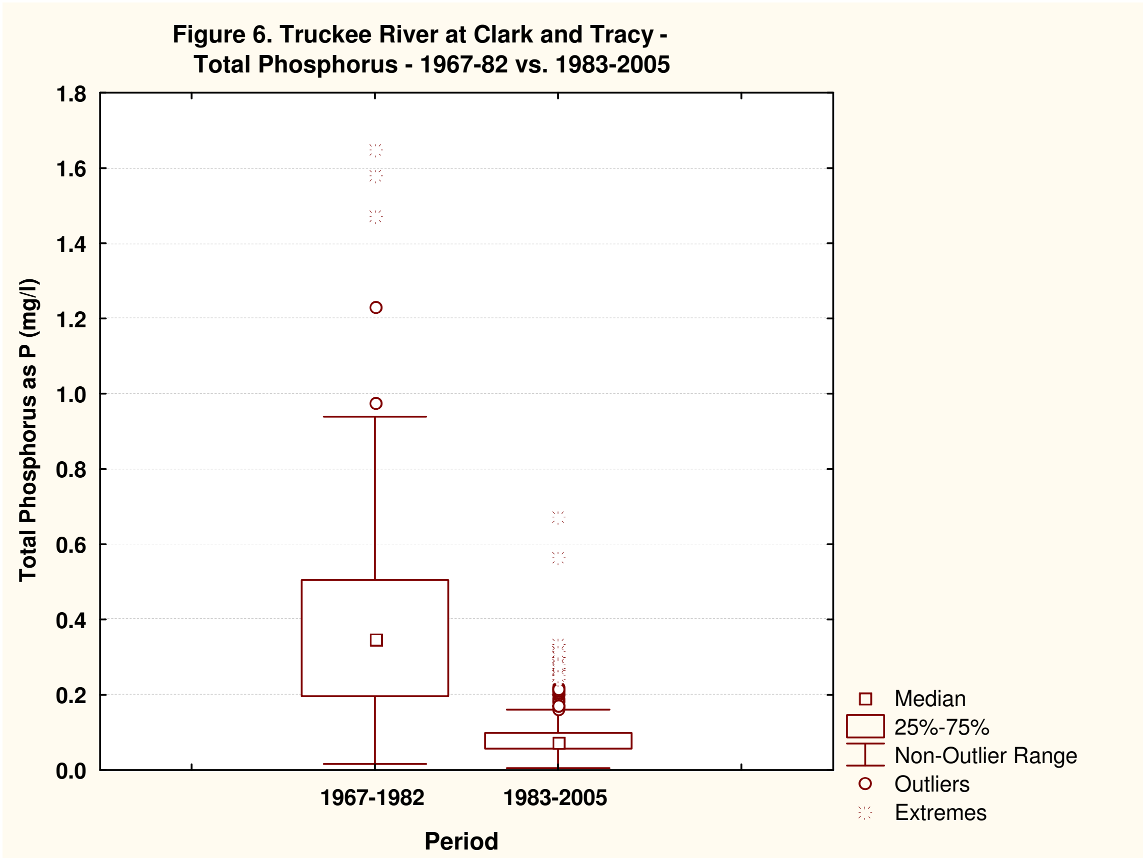


Figure 7. Tracy and Clark - OP:TP Ratio

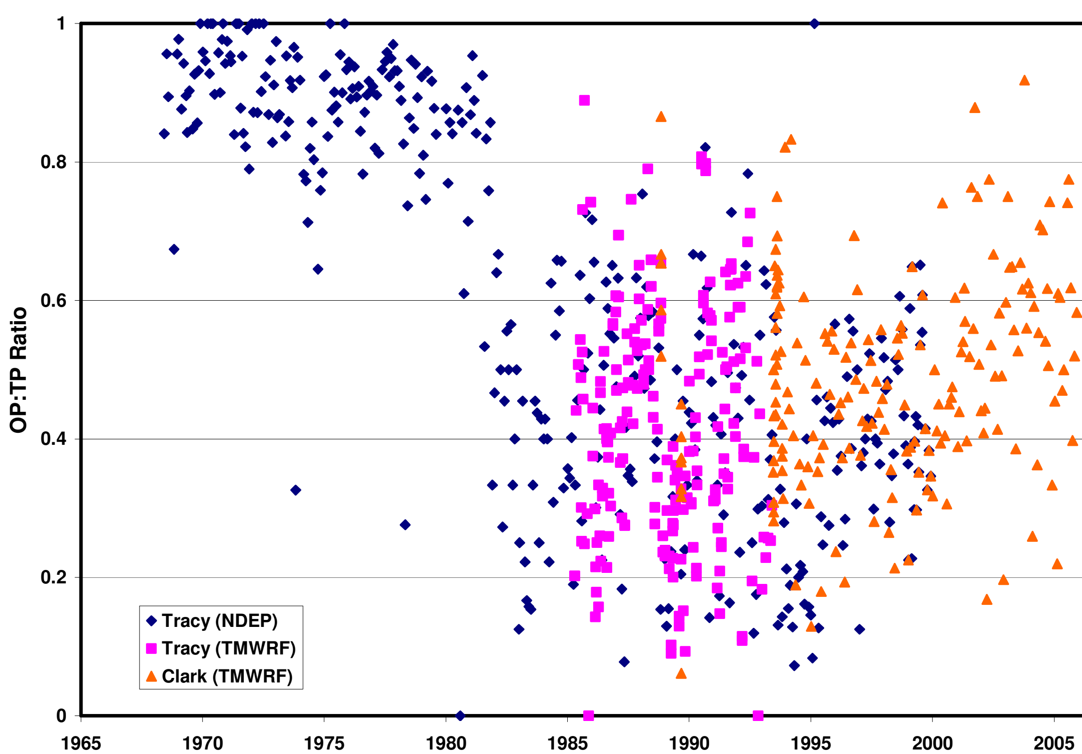


Figure 8. Truckee River at Tracy and Clark - Nitrate/Nitrite

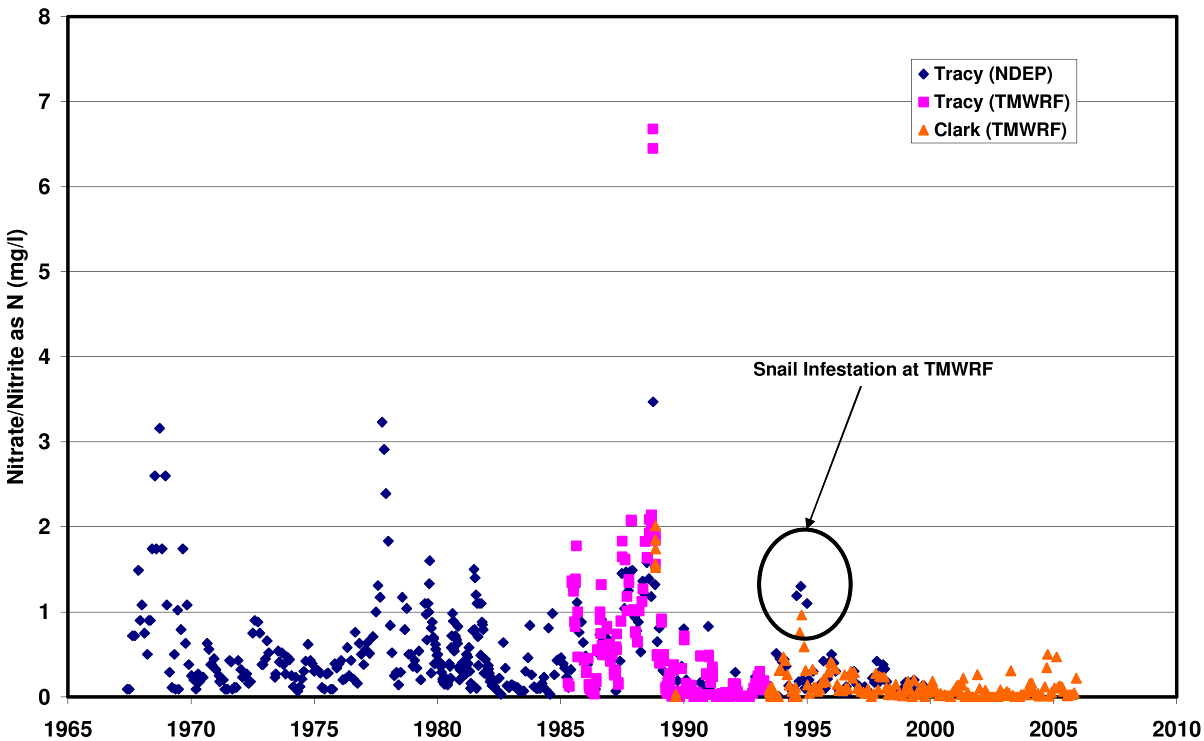
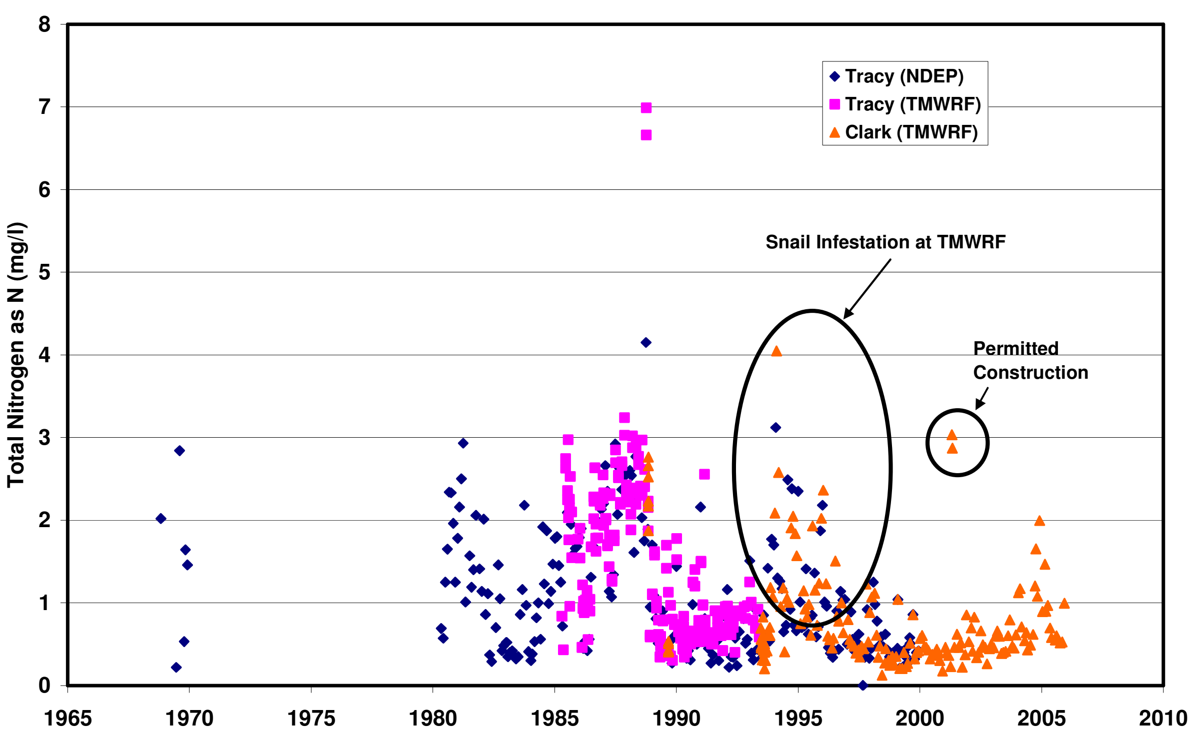


