California Regional Water Quality Control Board
Lahontan Region

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Governor

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SUMMARY OF FECAL COLIFORM STATISTICS ON MEISS GRAZING ALLOTMENT--1999 AND 2000 SEASONS AND RECOMMENDATIONS FOR 2001 SEASON

BACKGROUND

Thank you for the recent submittal of information on fecal coliform monitoring at the LTBMU Meiss Grazing allotment. Regional Board staff have reviewed the "Meiss Grazing Allotment Water Quality 2000 Report" and the proposed 2001 grazing strategy for the Meiss allotment. Staff did not re-evaluate pre-1999 data since this data was evaluated in the Regional Board's August 25, 1999 Notice of Violation and LTBMU narrative concurs that the data shows violations of fecal coliform water quality objectives were associated with the onset of grazing during these years. We have re-evaluated monitoring data from 1999 and 2000 grazing seasons, and have prepared some summary figures and tables to illustrate water quality trends with respect to violations of numerical water quality objectives of the Water Quality Control Plan for the Lahontan Region (1995) which states:

"The fecal coliform concentration during any 30-day period shall not exceed a log mean of 20/100 ml, nor shall more than 10 percent of all samples collected during any 30-day period exceed 40/100 ml."

There was a misunderstanding of these criteria in the LTBMU Report, which gave absolute values exceeding 20 colonies/100 ml as a violation rather than the correct 30-day log normalized value. Lumping of up-, mid-, and down-stream samples does not provide the best representation of background fecal coliform or of potential grazing impacts, so each sample site was treated separately. All data and calculations of violations are given in Appendix 1.

<u>Comparisons of Data and Violations with and without Livestock</u>

Figures 1-6 show the 30-day log normalized data with time by station, comparing grazing (1999) with no grazing (2000). Figure 1 (BM-1 - Big Meadows downstream station) illustrates the nearly 10-fold increase in fecal coliform during the grazing season. The 30-day log mean 20 standard was violated four times during July 16-October 1, 2000 (non-grazed) indicating the level of non-grazing impacts (horses, hikers, campers, dogs, wildlife, etc.) for that year. Figure 2 (BM-2) shows consistent violations with grazing and no violations without grazing. Figure 3 (BM-3, upstream) shows for the grazing period of July 16 through October 1, four out of six data in violation with grazing and two out of ten data in violation without grazing.

The Dardanelles (Meiss) grazing allotment showed violations of the log mean 20 standard in the late grazing season when livestock were present for only the M-2 (Figure 5) and M-3 (Figure 6) sites. No violations were found on M-1 (Figure 4) for either year.

Table 1 is in response to LTBMU Figure 8, using the correct absolute value of 40 colonies/100 ml for violations. Rather than lump the data for all stations, down-, mid- and up-stream samples were analyzed separately. Table 1.a. gives the number of violations by station, year, and period (pre-graze vs. grazed). Table 1.b. gives the corresponding percentage exceeding the > 40 colonies/100 ml standard. The Big Meadows 2000 pre-graze period (early summer) was unusual for violations as compared to prior years when no violations were measured. However, during the grazing period of July 16-October 1, 1999 samples with livestock present had violations from 50-70% of the time, whereas the corresponding 2000 season period had only 0-9% violations without livestock present.

There were no pre-graze period violations at Dardanelles. Results for the grazing period ranged from 0-31% (average of 20%) grazed and 0-18% (average of 6%) not grazed.

<u>Evaluation of Violations and Strategies for the 2001 Season</u>

Table 2 gives the average fecal coliform value and the corresponding 95% confidence interval for the 2000 (no livestock present) grazing period data on the Big Meadows allotment. In no cases, did the average plus the confidence interval exceed 40. Figure 3 likewise gives the average fecal coliform value and the corresponding 95% confidence interval for the 2000 (no livestock present) grazing period data on the Dardanelles allotment. The average plus confidence interval for station M-1 is 41, a minor amount above the standard, but above it nonetheless. The sum of average and confidence intervals for Stations M-2 and M-3 are well below 40.

These data suggest that the 40 colonies /100 ml standard is an appropriate standard that is achievable, but that the possibility of recording spurious data above 40 exists in some instances. The LTBMU proposed 2001 grazing strategy is for the most part appropriate. It states that:

"If fecal coliform levels exceed the state standard between July 16 and August 6 for two or more samples before the on-date, there will be no livestock use for the season."

Since it is apparent from the data that more violations of the Regional Board's fecal coliform water quality objective occur and higher numbers of fecal coliform are detected during grazing activities, we support your decision to either significantly limit or eliminate grazing to meet the Regional Board's fecal coliform water quality objective. If you decide to allow limited grazing in 2001, we recommend increased herding as a requirement and removal of cattle if two or more samples exceed the Regional Board standard after grazing has commenced (given the uncertainties associated with variable data in the 2000 samples).

Recreation Strategy and Continued Monitoring

The data indicates violations of Regional Board fecal coliform water quality objectives during periods when no grazing occurs. We are concerned that recreational use contributes to these violations. Regardless of whether grazing occurs in 2001, we request the LTBMU continue fecal coliform monitoring at the same level as 2000.

Further, we request the LTBMU submit a recreation strategy to reduce discharges that may contribute to fecal coliform contamination. We suggest an aggressive education campaign coupled with increased compliance assurance activities (monitoring, surveillance, enforcement), focused on proper human waste disposal and animal waste disposal (e.g. leashing, bagging waste, etc.). Please submit a Recreation Plan to prevent fecal coliform contamination from human activities by **April 1, 2001**.

Should you have any questions, please contact Dr. Bruce Warden, Environmental Specialist III at (530) 542-5416 or me at (530) 542-5436.

Sincerely,

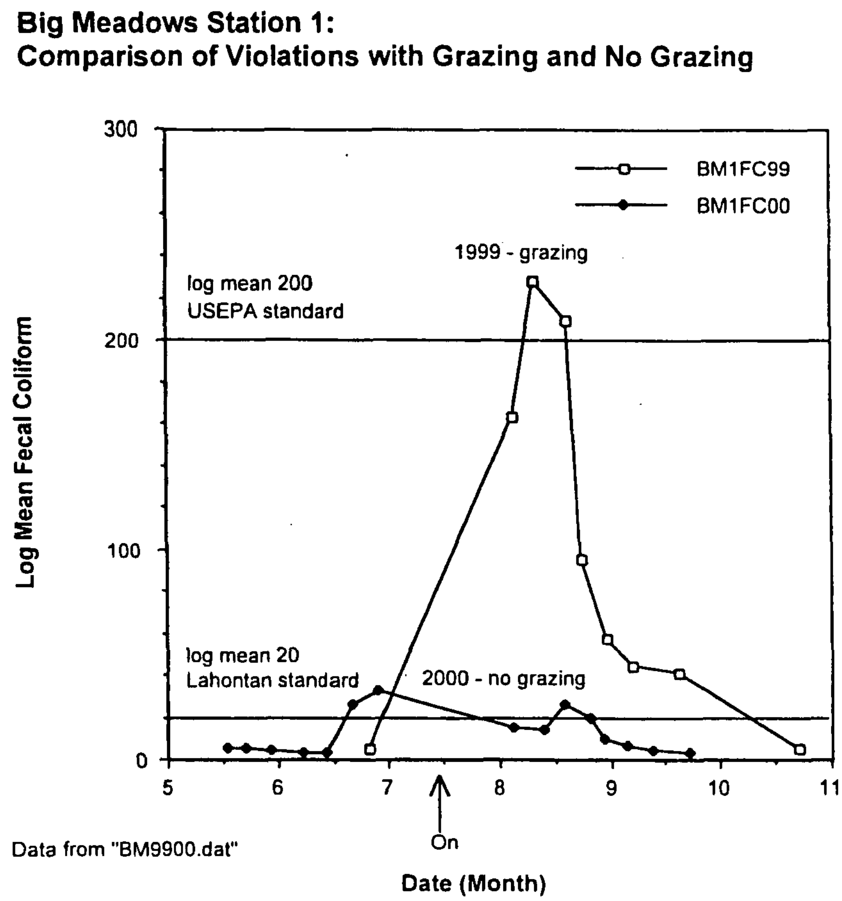
Lauri Kemper
Chief, Lake Tahoe Watershed Unit