Figure 9. Truckee River at Tracy and Clark - Total Nitrogen



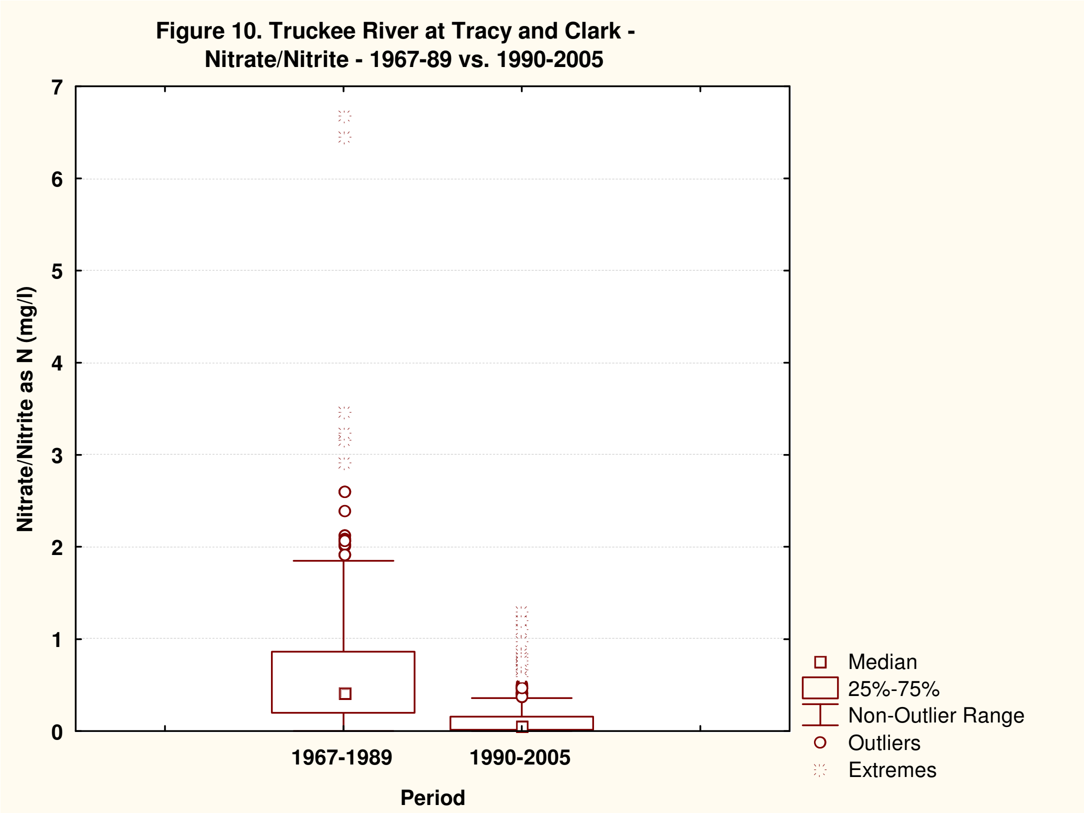


Figure 10. Truckee River at Tracy and Clark -
Nitrate/Nitrite - 1967-89 vs. 1990-2005
Nitrate/Nitrite as N (mg/l)
0
1
2
3
4
5
6
7
1967-1989
1990-2005
Period
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

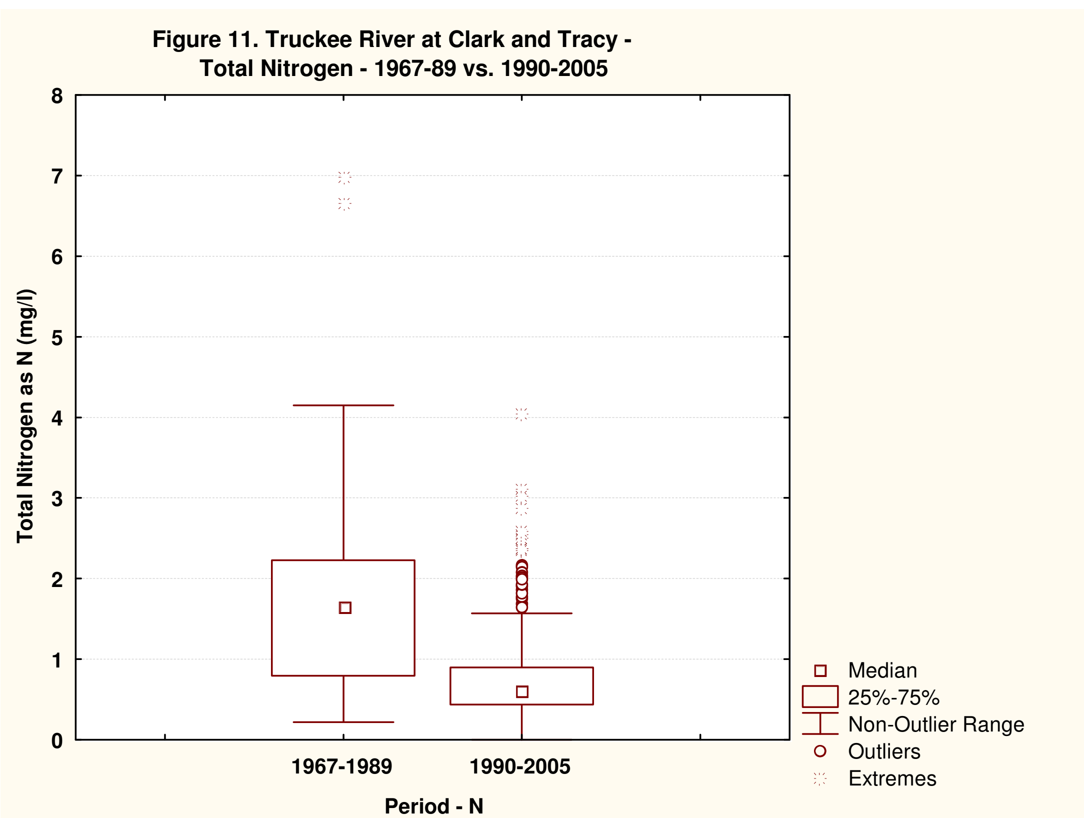
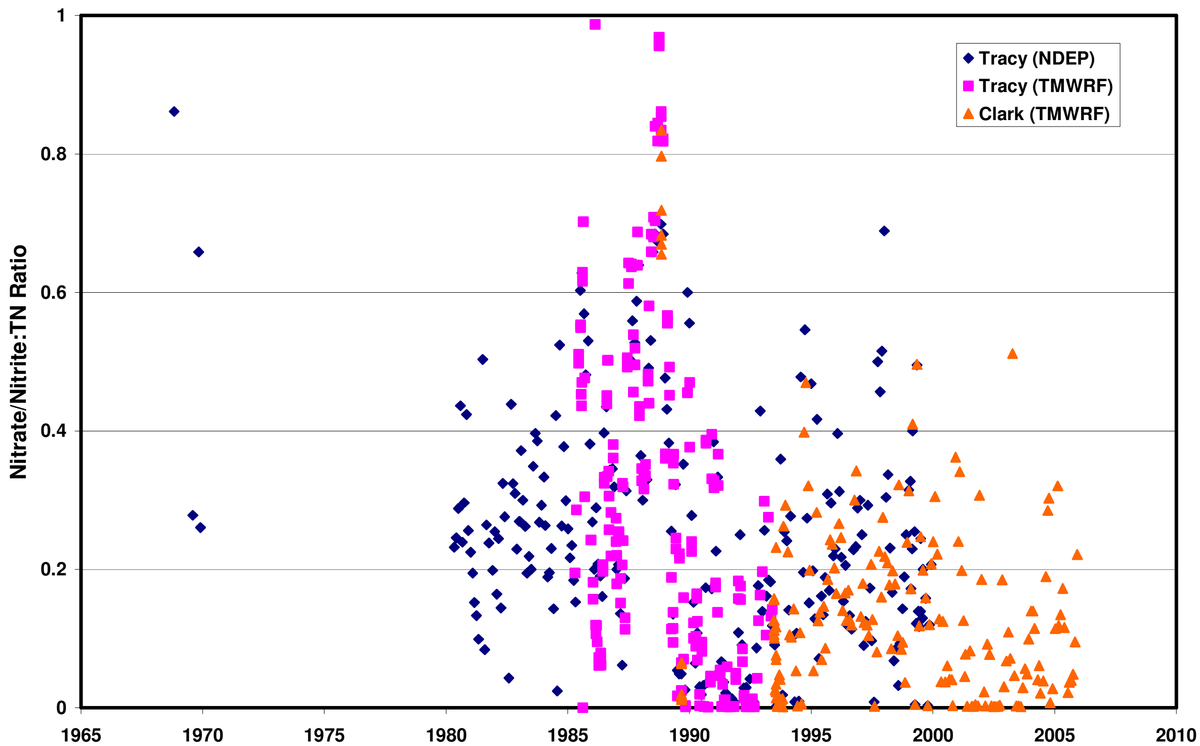


Figure 11. Truckee River at Clark and Tracy -
Total Nitrogen - 1967-89 vs. 1990-2005
Total Nitrogen as N (mg/l)
0
1
2
3
4
5
6
7
8
1967-1989
1990-2005
Period - N
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Figure 12. Tracy and Clark - Nitrate/Nitrite:TN Ratio



While a visual inspection of the data indicate that OP, TP, Nitrate and TN concentrations have decreased, Mann-Whitney tests were performed to determine the statistical significance of these differences. These tests show that the differences between the median values for "before TMWRF upgrades" and "after TMWRF upgrades" are significant in all instances at the 95% confidence level (Table 1).

Table 1. Mann-Whitney Test Results for Truckee River at Clark/Tracy, NV Water Quality Data

Constituent	1967-82 Median (mg/l)	1983-2005 Median (mg/l)	Percent Reduction	Significant difference between the 2 groups at $p<0.05$
OP	0.30	0.03	90%	Yes ($p = 0.000$)
TP	0.35	0.08	77%	Yes ($p = 0.000$)
	1967-89 Median (mg/l)	**1990-2005 Median (mg/l)**		
NO3/NO2	0.43	0.07	84%	Yes ($p = 0.000$)
TN	1.65	0.60	64%	Yes ($p = 0.000$)

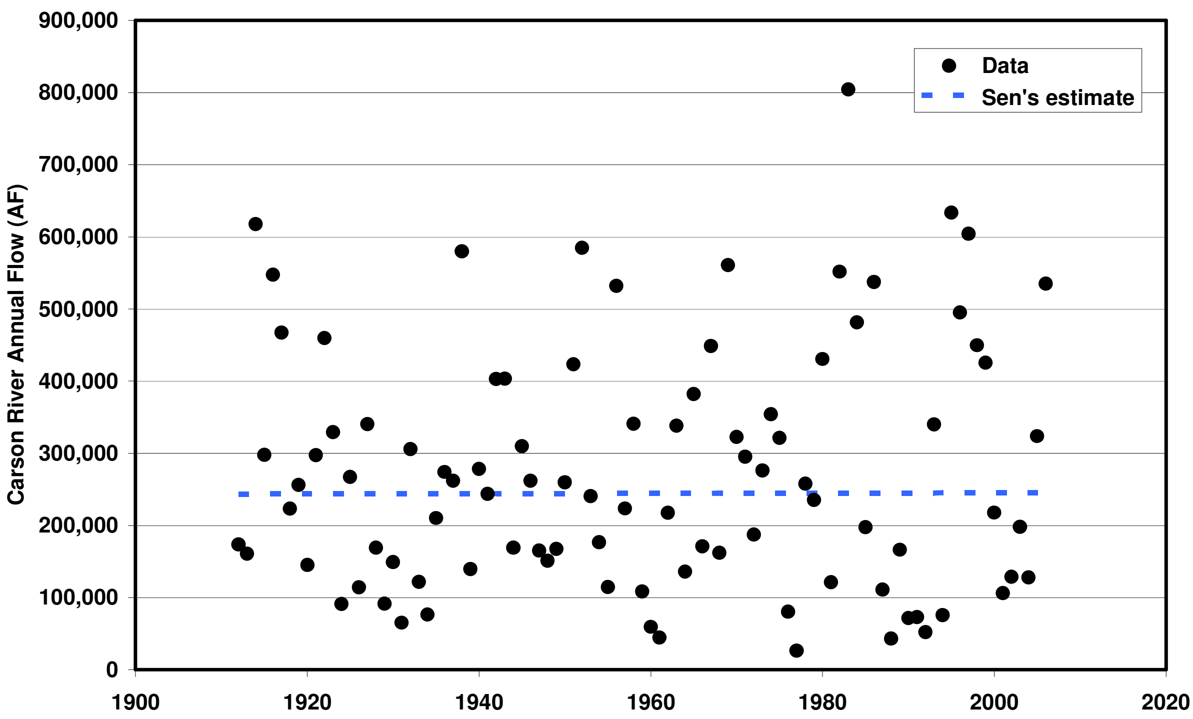
Carson River

As with the Truckee Canal flows, a Mann-Kendall test was performed on the Carson River inflows to Lahontan Reservoir to check for any detectable trends. The analysis indicates that the trend line is not significantly different from zero (i.e. no increasing/decreasing trend) (Figure 13).