Attachments: Appendix 1: Meiss Grazing Allotment Data and Violations for 1999 and 2000 Seasons

cc: League to Save Lake Tahoe/Dave Roberts

BW/shT:LTBMU.Fecal.Stats.99-00

Figure 1:



Big Meadows Station 1:
Comparison of Violations with Grazing and No Grazing
BM1FC99
BM1FC00
1999 - grazing
log mean 200
USEPA standard
log mean 20
Lahontan standard
2000 - no grazing
Log Mean Fecal Coliform
300
200
100
0
5
6
7
8
9
10
11
On
Data from "BM9900.dat"
Date (Month)

Figure 2:

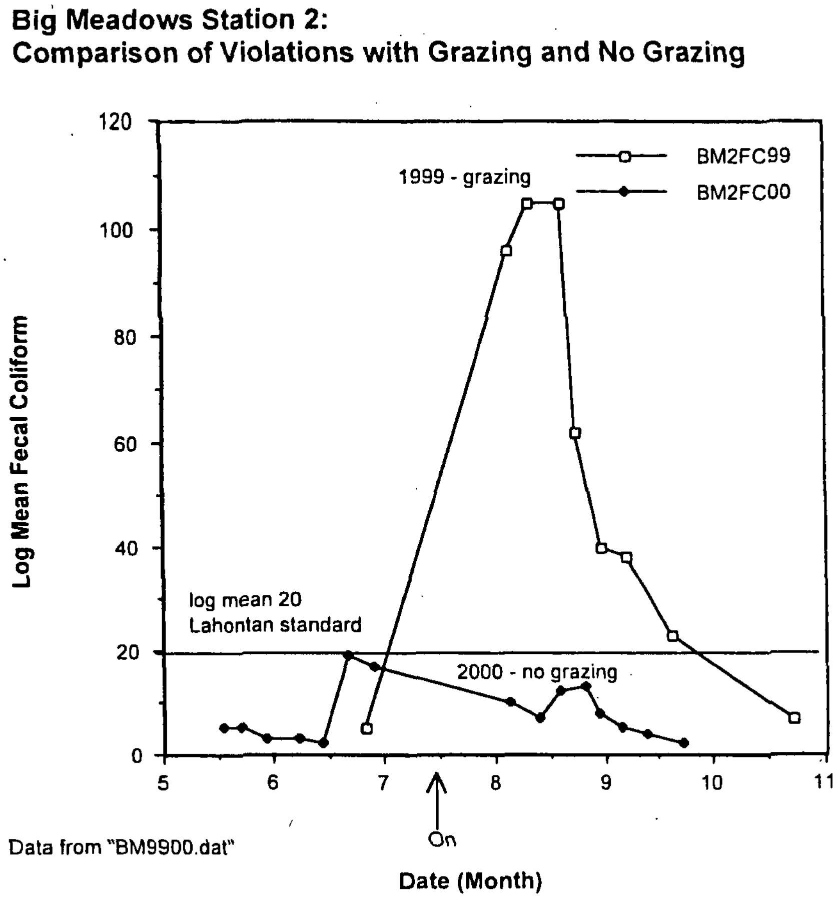

Big Meadows Station 2:
Comparison of Violations with Grazing and No Grazing
BM2FC99
BM2FC00
1999 - grazing
2000 - no grazing
log mean 20
Lahontan standard
120
100
80
60
40
20
0
5
6
7
8
9
10
11
Log Mean Fecal Coliform
On
Data from "BM9900.dat"
Date (Month)

Figure 3:

Big Meadows Station 3:
Comparison of Violations with Grazing and No Grazing

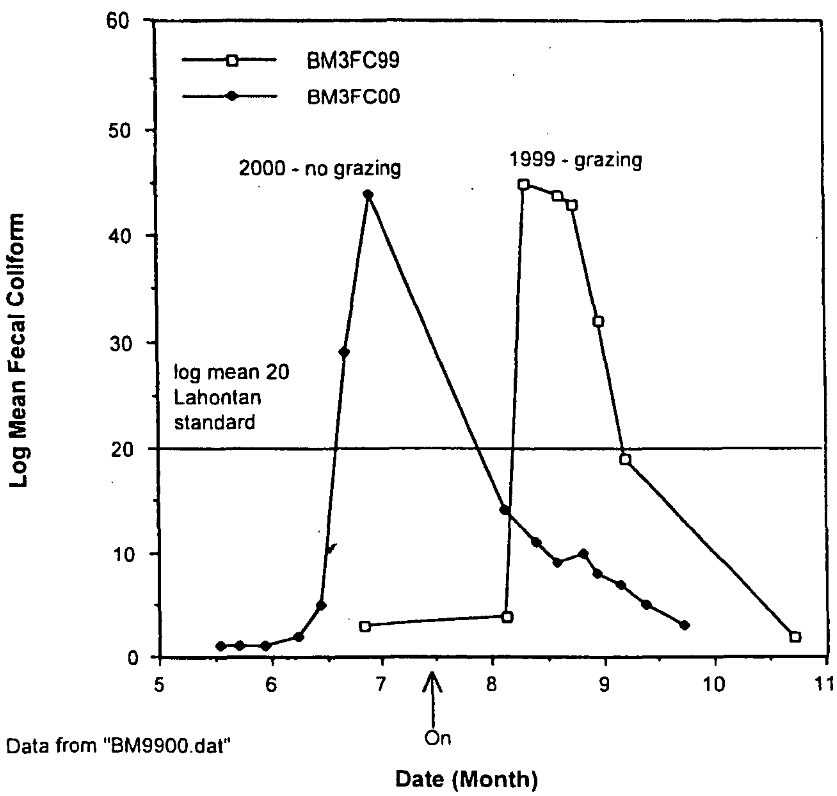


Figure 4:

Dardanelles Station 1:
Comparison of Violations with Grazing and No Grazing

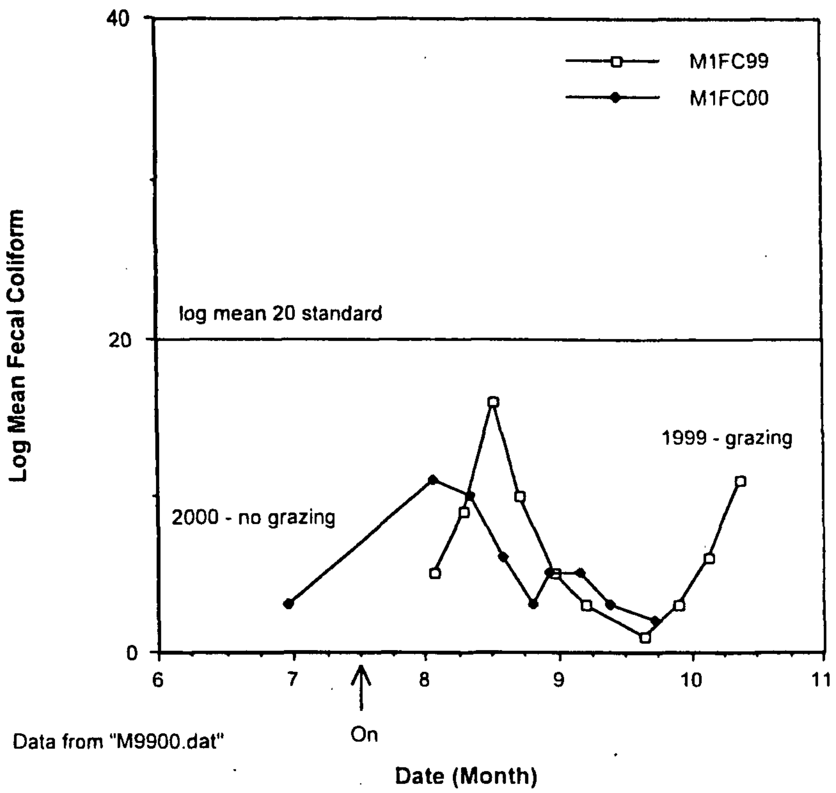
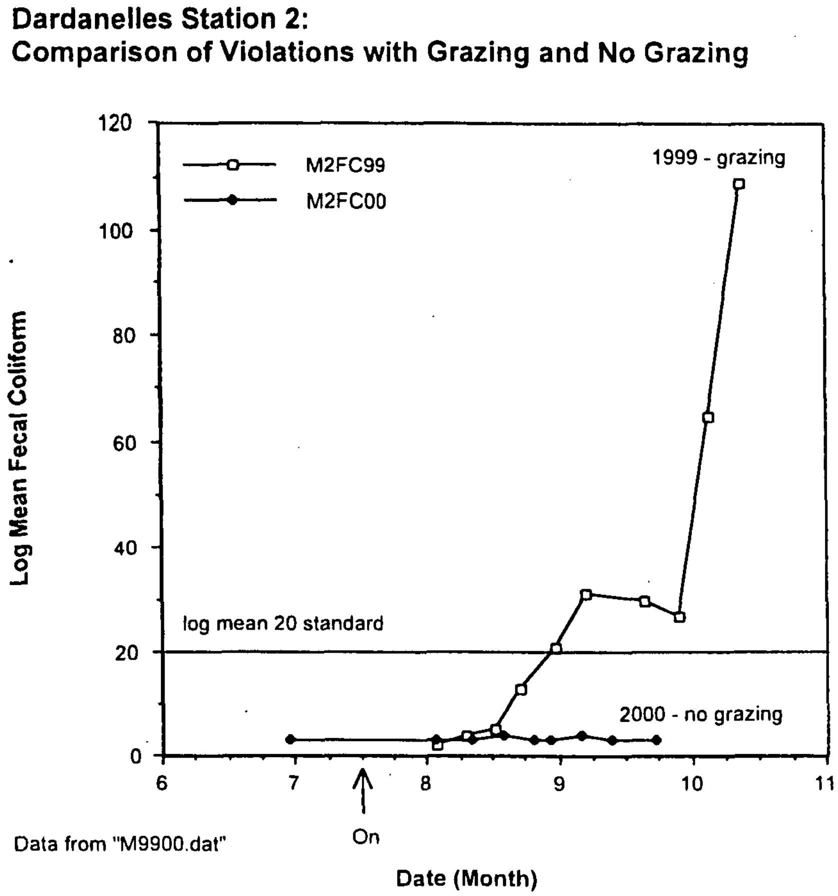
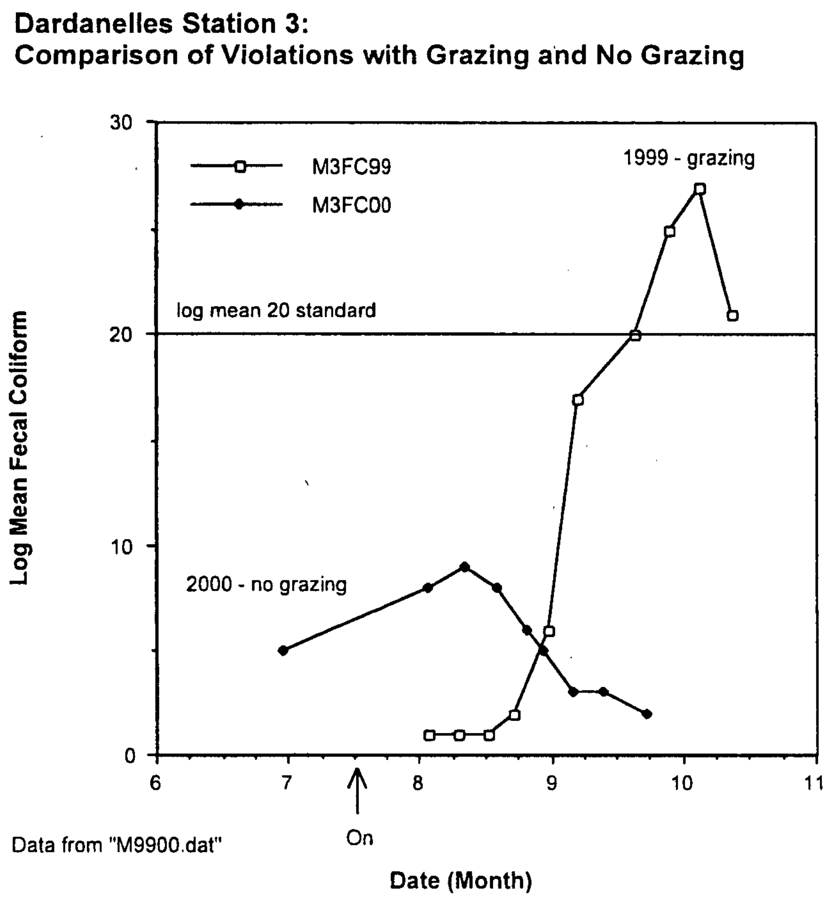


Figure 5:



Dardanelles Station 2:
Comparison of Violations with Grazing and No Grazing
120
100
80
60
40
20
0
M2FC99
M2FC00
1999 - grazing
log mean 20 standard
2000 - no grazing
Log Mean Fecal Coliform
6
7
8
9
10
11
On
Data from "M9900.dat"
Date (Month)

Figure 6:



Dardanelles Station 3:
Comparison of Violations with Grazing and No Grazing
30
20
10
0
6
7
8
9
10
11
M3FC99
M3FC00
1999 - grazing
log mean 20 standard
2000 - no grazing
Log Mean Fecal Coliform
On
Data from "M9900.dat"
Date (Month)

Table 1: Meiss Allotment Grazing 1999-2000 Comparisons*

a. Number of Values Exceeding 40 CFU/100 ml in > 10% of Samples over a 30 day period.