Orthophosphate concentrations in the Carson River prior to entering Lahontan Reservoir experienced a decrease following the removal of direct effluent discharges in 1987 (Kilroy et al., 1997) (Figure 14). However, the total phosphorus concentration data do not show the same dramatic reduction (Figure 15).[2] In fact, a plot of particulate phosphorus concentrations (total phosphorus minus orthophosphates) suggest that this phosphorus form has increased over time (Figure 16). Boxplots of the orthophosphate and total phosphorus data show how the median concentrations are lower for the period after 1987 (Figures 17 and 18). Concurrently, the data show a decrease in the OP:TP ratios after 1987 (Figure 19).

Nitrate/nitrite concentrations in the Carson River near Lahontan Reservoir appear to have decreased following the removal of direct effluent discharges (Figure 20). There are insufficient 1967-89 data to draw conclusions regarding TN trends (Figure 21). Boxplots (Figures 22 and 23) of these data show how the median nitrate/nitrite concentrations have decreased after 1987. However, there are insufficient total nitrogen data for the 1967-87 period to draw any such conclusion. Figure 24 shows that the nitrate:TN ratios may have reduced since 1987[3].

Figure 13. Trend in Annual Flows in Carson River (Sta. 10312000) - 1916-2006



[2] In order to maximize the dataset size, water quality data from four sampling sites in the vicinity of Weeks Bridge were used in the analysis: 1) USGS Site 10312000 – Ft. Churchill; 2) USGS Site 10312020 – Silver Springs; 3) NDEP Site C10 – Weeks; 4) Dayton Valley Conservation Dist. Site Weeks.

Figure 14. Carson River near Weeks/Fort Churchill - Orthophosphate

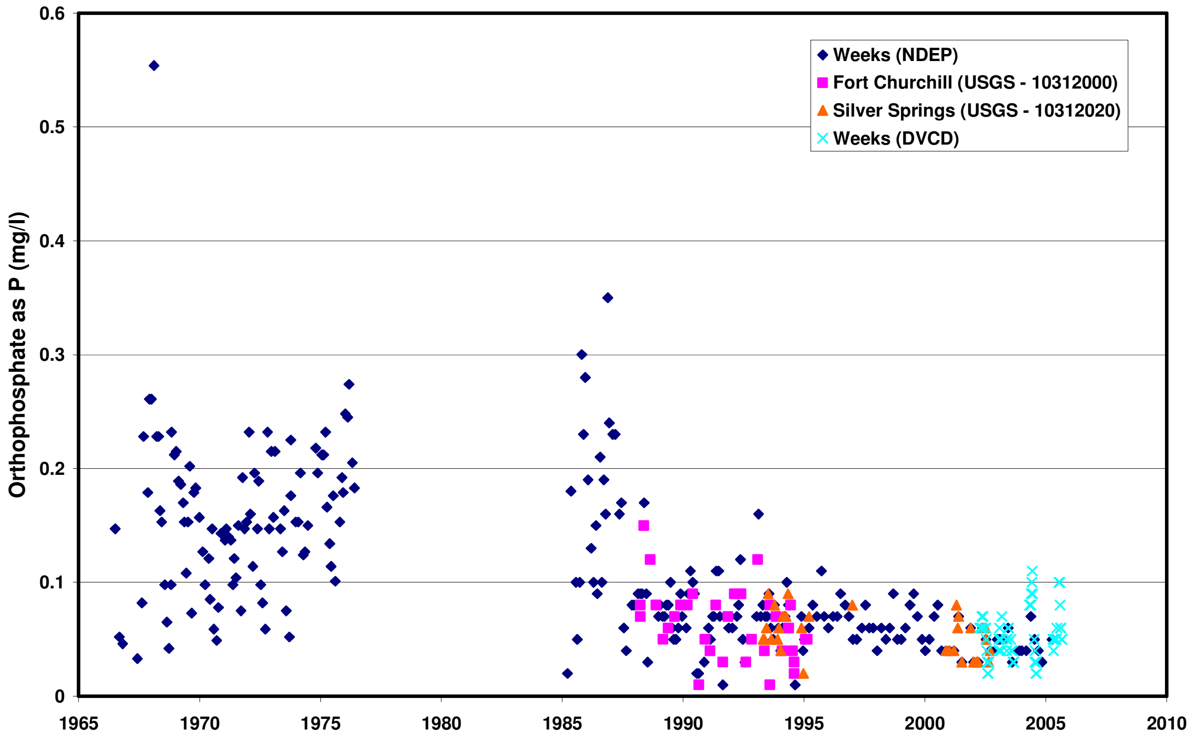
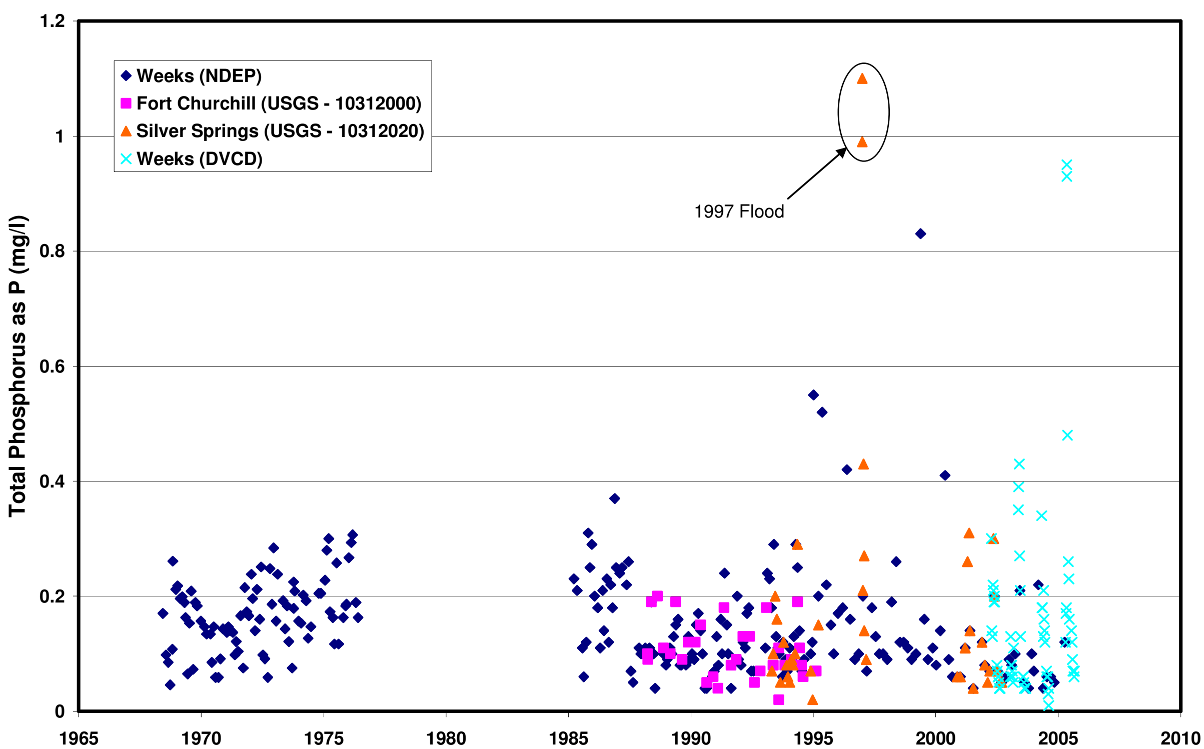


Figure 15. Carson River near Weeks/Fort Churchill - Total Phosphorus



[3] In 2004, nitrate detection levels switched to a high value of 0.5 mg/l. With a majority of the data below detection, these data were not used in the analysis.

Figure 16. Carson River near Weeks/Fort Churchill - Particulate Phosphorus (Total Phosphorus minus Orthophosphates)

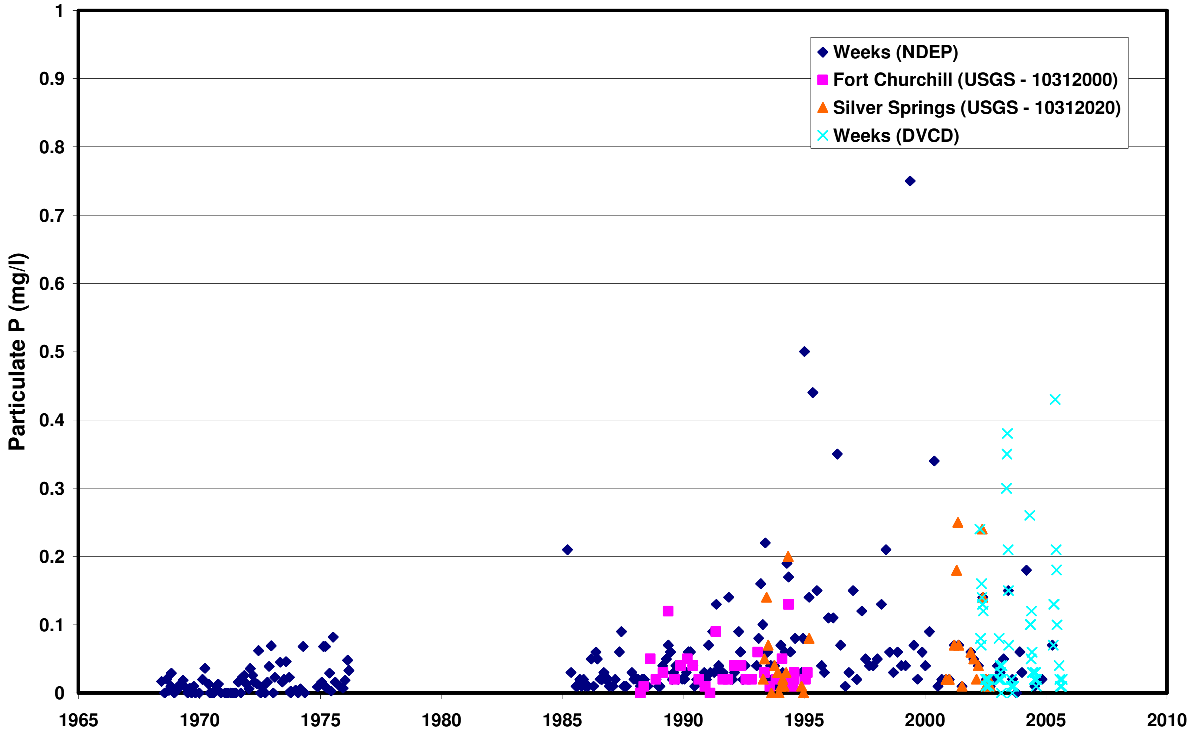


Figure 17. Carson River near Weeks/Ft. Churchill - Orthophosphates - 1966-87 vs. 1988-2005

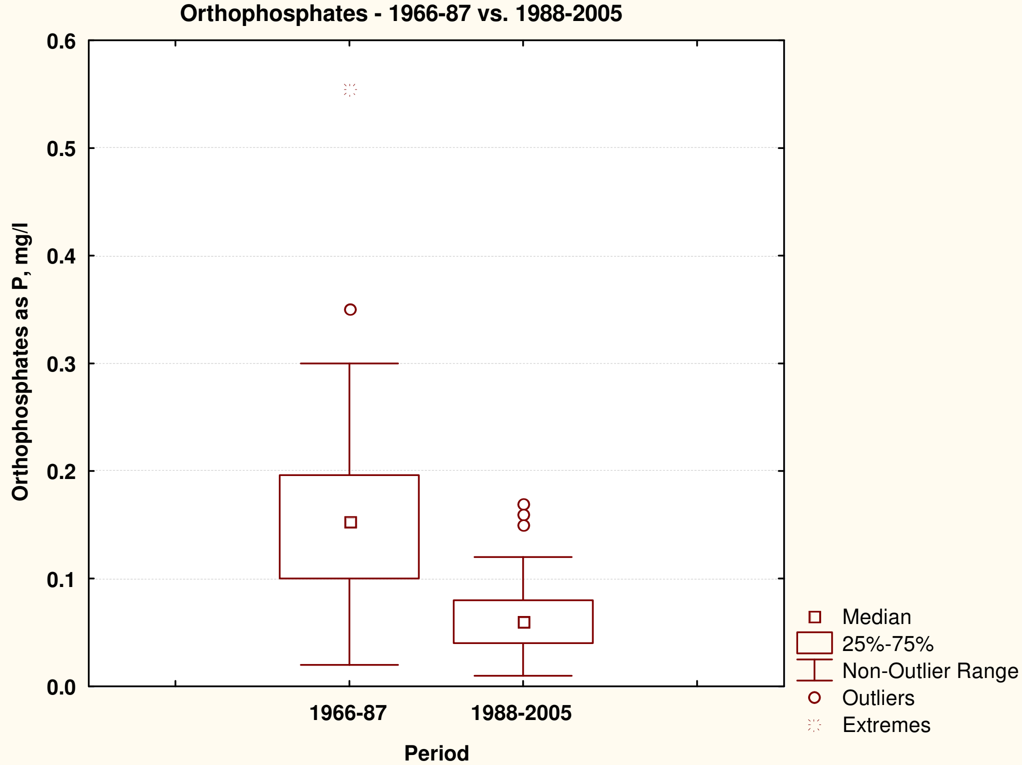


Figure 18. Carson River near Weeks/Ft. Churchill -
Total Phosphorus - 1966-87 vs. 1988-2005

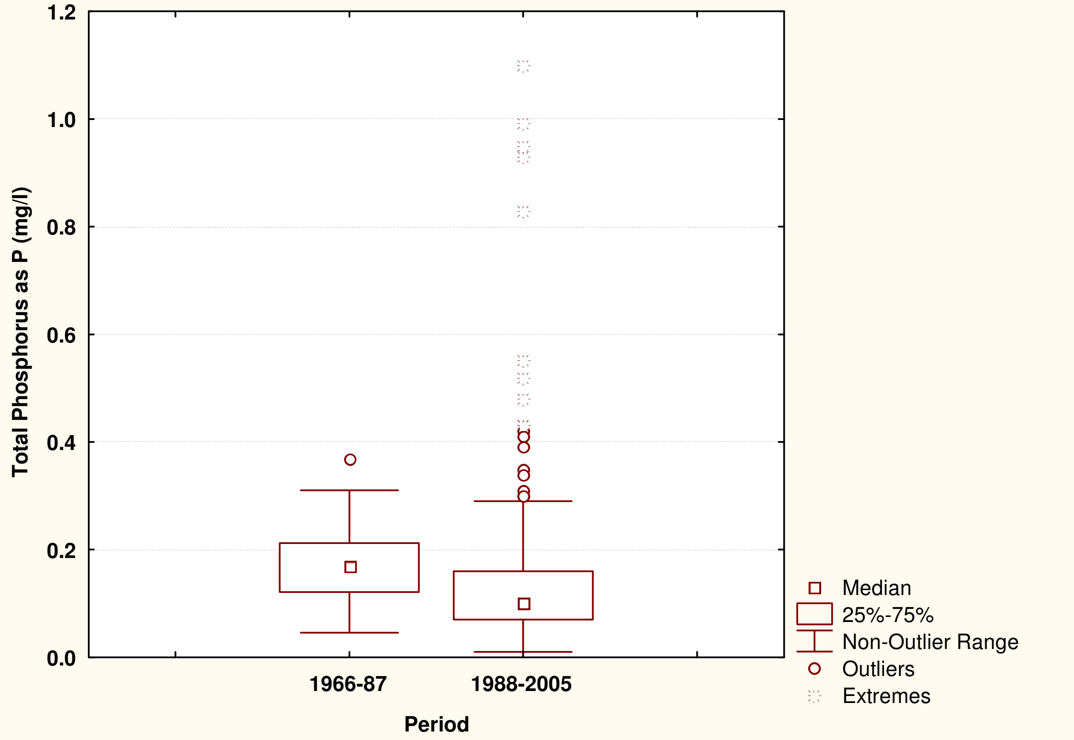


Figure 19. Carson River near Weeks/Ft. Churchill - OP:TP Ratio

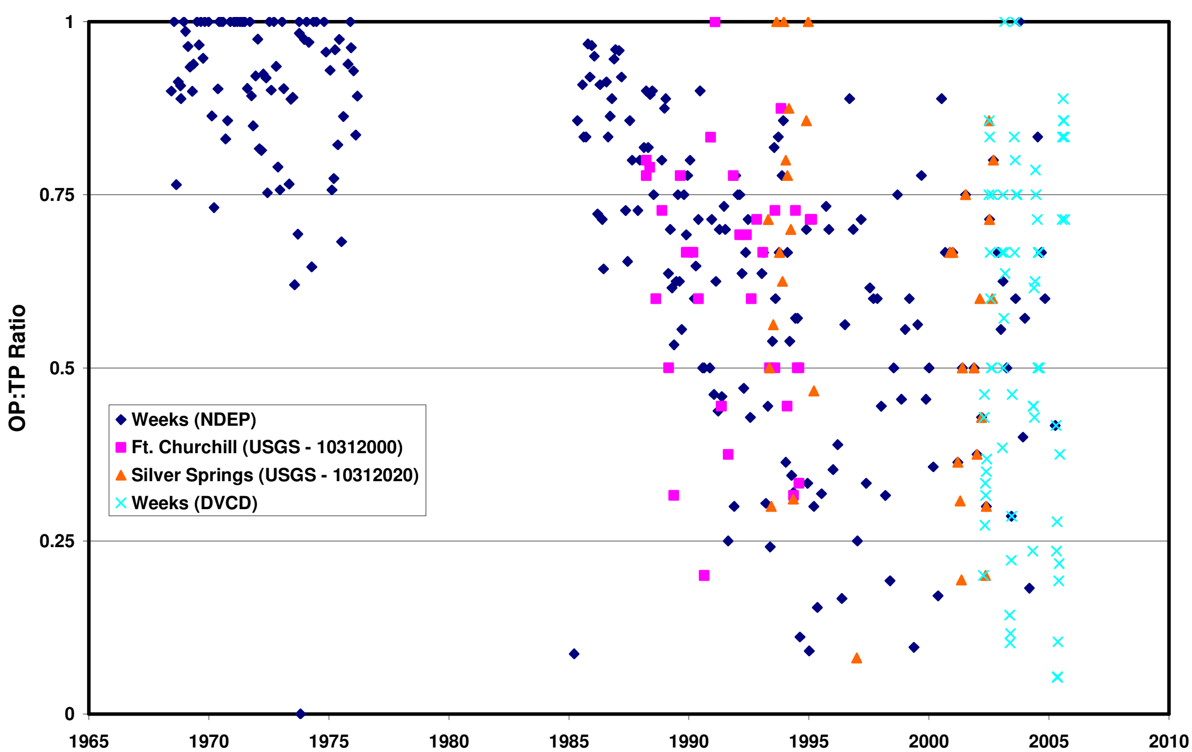


Figure 20. Carson River Near Fort Churchill - Nitrate/Nitrite

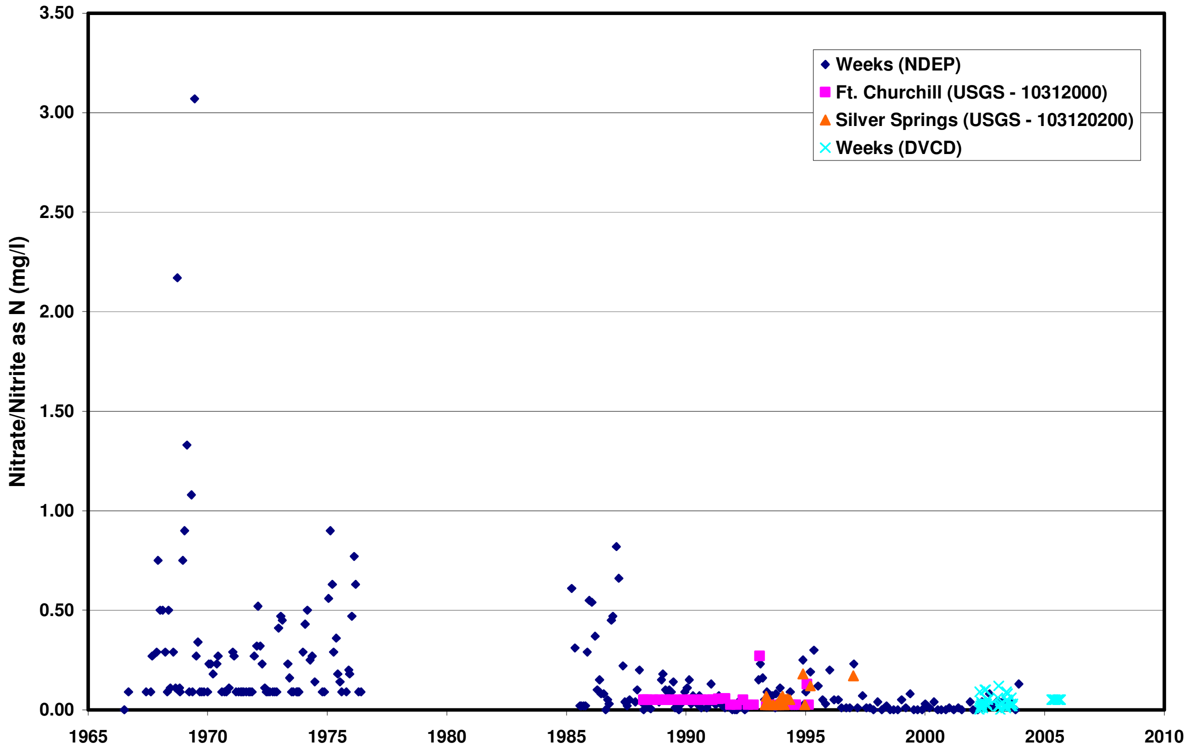


Figure 21. Carson River near Fort Churchill - Total Nitrogen

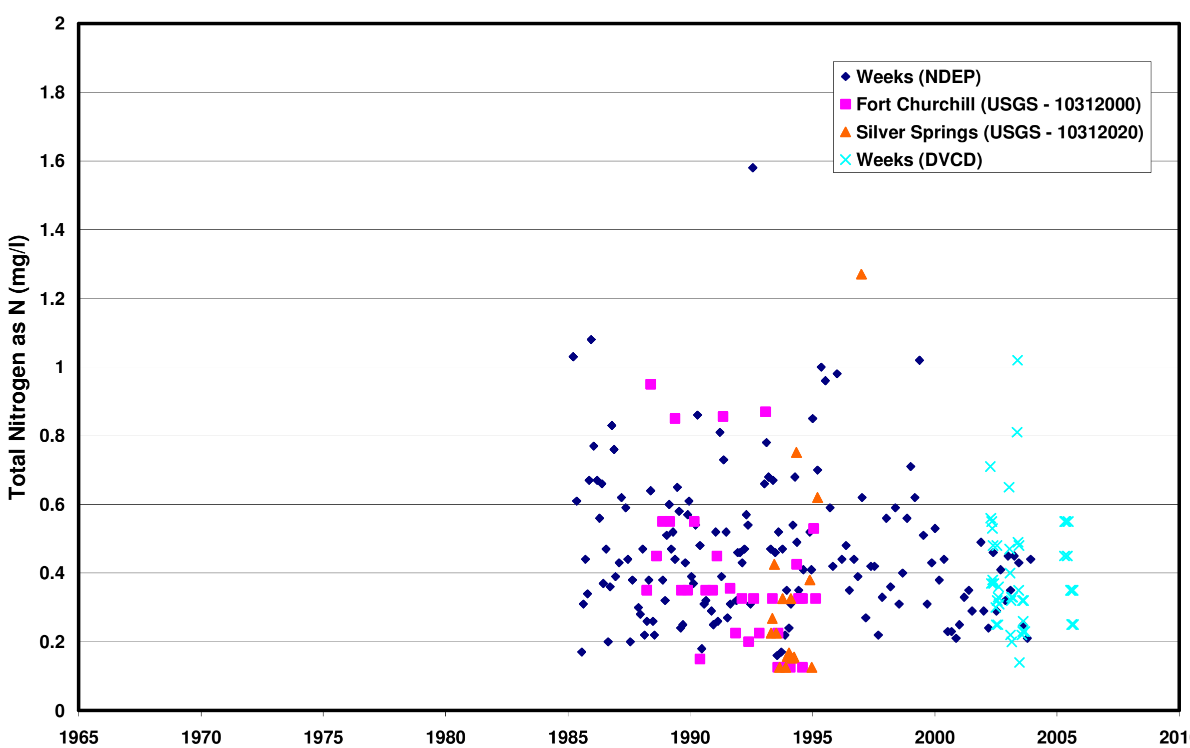


Figure 22. Carson River near Weeks/Ft. Churchill - Nitrate/Nitrite - 1966-87 vs. 1988-2005