	Pre-Graze Period		Grazing Period	
Station	1999	2000	1999	2000
BM-1	0	3	7	1
BM-2	0	2	5	0
BM-3	0	2	5	0
N = # of samples / station	10	10	10	11
M-1	0	0	0	2
M-2	0	0	4	0
M-3	0	0	4	0
N = # of samples / station	2	4	13	11

N = number of samples events for each station.

b. Percent of Samples Exceeding >40 Standard.

	Pre-Graze Period		Grazing Period	
Station	1999	2000	1999	2000
BM-1	0%	30%	70%	9%
BM-2	0%	20%	50%	0%
BM-3	0%	20%	50%	0%
M-1	0%	0%	0%	18%
M-2	0%	0%	31%	0%
M-3	0%	0%	31%	0%

* Note 1999 season had grazing during the grazing period;
2000 season had no grazing during that same period.

Table 2: USFS LTBMU 2000 Grazing Period - Fecal Coliform Data
Big Meadows

Station[1]	Sample Date	Fecal Colif.	Confidence Int. (95%)
BM1	7/20/00	34	
BM1	7/28/00	1	
BM1	8/3/00	41	
BM1	8/10/00	23	
BM1	8/15/00	26	
BM1	8/21/00	25	
BM1	8/28/00	21	
BM1	9/7/00	9	
BM1	9/11/00	1	
BM1	9/18/00	5	
BM1	9/25/00	1	
Average		17	8
BM2	7/20/00	36	
BM2	7/28/00	1	
BM2	8/3/00	17	
BM2	8/10/00	20	
BM2	8/15/00	7	
BM2	8/21/00	5	
BM2	8/28/00	20	
BM2	9/7/00	22	
BM2	9/11/00	2	
BM2	9/18/00	1	
BM2	9/25/00	1	
Average		12	7
BM3	7/20/00	31	
BM3	7/28/00	11	
BM3	8/3/00	19	
BM3	8/10/00	16	
BM3	8/15/00	6	
BM3	8/21/00	8	
BM3	8/28/00	5	
BM3	9/7/00	28	
BM3	9/11/00	5	
BM3	9/18/00	3	
BM3	9/25/00	0	
Average		12	6
Overall Statistics		**14**	**7**

1 BM = Big Meadows.
Stations numbered consecutively downstream-to-upstream.

Table 3: USFS LTBMU 2000 Grazing Period - Fecal Coliform Data
Dardenelles (Meiss)

Station[1]	Sample Date	Fecal Colif.	Confidence Int. (95%)
M1	7/18/00	22	
M1	7/27/00	97	
M1	8/3/00	77	
M1	8/10/00	1	
M1	8/15/00	1	
M1	8/21/00	14	
M1	8/28/00	5	
M1	9/7/00	2	
M1	9/11/00	16	
M1	9/18/00	1	
M1	9/25/00	0	
Average		21	20
M2	7/18/00	5	
M2	7/27/00	4	
M2	8/3/00	5	
M2	8/10/00	1	
M2	8/15/00	2	
M2	8/21/00	4	
M2	8/28/00	14	
M2	9/7/00	4	
M2	9/11/00	1	
M2	9/18/00	7	
M2	9/25/00	0	
Average		4	2
M3	7/18/00	0	
M3	7/27/00	32	
M3	8/3/00	31	
M3	8/10/00	2	
M3	8/15/00	13	
M3	8/21/00	3	
M3	8/28/00	10	
M3	9/7/00	11	
M3	9/11/00	0	
M3	9/18/00	1	
M3	9/25/00	0	
Average		9	7
Overall Statistics		**12**	**10**

1 M = Dardanelles (Meiss).
Stations numbered consecutively downstream-to-upstream.

APPENDIX 1: : Meiss Grazing Allotment Data and Violations for 1999 and 2000 Seasons

USFS LTBMU 1999 Season - Fecal Coliform Data
Big Meadows

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
BM1	6/26/99		0	1E-07		^
BM1	7/3/99		4	1.38629		|
BM1	7/6/99		18	2.89037		|
BM1	7/8/99		7	1.94591		|
BM1	7/10/99	06/11/99	9	2.19722	**5**	pregraze
BM1	7/20/99	08/18/99	6	1.79176	**164**	graze: violations >log mean 20
BM1	7/26/99	08/24/99	**328**	5.79301	**229**	graze: violations >log mean 20; >40
BM1	8/4/99	09/02/99	**872**	6.77079	**210**	graze: violations >log mean 20; >40
BM1	8/8/99	09/06/99	**420**	6.04025	**95**	graze: violations >log mean 20; >40
BM1	8/16/99	09/14/99	**85**	4.44265	**57**	graze: violations >log mean 20; >40
BM1	8/22/99	09/20/99	**62**	4.12713	**44**	graze: violations >log mean 20; >40
BM1	9/4/99	10/03/99	37	3.61092	**41**	
BM1	9/11/99	10/10/99	**55**	4.00733		
BM1	9/19/99	10/18/99	29	3.3673		
BM1	9/25/99	10/24/99	**49**	3.89182		
BM1	10/9/99		4	1.38629		^
BM1	10/16/99		1	0		|
BM1	10/18/99		14	2.63906		|
BM1	10/30/99		17	2.83321		|
BM1	11/6/99	10/08/99	5	1.60944	**5**	postgraze
BM2	6/26/99		3	1.09861		^
BM2	7/3/99		1	0		|
BM2	7/6/99		22	3.09104		|
BM2	7/8/99		10	2.30259		|
BM2	7/10/99	06/11/99	6	1.79176	**5**	pregraze
BM2	7/20/99	08/18/99	11	2.3979	**96**	graze: violations >log mean 20
BM2	7/26/99	08/24/99	**107**	4.67283	**105**	graze: violations >log mean 20; >40
BM2	8/4/99	09/02/99	**259**	5.55683	**105**	graze: violations >log mean 20; >40
BM2	8/8/99	09/06/99	**282**	5.64191	**62**	graze: violations >log mean 20; >40
BM2	8/16/99	09/14/99	**41**	3.71357	**40**	graze: violations >log mean 20; >40
BM2	8/22/99	09/20/99	40	3.68888	**38**	graze: violations >log mean 20
BM2	9/4/99	10/03/99	31	3.43399	**23**	graze: violations >log mean 20
BM2	9/11/99	10/10/99	**52**	3.95124		graze: violations >40
BM2	9/19/99	10/18/99	33	3.49651		
BM2	9/25/99	10/24/99	5	1.60944		
BM2	10/9/99		7	1.94591		^
BM2	10/16/99		10	2.30259		|
BM2	10/18/99		6	1.79176		|
BM2	10/30/99		11	2.3979		|
BM2	11/6/99	10/08/99	4	1.38629	**7**	postgraze
BM3	6/26/99		0	1E-07		^
BM3	7/3/99		11	2.3979		|
BM3	7/6/99		4	1.38629		|
BM3	7/8/99		4	1.38629		|
BM3	7/10/99	06/11/99	0	1E-07	**3**	pregraze
BM3	7/20/99	08/18/99	10	2.30259	**4**	graze
BM3	7/26/99	08/24/99	29	3.3673	**45**	graze: violations >log mean 20
BM3	8/4/99	09/02/99	**52**	3.95124	**44**	graze: violations >log mean 20; >40