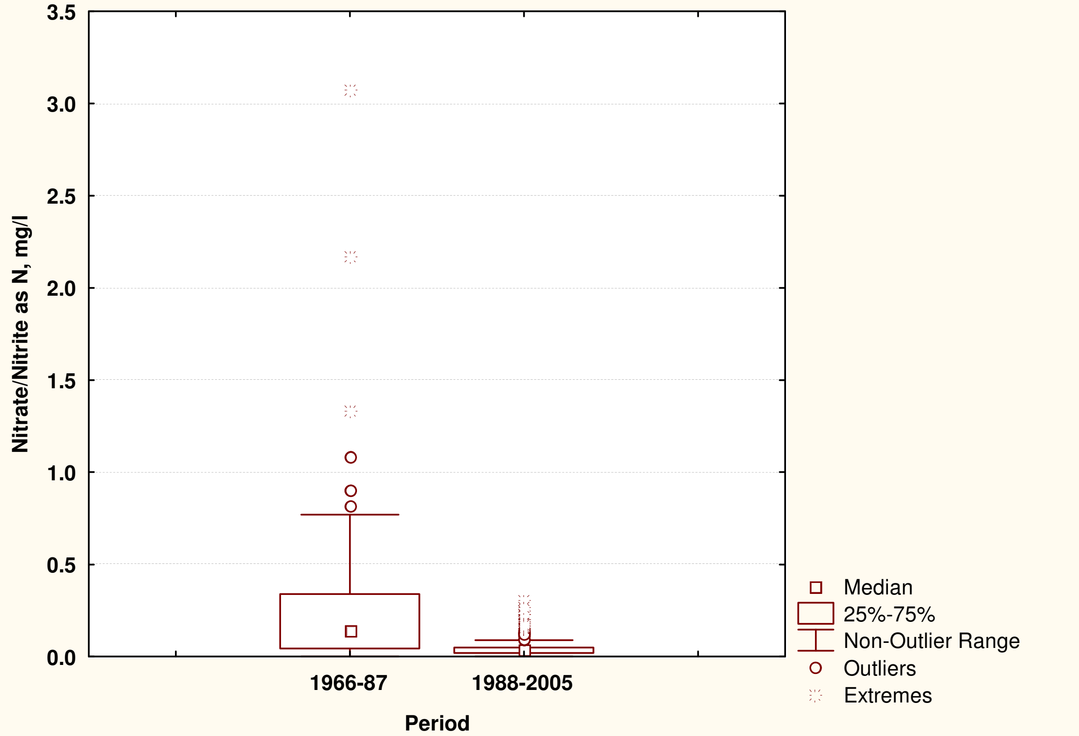


Figure 23. Carson River near Weeks/Ft. Churchill - Total Nitrogen - 1966-87 vs. 1988-2005

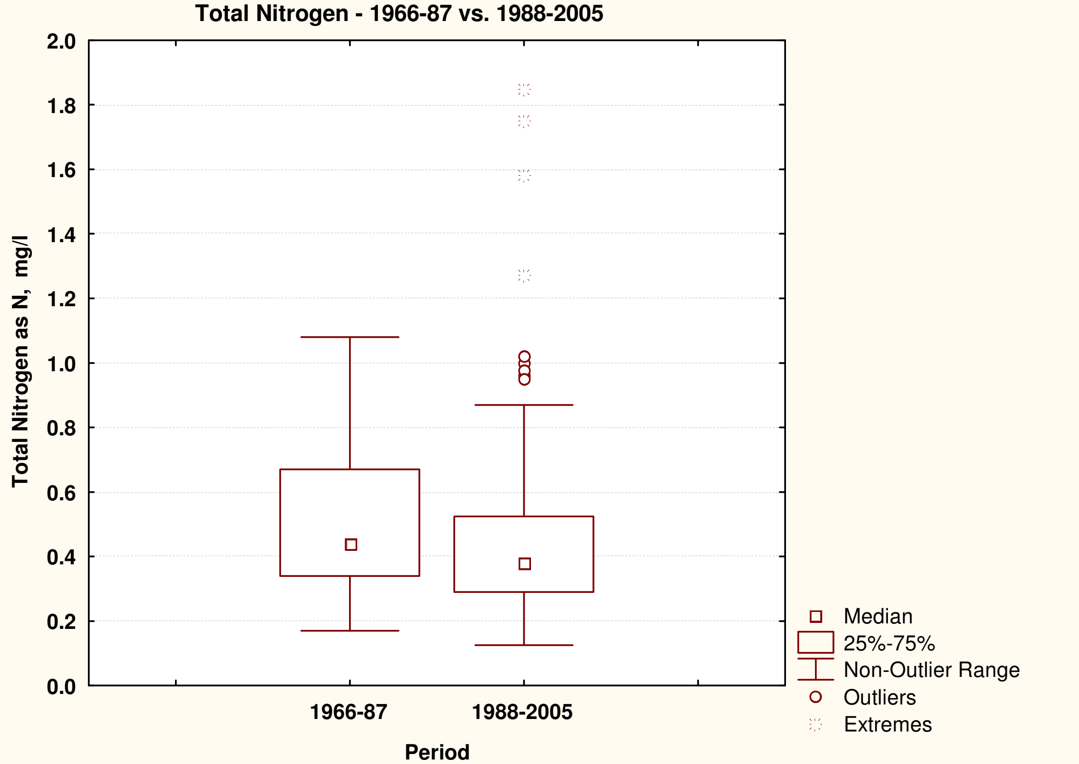
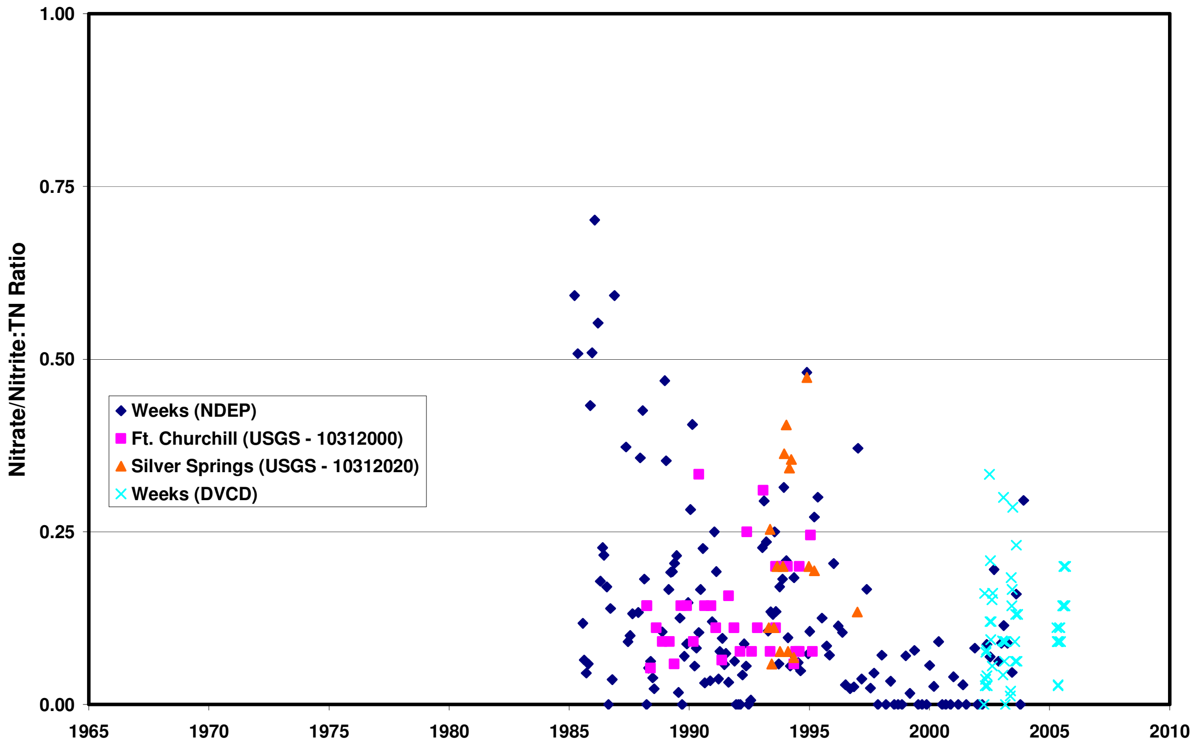


Figure 24. Carson River near Ft. Churchill - Nitrate/Nitrite:TN Ratio



As with the Truckee River data, Mann-Whitney tests were performed to determine the statistical significance in the differences between the pre-1988 data and the post 1987 data. These tests show that the differences between the median values for the 1967-1987 period and the 1988-2005 period are significant in all instances at the 95% confidence level (Table 2). However, there were insufficient 1967-87 TN data to make any valid conclusions regarding TN trends.

Table 2. Mann-Whitney Test Results for Carson River near Weeks, NV Water Quality Data

Constituent	1967-87 Median (mg/l)	1988-2005 Median (mg/l)	Percent Reduction	Significant difference between the 2 groups at $p<0.05$
OP	0.15	0.06	60%	Yes (p = 0.000)
TP	0.17	0.10	41%	Yes (p = 0.000)
NO2/NO3	0.14	0.04	71%	Yes (p = 0.000)
TN	0.44	0.38	n/a	**Insufficient data during 1967-87 period for valid comparison**

Estimates of Annual Nutrient Loads to Lahontan Reservoir

While the previous section examined trends in the water quality sampling data (concentrations), this section focuses on changes in annual average loads to Lahontan Reservoir via the Truckee Canal and the Carson River. Over the years, annual nutrient load estimates for Lahontan Reservoir have been generated by a number of authors. Based upon more current information, updated nutrient loading values have been estimated for the time period 1990-2005[4] and compared to previous work.

Two different techniques were utilized to estimate annual nutrient loads from the Truckee Canal and from the Carson River. Given the extensive monthly water quality data for the Truckee River, a rather simple approach (monthly nutrient concentrations were assumed to be representative of levels through the month) was taken to estimate Truckee Canal loads. Data for the Carson River are less intensive, so a different approach was taken to estimate Carson River loads. This methodology was based upon regressions between loads and flow.

Carson River

Using the same approach described by Helsel and Hirsch (2000) and as used recently by Alvarez and Seiler (2004), annual Carson River nutrient loads to Lahontan Reservoir were estimated from a series of simple linear regression equations relating loads to streamflows (using NDEP, USGS, DVCD data). The basic form of these regression equations is shown in the following equation[5]:

$$\ln[load] = \beta_0 + \beta_1 * \ln[Q] \qquad \text{[Eq. 1]}$$

Where:

ln[] = natural logarithm
load = load in pounds per day
β_0 = intercept coefficient
β_1 = slope coefficient
Q = streamflow in cubic feet per second

Table 3 summarizes the equation coefficients (β_0; β_1) and the coefficients of determination (R^2) for the 4 equations for OP, TP, nitrite/nitrate, and TN loads developed from 1988-2005 data. Figures 25 through 28 provide a graphical representation of the data and the resulting regressions. While all of the regressions yielded high R^2 values, this does not necessarily guarantee a good model (Helsel and Hirsch, 2000). Certain assumptions are made when one uses simple linear regressions, and these assumptions need to be examined to determine whether or not an appropriate model has been developed. Assumptions of particular interest include (Helsel and Hirsch, 2000):

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[4] The period 1990-2005 was selected as this is the period during which both TMWRF N/P biological removal has been in place, and direct discharges of treated effluent were removed from the Carson River.

[5] This equation can be rewritten in the following form: $load = \frac{Q^{\beta_1}}{e^{\beta_0}}$; Where e = natural logarithm base ≈ 2.718

- The variance of the residuals[6] is constant (homoscedastic).[7]
- The residuals are independent (no serial correlation).[8]
- The residuals are normally distributed.[9]

The appropriate tests indicated that the above-assumptions are met and that the linear regression models are suitable. To generate loads for 1990 through 2005, daily loads were calculated by using daily streamflows to solve Equation 2; and then combined to estimate annual loads. Since the calculations yielded the natural logarithm of daily loads, the results needed to be retransformed back to their original units (pounds/day). It was then necessary to multiply the resulting annual load by a "bias correction factor" as presented by Helsel and Hirsch (2000) using Equation 3, to adjust for biases introduced by transforming the flow and load to logarithm and then back to original units:

$$Bias\ Correction = \frac{\sum_{i=1}^{n} e^{(\ln[load_{Observed}] - \ln[load_{Predicted}])}}{n} \qquad \text{[Eq. 2]}$$

Where:

n = number of samples
i = sample number
ln[] = natural logarithm
e = natural logarithm base ≈ 2.718

The resulting annual load estimates for the Carson River are summarized in Table 5.

Table 3. Coefficients and Bias Correctors for Nutrient Load-Flow Regressions – Carson River

Parameter	No. of Samples	β_0 (intercept)	β_1 (slope)	R^2	Bias-corrector
Orthophosphates (as P)	259	-1.560	1.079	0.98	1.08
Total Phosphorus (as P)	265	-1.343	1.185	0.97	1.15
Nitrates/Nitrites (as N)	220	-2.067	1.079	0.89	1.48
Total Nitrogen (as N)	217	0.343	1.087	0.97	1.10

[6] Residuals = observed "ln[load]" – predicted "ln[load]"
[7] Compliance with this assumption can be checked by plotting *residuals vs. time* and *residuals vs. predicted values* on scatterplots; The variance of the residuals is considered constant if these plots show no structure in the scatterplots.
[8] Compliance with this assumption can be checked by comparing the residual dataset to a lagged (offset by 1 time period) residual dataset; compute Kendall's tau (or Spearman's rho) between the 2 datasets; if the correlation is statistically significant, the residuals are correlated.
[9] Compliance with this assumption is checked by plotting the residuals on a normal probability plot; If the distribution is normal, the points should fall close to the diagonal normal probability line.

Figure 25. Relationship between Flow and Orthophosphate Load - Carson River (1988-2005)

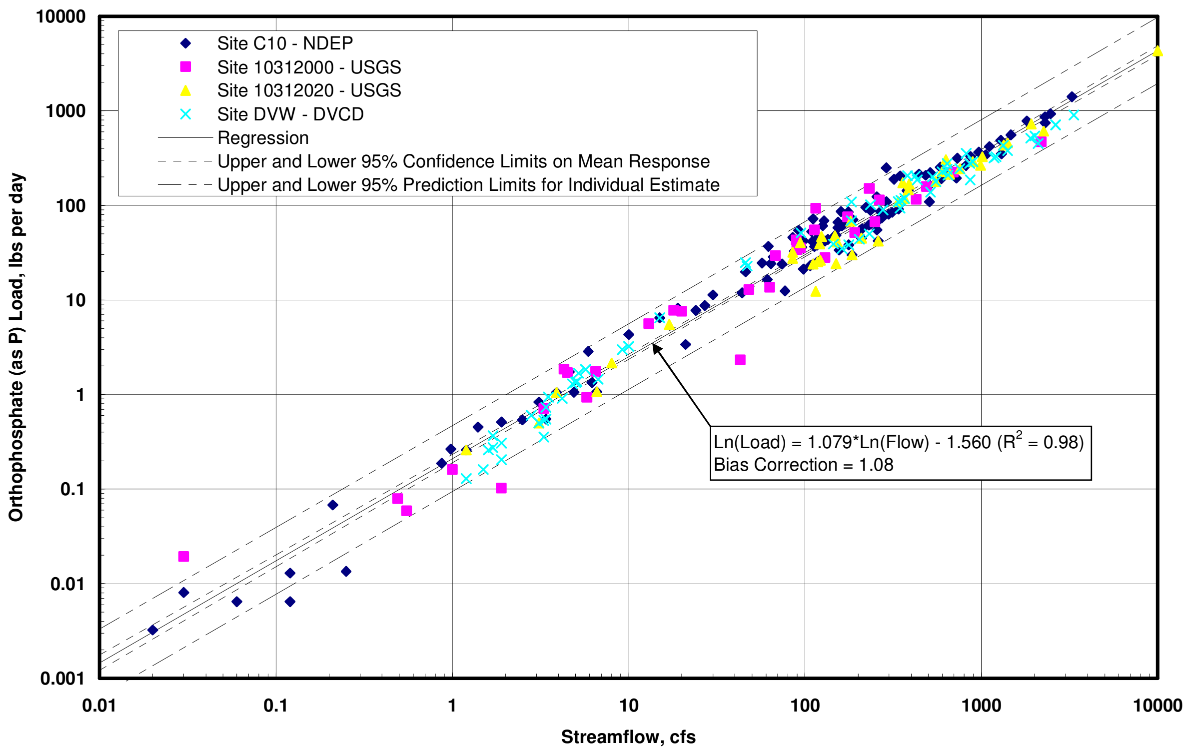

Figure 26. Relationship between Flow and Total Phosphorus Load - Carson River (1988-2005)

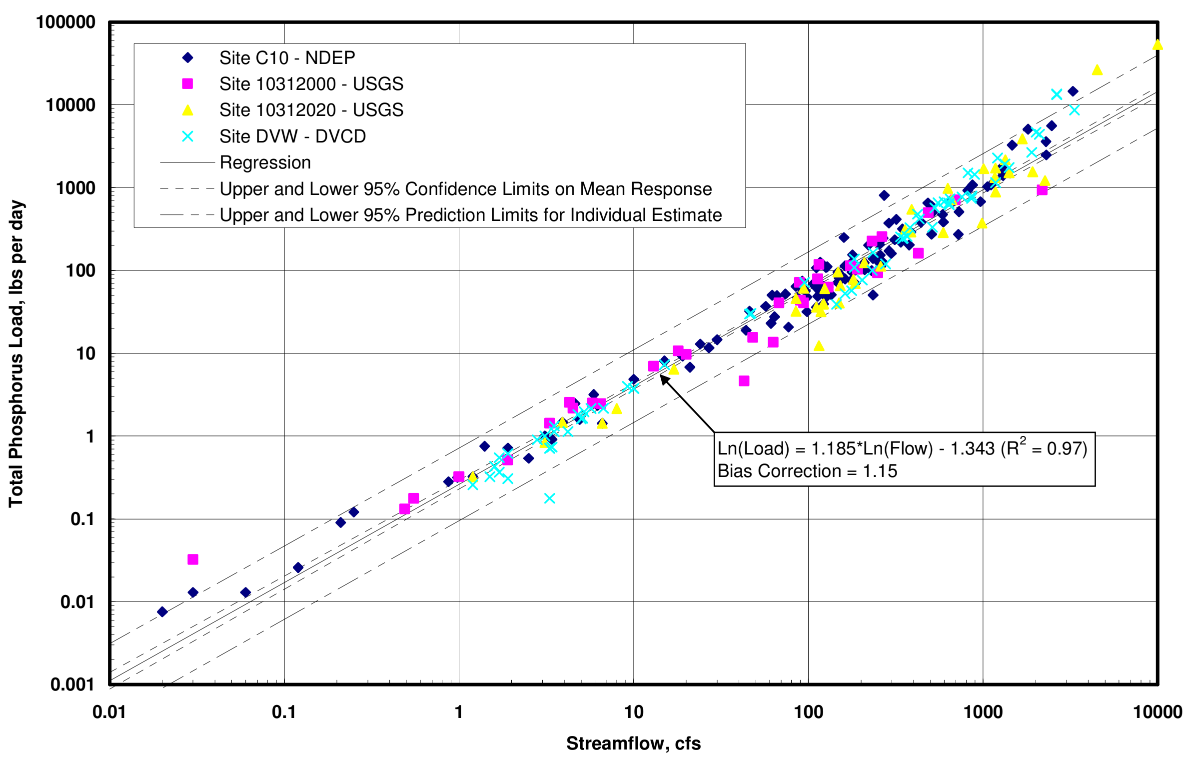

Figure 27. Relationship between Flow and Nitrate/Nitrite Load - Carson River (1988-2005)

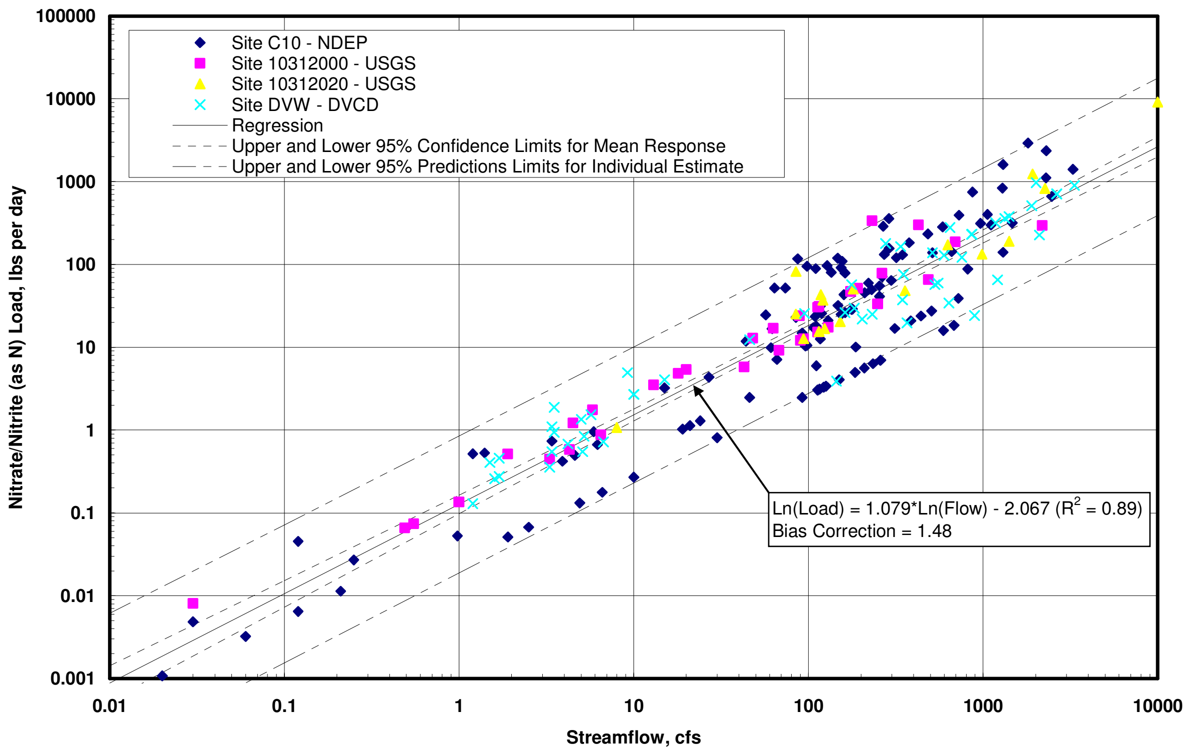

Figure 28. Relationship between Flow and Total Nitrogen Load - Carson River (1988-2005)