USFS LTBMU 1999 Season - Fecal Coliform Data
Big Meadows

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
BM3	8/8/99	09/06/99	**50**	3.91202	**43**	graze: violations >log mean 20; >40
BM3	8/16/99	09/14/99	**56**	4.02535	**32**	graze: violations >log mean 20; >40
BM3	8/22/99	09/20/99	**42**	3.73767	**19**	graze: violations >40
BM3	9/4/99		28	3.3322		
BM3	9/11/99		15	2.70805		
BM3	9/19/99		7	1.94591		
BM3	9/25/99		**189**	5.24175		graze: violation >40
BM3	10/9/99		17	2.83321		^
BM3	10/16/99		1	0		|
BM3	10/18/99		0	1E-07		|
BM3	10/30/99		0	1E-07		|
BM3	11/6/99	10/08/99	2	0.69315	**2**	postgraze

1 USFS Allotments: B = Baldwin; BM = Big Meadows; M = Meiss. Stations numbered consecutively downstream-to-upstream.

2 The fecal coliform concentration during any 30-day period shall not exceed a log mean of 20/100 ml, nor shall more than 10 percent of all samples collected during any 30-day period exceed 40/100 ml.

USFS LTBMU 1999 Season - Fecal Coliform Data
Dardenelles (Meiss)

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
M1	7/12/99		0	1E-07		pregraze
M1	7/18/99	08/16/99	1	0	**5**	graze
M1	7/25/99	08/23/99	0	1E-07	**9**	
M1	8/1/99	08/30/99	13	2.56495	**16**	
M1	8/7/99	09/05/99	26	3.2581	**10**	
M1	8/16/99	09/14/99	10	2.30259	**5**	
M1	8/22/99	09/20/99	18	2.89037	**3**	
M1	9/4/99	10/03/99	2	0.69315	**1**	
M1	9/12/99	10/11/99	2	0.69315	**3**	
M1	9/19/99	10/18/99	1	0	**6**	
M1	9/26/99	10/25/99	1	0	**11**	
M1	10/10/99		29	3.3673		
M1	10/17/99		40	3.68888		
M1	10/31/99		15	2.70805		cows not gone till 10/31
M1	11/6/99		1	0		
M2	7/12/99		0	1E-07		pregraze
M2	7/18/99	08/16/99	1	0	**2**	graze
M2	7/25/99	08/23/99	2	0.69315	**4**	
M2	8/1/99	08/30/99	2	0.69315	**5**	
M2	8/7/99	09/05/99	4	1.38629	**13**	
M2	8/16/99	09/14/99	3	1.09861	**21**	graze: violations >log mean 20
M2	8/22/99	09/20/99	25	3.21888	**31**	graze: violations >log mean 20
M2	9/4/99	10/03/99	**92**	4.52179	**30**	graze: violations >log mean 20; >40
M2	9/12/99	10/11/99	27	3.29584	**27**	graze: violations >log mean 20
M2	9/19/99	10/18/99	14	2.63906	**65**	graze: violations >log mean 20
M2	9/26/99	10/25/99	22	3.09104	**109**	graze: violations >log mean 20
M2	10/10/99		**67**	4.20469		graze: violations >40
M2	10/17/99		**871**	6.76964		graze: violations >40
M2	10/31/99		**67**	4.20469		graze: violations >40
M2	11/6/99		11	2.3979		

USFS LTBMU 1999 Season - Fecal Coliform Data
Dardenelles (Meiss)

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
M3	7/12/99		1	0		pregraze
M3	7/18/99	08/16/99	1	0	**1**	graze
M3	7/25/99	08/23/99	0	1E-07	**1**	
M3	8/1/99	08/30/99	1	0	**1**	
M3	8/7/99	09/05/99	0	1E-07	**2**	
M3	8/16/99	09/14/99	1	0	**6**	
M3	8/22/99	09/20/99	4	1.38629	**17**	
M3	9/4/99	10/03/99	6	1.79176	**20**	
M3	9/12/99	10/11/99	**60**	4.09434	**25**	graze: violations >log mean 20; >40
M3	9/19/99	10/18/99	**58**	4.06044	**27**	graze: violations >log mean 20; >40
M3	9/26/99	10/25/99	7	1.94591	**21**	graze: violations >log mean 20
M3	10/10/99		15	2.70805		
M3	10/17/99		**83**	4.41884		graze: violations >40
M3	10/31/99		**78**	4.35671		graze: violations >40
M3	11/6/99		16	2.77259		

1 USFS Allotments: B = Baldwin; BM = Big Meadows; M = Meiss. Stations numbered consecutively downstream-to-upstream.

2 The fecal coliform concentration during any 30-day period shall not exceed a log mean of 20/100 ml, nor shall more than 10 percent of all samples collected during any 30-day period exceed 40/100 ml.

USFS LTBMU 2000 Season - Fecal Coliform Data
Big Meadows

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
BM1	5/4/00		0	1E-07		
BM1	5/13/00		**93**	4.5326		pregraze violation > 40
BM1	6/1/00	05/03/00	0	1E-07	**5**	
BM1	6/6/00	05/08/00	0	1E-07	**5**	
BM1	6/13/00	05/15/00	2	0.6931	**4**	
BM1	6/22/00	05/24/00	20	2.9957	**3**	
BM1	6/29/00	05/31/00	6	1.7918	**3**	
BM1	7/6/00	06/07/00	33	3.4965	**9**	pregraze violation > log mean 20
BM1	7/13/00	06/14/00	**280**	5.6348	**32**	pregraze violation > log mean 20; >40
BM1	7/20/00	08/18/00	34	3.5264	**15**	
BM1	7/28/00	08/26/00	1	0	**14**	
BM1	8/3/00	09/01/00	**41**	3.7136	**26**	nograze violation > log mean 20; >40
BM1	8/10/00	09/08/00	23	3.1355	**20**	
BM1	8/15/00	09/13/00	26	3.2581	**10**	
BM1	8/21/00	09/19/00	25	3.2189	**7**	
BM1	8/28/00	09/26/00	21	3.0445	**4**	
BM1	9/7/00	10/06/00	9	2.1972	**3**	
BM1	9/11/00		1	0		
BM1	9/18/00		5	1.6094		
BM1	9/25/00		1	0		
BM1	10/2/00		3	1.0986		
BM2	5/4/00		3	1.0986		
BM2	5/13/00		**49**	3.8918		pregraze violation >40
BM2	6/1/00	05/03/00	0	1E-07	**5**	
BM2	6/6/00	05/08/00	3	1.0986	**5**	
BM2	6/13/00	05/15/00	1	0	**3**	
BM2	6/22/00	05/24/00	22	3.091	**3**	
BM2	6/29/00	05/31/00	0	1E-07	**2**	
BM2	7/6/00	06/07/00	37	3.6109	**5**	
BM2	7/13/00	06/14/00	**96**	4.5643	**17**	pregraze violation >40
BM2	7/20/00	08/18/00	36	3.5835	**10**	
BM2	7/28/00	08/26/00	1	0	**7**	
BM2	8/3/00	09/01/00	17	2.8332	**12**	
BM2	8/10/00	09/08/00	20	2.9957	**13**	
BM2	8/15/00	09/13/00	7	1.9459	**8**	
BM2	8/21/00	09/19/00	5	1.6094	**5**	
BM2	8/28/00	09/26/00	20	2.9957	**4**	
BM2	9/7/00	10/06/00	22	3.091	**2**	
BM2	9/11/00		2	0.6931		
BM2	9/18/00		1	0		
BM2	9/25/00		1	0		
BM2	10/2/00		1	0		
BM3	5/4/00		1	0		
BM3	5/13/00		0	1E-07		
BM3	6/1/00	05/03/00	0	1E-07	**1**	
BM3	6/6/00	05/08/00	2	0.6931	**1**	
BM3	6/13/00	05/15/00	0	1E-07	**1**	
BM3	6/22/00	05/24/00	6	1.7918	**2**	

USFS LTBMU 2000 Season - Fecal Coliform Data
Big Meadows

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
BM3	6/29/00	05/31/00	**210**	5.3471	**5**	pregraze violation >40
BM3	7/6/00	06/07/00	**94**	4.5433	**12**	pregraze violation > log mean 20; >40
BM3	7/13/00	06/14/00	33	3.4965	**44**	pregraze violation > log mean 20
BM3	7/20/00	08/18/00	31	3.434	**14**	
BM3	7/28/00	08/26/00	11	2.3979	**11**	
BM3	8/3/00	09/01/00	19	2.9444	**9**	
BM3	8/10/00	09/08/00	16	2.7726	**10**	
BM3	8/15/00	09/13/00	6	1.7918	**8**	
BM3	8/21/00	09/19/00	8	2.0794	**7**	
BM3	8/28/00	09/26/00	5	1.6094	**5**	
BM3	9/7/00	10/06/00	28	3.3322	**3**	
BM3	9/11/00		5	1.6094		
BM3	9/18/00		3	1.0986		
BM3	9/25/00		0	1E-07		
BM3	10/2/00		0	1E-07		

1 USFS Allotments: B = Baldwin; BM = Big Meadows; M = Meiss; T = Trout Creek. Stations numbered consecutively downstream-to-upstream.

2 The fecal coliform concentration during any 30-day period shall not exceed a log mean of 20/100 ml, nor shall more than 10 percent of all samples collected during any 30-day period exceed 40/100 ml.

USFS LTBMU 2000 Season - Fecal Coliform Data
Dardenelles (Meiss)

	FROM	30-Days To	#/100 mL		30 -day	
Station[1]	Sample Date	Date (inclusive)	Fecal Colif.	log FC	log mean	NOTES[2]
M1	6/20/00		0	1E-07		
M1	6/30/00		5	1.60944		
M1	7/14/00	06/15/00	6	1.79176	**3**	
M1	7/18/00	08/16/00	22	3.09104	**11**	
M1	7/27/00	08/25/00	**97**	4.57471	**10**	nograze violation > 40
M1	8/3/00	09/01/00	**77**	4.34381	**6**	nograze violation > 40
M1	8/10/00	09/08/00	1	0	**3**	
M1	8/15/00	09/13/00	1	0	**5**	
M1	8/21/00	09/19/00	14	2.63906	**5**	
M1	8/28/00	09/26/00	5	1.60944	**3**	
M1	9/7/00	10/06/00	2	0.69315	**2**	
M1	9/11/00		16	2.77259		
M1	9/18/00		1	0		
M1	9/25/00		0	1E-07		
M1	10/2/00		0	1E-07		
M2	6/20/00	07/19/00	1	0		
M2	6/30/00	07/29/00	7	1.94591		
M2	7/14/00	08/12/00	0	1E-07	**3**	
M2	7/18/00	08/16/00	5	1.60944	**3**	
M2	7/27/00	08/25/00	4	1.38629	**3**	
M2	8/3/00	09/01/00	5	1.60944	**4**	
M2	8/10/00	09/08/00	1	0	**3**	
M2	8/15/00	09/13/00	2	0.69315	**3**	
M2	8/21/00	09/19/00	4	1.38629	**4**	
M2	8/28/00	09/26/00	14	2.63906	**3**	
M2	9/7/00	10/06/00	4	1.38629	**3**	
M2	9/11/00		1	0		
M2	9/18/00		7	1.94591		
M2	9/25/00		0	1E-07		
M2	10/2/00		7	1.94591		

USFS LTBMU 2000 Season - Fecal Coliform Data
Dardenelles (Meiss)

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
M3	6/20/00	07/19/00	0	1E-07		
M3	6/30/00	07/29/00	1	0		
M3	7/14/00	08/12/00	0	1E-07	5	
M3	7/18/00	08/16/00	0	1E-07	8	
M3	7/27/00	08/25/00	32	3.46574	9	
M3	8/3/00	09/01/00	31	3.43399	8	
M3	8/10/00	09/08/00	2	0.69315	6	
M3	8/15/00	09/13/00	13	2.56495	5	
M3	8/21/00	09/19/00	3	1.09861	3	
M3	8/28/00	09/26/00	10	2.30259	3	
M3	9/7/00	10/06/00	11	2.3979	2	
M3	9/11/00		0	1E-07		
M3	9/18/00		1	0		
M3	9/25/00		0	1E-07		
M3	10/2/00		0	1E-07		

1 USFS Allotments: B = Baldwin; BM = Big Meadows; M = Meiss; T = Trout Creek. Stations numbered consecutively downstream-to-upstream.

2 The fecal coliform concentration during any 30-day period shall not exceed a log mean of 20/100 ml, nor shall more than 10 percent of all samples collected during any 30-day period exceed 40/100 ml.

From: "Jeff Reiner/R5/USDAFS" <jreiner@fs.fed.us>
To: <bwarden@rb6s.swrcb.ca.gov>, <bwarden@rb6s.swrcb.ca.gov>
Date: 1/7/02 2:37PM
Subject: data

Bruce, here is the 01 data. I keep getting too busy, and I forget.