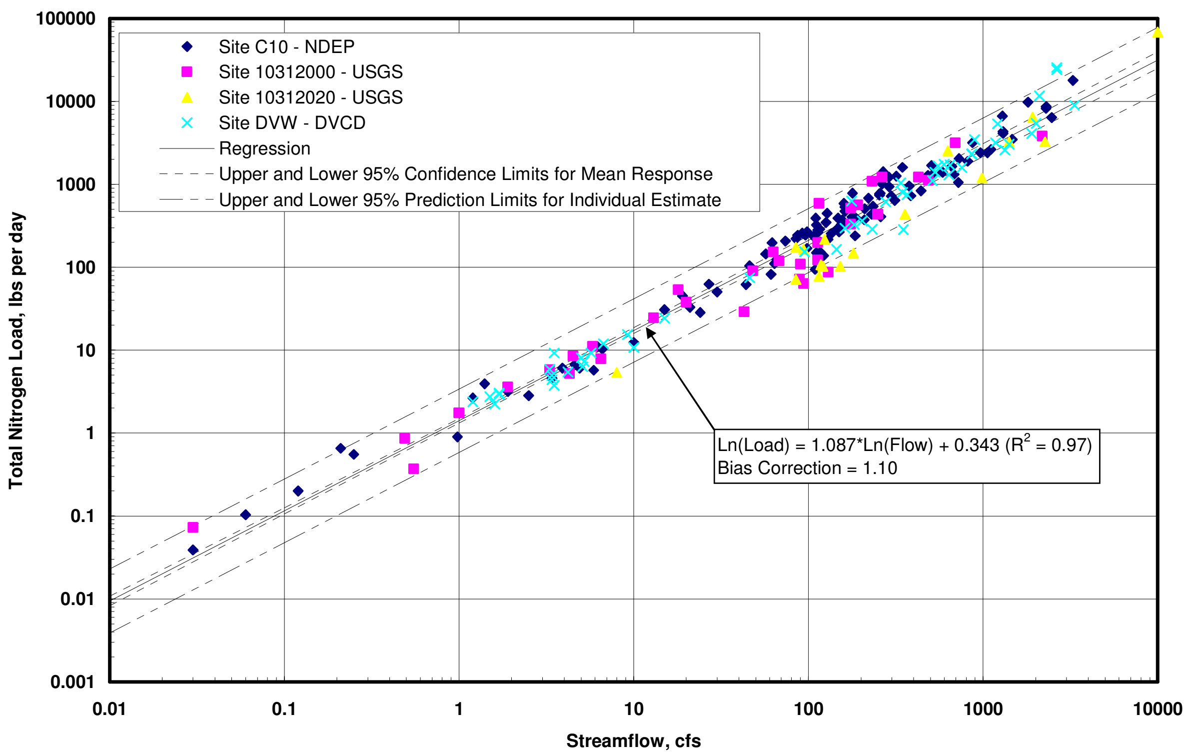

Table 4. Carson River Estimated Loads to Lahontan Reservoir, 1990-2005

Water Year	Flow, AF	Loads (tons/year)			
		OP	TP	NO2 + NO3	TN
1990	72,000	7	14	5	43
1991	73,000	7	15	5	46
1992	52,000	5	10	4	31
1993	340,000	36	94	28	244
1994	76,000	7	15	5	46
1995	633,000	69	191	54	473
1996	496,000	53	140	41	359
1997	604,000	66	184	51	452
1998	450,000	48	124	37	322
1999	425,000	45	117	35	303
2000	218,000	22	53	17	148
2001	106,000	10	23*	8	68
2002	129,000	13	29*	10	84
2003	198,000	20	51	16	137
2004	128,000	12	29	10	83
2005	324,000	34	90	27	233
Average	270,000	28	74	22	192

* Alvarez and Seiler (2004) estimated similar annual TP loads of 24.9 tons (2001) and 31.2 tons (2002).

Truckee Canal

Truckee Canal nutrient loads to Lahontan Reservoir were calculated from two separate approaches: 1) using load vs. flow regressions, such as used for the Carson River loading estimates; and 2) using monthly nutrient concentration and streamflow data.

Load vs. Streamflow Regressions: In the first step, load versus streamflow relationships were developed for the Truckee River immediately above Derby Dam using nutrient data collected just below Derby Dam and streamflows measured at 10350340 – Truckee River near Tracy, Nevada.[10] The data were limited to the 1990-2005 period to reflect water quality improvements due to TMWRF improvements. Table 5 summarizes the equation coefficients (β_0; β_1), the bias corrections and the coefficients of determination (R^2) for the 4 equations for OP, TP, nitrite/nitrate, and TN loads. Figures 29 through 32 provide a graphical representation of the data and the resulting regressions. These regressions had lower coefficients of determination compared to the Carson River regression, especially the nitrates/nitrites relation. Periods of higher nitrogen levels in the TMWRF discharge due to the snail infestation during the mid-1990s appear to have affected the quality of the nitrogen regression models.

In the next step, daily loads for the Truckee River above Derby Dam (1990-2005) were calculated using the load-flow regression relationships. To determine the proportion of the daily load conveyed to Lahontan Reservoir, it was necessary to estimate the portion of the Truckee River load diverted and then conveyed in the Truckee Canal using the following equation:

[10] It was deemed inappropriate to develop Truckee Canal load vs. Truckee Canal flow relationships as this is an artificial system. The purpose of the regressions is to capture watershed processes which lead to the load-flow relations. Under an artificial system, flows and nutrient concentrations will not have the same interrelationship that exists in a natural watershed.

$$Daily\ Truckee\ Canal\ Loads = \frac{Daily\ Flow\ at\ 10351400\ (Truckee\ Canal)}{Daily\ Flow\ at\ 10350340\ (Truckee\ R.\ nr.\ Tracy)} x\ Daily\ Load\ above\ Derby\ Dam \quad \text{[Eq. 3]}$$

From the daily loads, the annual loads were determined (Table 6). **It must be noted that this method does not account for any transformations that occur in the nutrients during their trip from the Truckee River to Lahontan Reservoir. Also, Gage 10351400 is located over 3 miles from Lahontan Reservoir so actual inflows may be less due to canal losses.**

Table 5. Coefficients and Bias Correctors for Nutrient Load Regressions – Truckee River

Parameter	No. of Samples	β_0 (intercept)	β_1 (slope)	R^2	Bias-corrector
Orthophosphates (as P)	270	-0.877	0.868	0.77	1.06
Total Phosphorus (as P)	271	-0.655	0.964	0.83	1.09
Nitrates/Nitrites (as N)	211	-4.645	1.457	0.33	4.03
Total Nitrogen (as N)	210	2.084	0.857	0.70	1.10

Figure 29. Relationship between Flow and Orthophosphate Load - Truckee River Above Derby Dam (1990-2005)

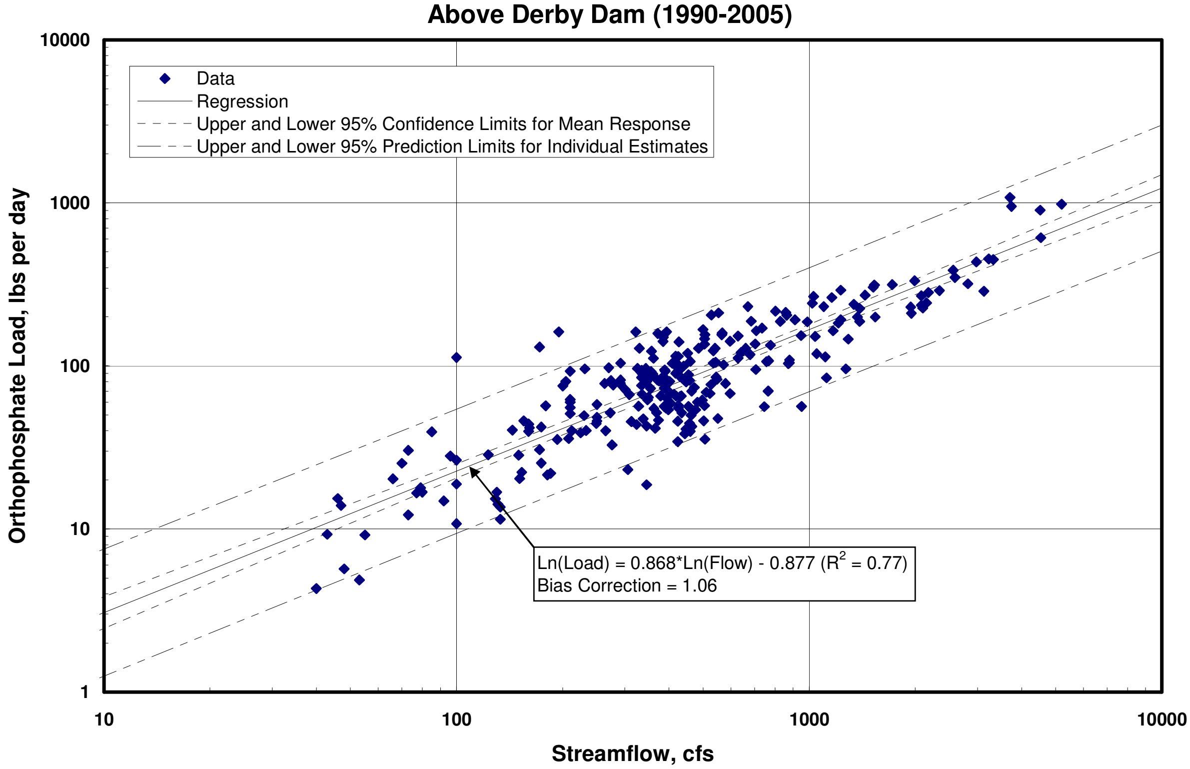

Figure 30. Relationship between Flow and Total Phosphorus Load - Truckee River Above Derby Dam (1990-2005)

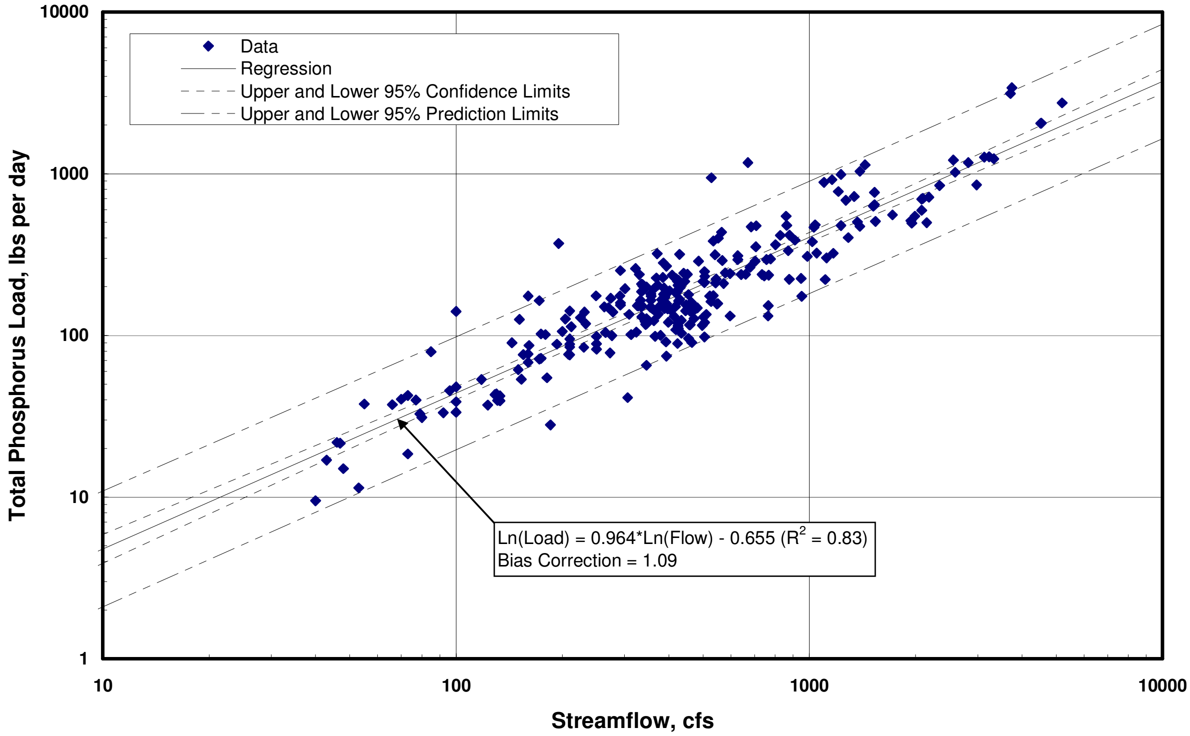

Figure 31. Relationship between Flow and Nitrate+Nitrite Load - Truckee River Above Derby Dam (1990-2005)