(See attached file: 01_fecal_data.xls)

Jeff Reiner
Watershed and Fisheries Program Leader
Lake Tahoe Basin
530-5732624
jreiner@fs.fed.us

Sample Date		M1	M1a	M2	M3	BM1	BM2	BM3	B1	B2	Control
5/30/01		4		0	0	1	0	0			0
6/7/01		7		0	0	0	0	0	42	1	0
6/13/01		0		1	0	0	0	1	14	4	0
6/20/01		1		0	1	0	0	0	33	8	0
6/25/01		0		1	0	0	0	3	33	32	0
7/5/01		36		2	3	6	3	30	79	264	0
7/10/01		36		1	14	4	6	26	7	219	0
7/16/01	These samples incubated for 72 hours! - resampled on 7/20										
7/20/01		7		3	11	11	13	44	96	44	0
7/26/01		2		0	2	27	5	20	41	19	0
7/31/01						12	19	13	42	31	0
8/1/01		1		1	32						0
8/8/01		1		1	2	268	47	23	83	17	0
8/15/01		0		2	4	110	8	6	75	29	0
8/15/01	duplicates			8		70					0
8/23/01		3		4	46	17	5	4	80	9	0
8/23/01	duplicates								108	4	0
8/28/01		0		8	2	1	1	47	77	19	0
9/5/01		0	90	13	9	dry	183	3			0
9/5/01	duplicates	1	93	7				1			0
9/6/01									42	1	0
9/6/01	duplicates									15	0
9/11/01		0	16	6	159	4	89	2	25	2	0
9/11/01	duplicates		14						23		
9/19/01		1	27	37	109	46	17	0	38	6	0
9/19/01	duplicates		58		113						
9/25/01		5	2	3	20	2	2	8	5	34	0
9/25/01	duplicates			5	0						
10/2/01		5	1	0	0	1	1	2	0	1	0
10/2/01	possible incubator malfunction - temperature too high										
10/9/01		0	16	1	11	6	0	3	43	0	0
10/16/01		1	0	5	4	0	2	0	66	8	0
10/16/01	duplicates			2					78		
10/23/01		6	4	1	88	2	0	0	61	5	0
10/23/01	duplicates						1		71		
10/23/01	last sample day of year 2001										

From: Bruce Warden
To: Unsicker, Judith
Date: 11/5/01 2:16PM
Subject: Re: Fecal Coliform listings

Since the USFS is assessing only the Cascade Stables horse grazing impacts on Tallac creek, they have only the two sampling locations on Tallac Creek bounding what they call the Baldwin allotment north of Hwy 89.

>>> Judith Unsicker 11/05/01 02:07PM >>>
Thanks for the information. Does the Forest Service have upstream stations on Tallac Creek? From eyeballing a map, it appears that this is the creek that parallels the Mt.Tallac trail (and therefore gets a lot of hiker,dog and perhaps pack animal use), and that it also runs through the Spring Creek summer home tract.

>>> Bruce Warden 11/05/01 01:52PM >>>
Based on years of data, the following surface water segments can be listed for fecal coliform, based on violations of our Basin Plan water quality objectives:

Upper Truckee River above Round Lake (USFS stn M-3) to Christmas Valley at Hawley Grade Lahontan stn 1), segment approximately 6 miles.

Big Meadows Creek (tributary to Upper Truckee River) from above upper Big Meadows (USFS stn BM-3) to just below USFS footbridge at lower Big Meadows (USFS stn BM-1) segment approximately 1 mile.

Upper Truckee River below City of South Lake Tahoe Airport (Lahontan stn 3) to below Hwy 50 bridge in South Lake Tahoe (Lahontan stn 6), segment approximately 1.5 miles.

Trout Creek from Hwy 50 bridge to confluence of Upper Truckee River/Lake Tahoe backwater, segment approximately 1 mile.

Tallac Creek from Hwy 89 bridge (USFS stn B-2) to Lake Tahoe (below USFS stn B-1), segment approximately 0.5 mile.

We need to get a map or more definative information from the USFS for their sampling staton locations. Abby or I can give you information of exactly where ours are.

CC: Curtis, Chuck; Kemper, Lauri

From: Bruce Warden
To: Unsicker, Judith
Date: Thu, Oct 25, 2001 2:31 PM
Subject: Upper Truckee River Fecal Coliform Data - 2001 Season

USFS is still collecting data in Meiss Meadows for fecal coliform this season. Our sampling from Christmas Valley to Lake Tahoe is complete. There were violations in both USFS allotments and in the private (Mosher) livestock facility in 2001. The UTR study has a complete violation analysis. The USFS data has been fully assessed in Meiss Meadows only, since that's where the cows were. However, of much interest, since it involves non-livestock impacts, is data from Big Meadows. Just a cursory lokk indicates violation-level fecal coliform concentrations--probably from dogs, horses, and human (hiking, camping) sources. Here's the data to date.

Bruce T. Warden, Ph.D.
Lahontan Regional Water Quality Control Board
2501 Lake Tahoe Blvd.
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(530) 542-5416
(530) 544-2271 fax
wardb@rb6s.swrcb.ca.gov

CC: Curtis, Chuck; Kemper, Lauri

Sample Date		M1	M1a	M2	M3	Control
5/30/2001		4		0	0	0
6/7/2001		7		0	0	0
6/13/2001		0		1	0	0
6/20/2001		1		0	1	0
6/25/2001		0		1	0	0
7/5/2001		36		2	3	0
7/10/2001		36		1	14	0
7/16/2001		Samples incubated for 72 hours! - resampled on 7/20				
7/20/2001		7		3	11	0
7/26/2001		2		0	2	0
7/31/2001						0
8/1/2001		1		1	32	0
8/8/2001		1		1	2	0
8/15/2001		0		2	4	0
8/15/2001	duplicates			8		0
8/23/2001		3		4	46	0
8/28/2001		0		8	2	0
9/5/2001		0	90	13	9	0
9/5/2001	duplicates	1	93	7		0

USFS LTBMU 2001 Season - Fecal Coliform Data
Dardenelles (Meiss)

Station[1]	FROM Sample Date	30-Days To Date (inclusive)	#/100 mL Fecal Colif.	log FC	30 -day log mean	NOTES[2]
M1	5/30/2001	06/28/01	4	1.38629	**2**	
M1	6/7/2001	07/06/01	7	1.94591	**3**	
M1	6/13/2001	07/12/01	0	1E-07	**4**	
M1	6/20/2001	07/19/01	1	0	**6**	
M1	6/25/2001	07/24/01	0	1E-07	**7**	
M1	7/5/2001	08/03/01	36	3.58352	**7**	
M1	7/10/2001	08/08/01	36	3.58352	**3**	
M1	7/20/2001	08/18/01	7	1.94591	**2**	
M1	7/26/2001	08/24/01	2	0.69315	**1**	
M1	8/1/2001	08/30/01	1	0	**1**	
M1	8/8/2001	09/06/01	1	0	**1**	
M1	8/15/2001	09/13/01	0	1E-07	**1**	average of duplicates
M1	8/23/2001	09/21/01	3	1.09861	**1**	
M1	8/28/2001	09/26/01	0	1E-07	**1**	
M1	9/5/2001	10/04/01	0.5	-0.6931	**2**	average of duplicates
M1	9/11/2001		0	1E-07		average of duplicates
M1	9/19/2001		1	0		average of duplicates
M1	9/25/2001		5	1.60944		
M1	10/2/2001		5	1.60944		
M1a	9/5/2001	10/04/01	91.5	4.51634	**10**	assess 30-d log mean violation after inclusion of data thru 10/4
M1a	9/11/2001		15	2.70805		
M1a	9/19/2001		42.5	3.7495		
M1a	9/25/2001		2	0.69315		
M1a	10/2/2001		1	0		
M2	5/30/2001	06/28/01	0	1E-07	**1**	
M2	6/7/2001	07/06/01	0	1E-07	**1**	