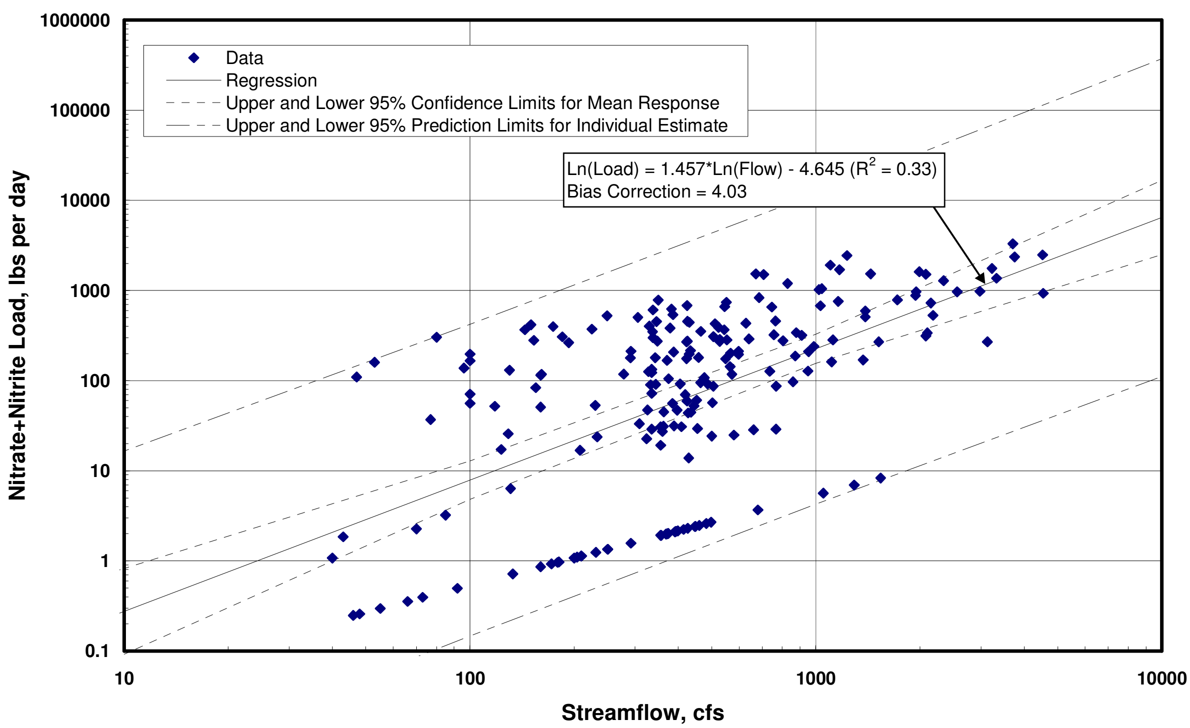

Figure 32. Relationship between Flow and Total Nitrogen Load - Truckee River Above Derby Dam (1990-2005)

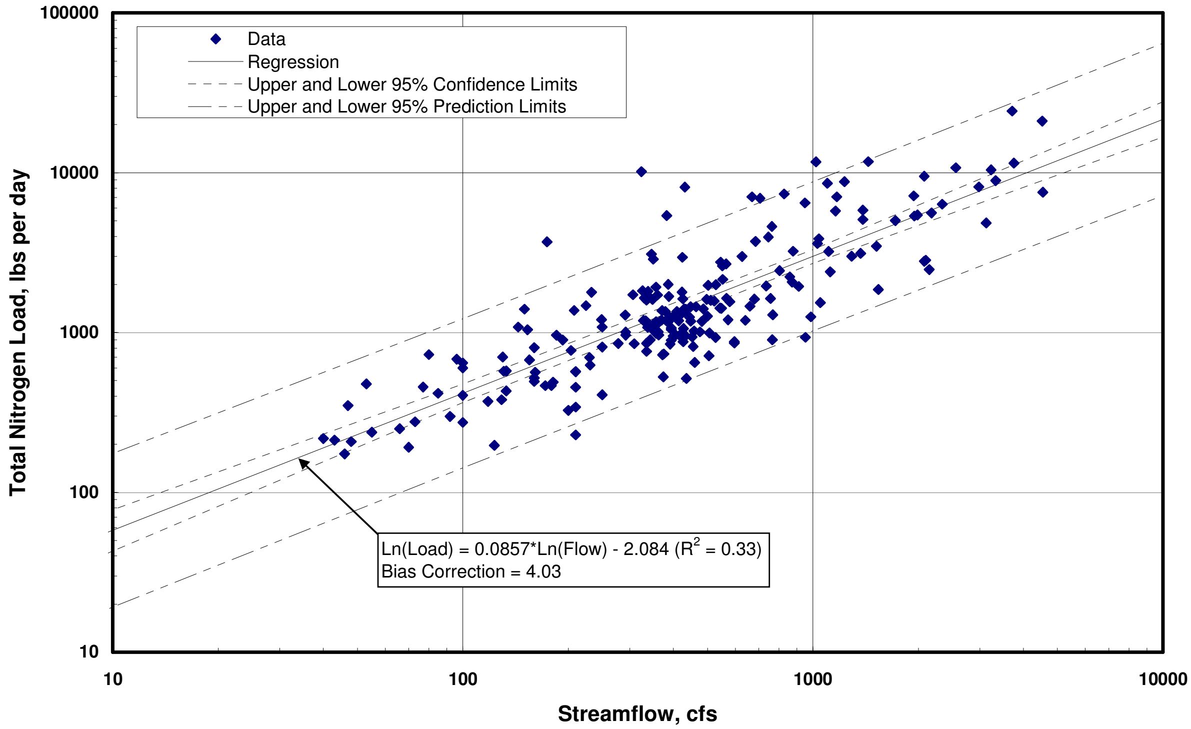

Table 6. Truckee Canal Loads, 1990-2005

Water Year	Flow, AF	Loads (tons/year)							
		OP		TP		NO2 + NO3		TN	
		Load vs. Flow Regress.	Monthly Conc. & Flow	Load vs. Flow Regress.	Monthly Conc. & Flow	Load vs. Flow Regress.	Monthly Conc. & Flow	Load vs. Flow Regress.	Monthly Conc. & Flow
1990	173,700	9	9	20	22	27	29	164	138
1991	111,400	6	6	13	17	15	13	110	98
1992	70,300	4	3	8	7	8	3	72	55
1993	109,400	5	4	12	14	21	28	98	116
1994	62,200	3	2	7	5	9	29	61	137
1995	87,000	4	3	10	14	18	28	78	131
1996	9,400	0	0	1	1	2	6	9	18
1997	26,000	1	1	3	2	8	8	20	36
1998	12,600	1	0	1	1	2	7	11	16
1999	1,700	0	0	0	0	0	0	1	1
2000	3,800	0	0	0	0	1	0	3	2
2001	183,400	9	5	21	15	31	7	168	88
2002	185,300	9	8	21	20	35	21	165	140
2003	154,800	8	6	18	13	27	8	141	91
2004	178,300	9	9	20	18	31	21	162	156
2005	41,000	2	2	5	6	5	9	41	58
Average	88,100	4	4	10	10	15	13	82	80

Monthly Concentrations and Flows: Under this method, Truckee Canal loads were calculating using monthly streamflow data collected by the USGS (Sta. 10351400 – Truckee Canal near Hazen, NV) and once-monthly water quality data for both the Truckee River at Derby Dam (as collected by TMWRF) and NDEP's Derby Canal site (at Highway 50). Monthly loads (tons) were estimated using the following equation:

$$Load = \frac{Concentration\ x\ Flow\ x\ 2.719}{2000} \qquad \text{[Eq. 1]}$$

Where:

Load = monthly OP, TP, Nitrate, TN load, in tons
Concentration = OP, TP, Nitrate, TN concentration for that month, in mg/l
Flow = Truckee Canal flow (Sta. 10351400) for that month, in acre-feet

When available for a given month, OP, TP, nitrate, TN concentrations for the NDEP site were assumed to be representative of the concentrations for that month. For those months without NDEP Truckee Canal data, Canal concentrations were assumed equal to those measured at the Truckee River at Derby Dam. Table 6 summarizes the results of these calculations. **It is recognized that this assumption does not account for any transformations that occur while the water is conveyed from the Truckee River to Lahontan Reservoir.** However, concurrent nutrient data do not exist upon which to base a different assumption. **Also, Gage 10351400 is located over 3 miles from Lahontan Reservoir so actual inflows may be less due to canal losses.**

Summary: Table 6 presents the estimated annual and 1990-2005 average loads from the Truckee Canal based upon 2 different methods. The load-flow regression and the monthly concentration-flow methods yielded very similar annual and average values for both the orthophosphate and the total phosphorus loads. For the nitrate+nitrite and total nitrogen loads, the 2 methods yielded somewhat different results depending upon the year. Nevertheless, the average annual loads were essentially the same.

Summary of Annual Load Estimates

Table 7 summarizes annual loads estimates developed by NDEP and others over the years. Some of these estimates were for particular years while others were averages for a set of years. Both Garcia and Carman (1985) and Cooper and Vigg (1983) provided annual average loads for a ten-year period (1971-80) prior to improvements to TMWRF and the elimination of direct discharge of effluent to the Carson River. Average annual loads developed for 1990-2005 indicate that nutrient loads have been significantly reduced following treatment improvements to TMWRF in the 1980s and the elimination of direct effluent discharges to the Carson River in 1987 (Table 8). Overall, total nitrogen and total phosphorus loads have decreased about 50 to 60%. The estimates show that the Truckee Canal loads experienced the largest decreases with 1990-2005 annual loads equal to about 15 – 25% of loads during the 1971-80 period. Some of this reduction was due to the decrease in average annual inflow from 151,000 to 88,000 acre-feet/year via the Truckee Canal. During the 1971-80 period, the Truckee Canal accounted for about 40% of the Lahontan Reservoir inflows. The Truckee Canal contributed about 25% of the total inflows during 1990-2005.

Table 7. Estimates of Annual Average Nutrient Loading to Lahontan Reservoir (tons/year)

	EPA (1977)	Garcia & Carman (1985)		Richard-Haggard (1982)	Cooper & Vigg (1983)			Cooper & Vigg (1984)	NDEP (this report)
	Avg. Year	WY 1980	WY 1971-80	Avg. Year	WY 1980	WY 1981	10 Year Mean (approx. 1971-80)	WY 1983	WY1990-2005
Carson River									
TN	616	670	340	---	603	230	361	617	192
NO3+NO2	---	100	---	---	---	---	---	---	22
TP	147	230	110	102.1	210	56	102**	310	74
DOP	---	57	---	44.2	---	---	---	---	28
Avg. Annual Flow (AF)	---	432,000	246,000	---	432,000	121,000	246,000	804,600	270,000
Truckee Canal									
TN	203	310	340*	---	271	390	336	21	80
NO3+NO2	---	140	---	---	---	---	---	---	13
TP	36	72	75*	67.3	59	65	67**	2.4	10
DOP	---	55	---	35.5		---	---	---	4
Avg. Annual Flow (AF)	---	127,000	151,000	---	127,000	133,000	151,000	30,000	88,000
Sediment Release									
TP	---	---	---	29.9	---	---	---	---	---
DOP	---	---	---	29.9	---	---	---	---	---
Bulk Precipitation									
TN	24	---	---	---	11	7.0	8.4	12	---
TP	<1	---	---	2.6	2.8	2.6	2.6**	3	---
DOP	---	---	---	Unknown	---	---	---	---	---
Other Sources									
TN	117***	---		---	4.5	4.5	4.5	4.5	---
TP	28***	---	---	0.2	0.2	0.2	0.2**	0.2	---
DOP	---	---	---	Negligible	---	---	---	---	---
Total									
TN	960	980	680	---	889	632	710	654	272
NO3+NO2	---	240	---	---	---	---	---	---	35
TP	211	300	180	202.1	272	124	172	315	84
DOP	---	110	---	109.6	---	---	---	---	32
Avg. Annual Flow (AF)	---	559,000	397,000	---	559,000	254,000	397,000	834,600	358,000

* Truckee Canal estimates were based only upon 2 years of data - WY 1975 and 1980 data
** From Richard-Haggard (1982)
*** Contributions from the watershed surrounding Lahontan Reservoir were estimated by assuming that the tons per square mile for the Carson River watershed applied to the immediate watershed surrounding Lahontan Reservoir. This is believed to be a gross overestimation of these local loads.

Table 8. Comparison of Average Annual Load Estimates for Periods 1971-80 and 1990-2005 (tons/year)

	Garcia and Carman (1985); Cooper and Vigg (1983)	NDEP (this report)	% Change
	1971-1980	**1990-2005**	
Carson River			
TN	340 – 361	192	-44 to -47
TP	102 – 110	74	-27 to -33
Avg. Flow (AF)	246,000	270,000	+10
Truckee Canal			
TN	336 – 340	80	-74 to -76
TP	67 – 75	10	-85 to -87
Avg. Flow	151,000	88,000	-42
Total			
TN	680 – 710	272	-60 to -62
TP	172 – 180	84	-51 to -53
Avg. Flow	397,000	358,000	-10

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