M2	6/13/2001	07/12/01	1	0	**1**	
M2	6/20/2001	07/19/01	0	1E-07	**1**	
M2	6/25/2001	07/24/01	1	0	**1**	
M2	7/5/2001	08/03/01	2	0.69315	**1**	
M2	7/10/2001	08/08/01	1	0	**1**	
M2	7/20/2001	08/18/01	3	1.09861	**2**	
M2	7/26/2001	08/24/01	0	1E-07	**2**	
M2	8/1/2001	08/30/01	1	0	**3**	
M2	8/8/2001	09/06/01	1	0	**4**	
M2	8/15/2001	09/13/01	5	1.60944	**6**	average of duplicates
M2	8/23/2001	09/21/01	4	1.38629	**9**	
M2	8/28/2001	09/26/01	8	2.07944	**12**	
M2	9/5/2001	10/04/01	10	2.30259	**7**	average of duplicates
M2	9/11/2001		6	1.79176		
M2	9/19/2001		37	3.61092		
M2	9/25/2001		3			
M2	10/2/2001		0			
M3	5/30/2001	06/28/01	0	1E-07	**1**	
M3	6/7/2001	07/06/01	0	1E-07	**1**	
M3	6/13/2001	07/12/01	0	1E-07	**2**	
M3	6/20/2001	07/19/01	1	0	**3**	
M3	6/25/2001	07/24/01	0	1E-07	**4**	
M3	7/5/2001	08/03/01	3	1.09861	**8**	
M3	7/10/2001	08/08/01	14	2.63906	**7**	
M3	7/20/2001	08/18/01	11	2.3979	**6**	
M3	7/26/2001	08/24/01	2	0.69315	**7**	
M3	8/1/2001	08/30/01	32	3.46574	**7**	
M3	8/8/2001	09/06/01	2	0.69315	**6**	
M3	8/15/2001	09/13/01	4	1.38629	**14**	
M3	**8/23/2001**	**09/21/01**	46	3.82864	**27**	30-d log normalized FC violation
M3	8/28/2001	**09/26/01**	2	0.69315		
M3	9/5/2001	**10/04/01**	9	2.19722		
M3	9/11/2001		159	5.0689		
M3	9/19/2001		111	4.70953		average of duplicates
M3	9/25/2001		20			

M3	10/2/2001	0

Meiss Grazing Allotment
Fecal Coliform Monitoring
2001 Season

Date	Station	CFU/100ml Fecal Coliform	Notes
30-May	Big Meadow 1	1	Pasture removed from grazing
	Big Meadow 2	0	
	Big Meadow 3	0	
7-Jun	Big Meadow 1	0	
	Big Meadow 2	0	
	Big Meadow 3	0	
13-Jun	Big Meadow 1	0	
	Big Meadow 2	0	
	Big Meadow 3	1	
20-Jun	Big Meadow 1	0	
	Big Meadow 2	0	
	Big Meadow 3	0	
25-Jun	Big Meadow 1	0	
	Big Meadow 2	0	
	Big Meadow 3	3	
5-Jul	Big Meadow 1	6	
	Big Meadow 2	3	
	Big Meadow 3	30	
10-Jul	Big Meadow 1	4	
	Big Meadow 2	6	
	Big Meadow 3	26	
20-Jul	Big Meadow 1	11	
	Big Meadow 2	13	
	Big Meadow 3	44	
26-Jul	Big Meadow 1	27	
	Big Meadow 2	5	
	Big Meadow 3	20	
31-Jul	Big Meadow 1	12	
	Big Meadow 2	19	
	Big Meadow 3	13	
8-Aug	Big Meadow 1	268	

	Big Meadow 2		47	
	Big Meadow 3		23	
15-Aug	Big Meadow 1		110	
	Big Meadow 2		8	
	Big Meadow 3		6	
23-Aug	Big Meadow 1		17	
	Big Meadow 2		5	
	Big Meadow 3		4	
28-Aug	Big Meadow 1		1	
	Big Meadow 2		1	
	Big Meadow 3		47	
5-Sep	Big Meadow 1	dry		Stream going subsurface, moved station upstream
	Big Meadow 2		183	
	Big Meadow 3		3	
11-Sep	Big Meadow 1		4	
	Big Meadow 2		89	
	Big Meadow 3		2	
19-Sep	Big Meadow 1		46	
	Big Meadow 2		17	
	Big Meadow 3		0	
25-Sep	Big Meadow 1		2	
	Big Meadow 2		2	
	Big Meadow 3		8	
2-Oct	Big Meadow 1		1	
	Big Meadow 2		1	
	Big Meadow 3		2	
30-May	Meiss 1		4	
	Meiss 2		0	
	Meiss 3		0	
7-Jun	Meiss 1		7	
	Meiss 2		0	
	Meiss 3		0	
13-Jun	Meiss 1		0	
	Meiss 2		1	
	Meiss 3		0	
20-Jun	Meiss 1		1	

	Meiss 2	0	
	Meiss 3	1	
25-Jun	Meiss 1	0	
	Meiss 2	1	
	Meiss 3	0	
5-Jul	Meiss 1	36	
	Meiss 2	2	
	Meiss 3	3	
10-Jul	Meiss 1	36	
	Meiss 2	1	
	Meiss 3	14	
20-Jul	Meiss 1	7	
	Meiss 2	3	
	Meiss 3	11	
26-Jul	Meiss 1	2	
	Meiss 2	0	
	Meiss 3	2	
1-Aug	Meiss 1	1	
	Meiss 2	1	
	Meiss 3	32	
6-Aug			100 cow/calf pairs on pasture
8-Aug	Meiss 1	1	
	Meiss 2	1	
	Meiss 3	2	
15-Aug	Meiss 1	0	
	Meiss 2	2	
	Meiss 3	4	
23-Aug	Meiss 1	3	
	Meiss 2	4	
	Meiss 3	46	
28-Aug	Meiss 1	0	
	Meiss 2	8	
	Meiss 3	2	
5-Sep	Meiss 1	0	
	Meiss 1a	90	
	Meiss 2	13	
	Meiss 3	9	

11-Sep	Meiss 1	0
	Meiss 1a	16
	Meiss 2	6
	Meiss 3	159
19-Sep	Meiss 1	1
	Meiss 1a	43
	Meiss 2	37
	Meiss 3	111
25-Sep	Meiss 1	5
	Meiss 1a	2
	Meiss 2	3
	Meiss 3	20
2-Oct	Meiss 1	5
	Meiss 1a	1
	Meiss 2	0
	Meiss 3	0

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform
Summer 2001

	STATION										
	Upper Xmas Valley	HWY 50 Meyers	Airport	Upper Barton Main	Upper Barton Bypass	HWY 50 SLT	Trout Cr. @ HWY 50	Lower Barton Beach	Lower Barton Midway	Lower Trout Cr.	
Date	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**NOTES**
6/4/2001	1	3	0	2	25	2	6	7	*	25	Station #9 is not reachable: low water level and sampling on foot.
#######	1	6	7	8	3	3	19	15	*	3	
#######	0	1	1	6	0	14	26	0	*	2	
#######	8	7	6	14	7	8	53	17	*	19	Very windy at station #8, water turbid.
#######	2	6	6	6	1	11	35	11	*	6	Very windy at station #8, water turbid.
#######	13	24	5	75	14	40	22	52	*	17	High numbers possibly due to homeless living on meadow.
#######	17	5	1	15	11	14	35	43	*	10	Very windy at station #8, water turbid.
#######	15	0	3	9	103	17	11	63	*	3	
#######	17	1	1	20	45	49	52	8	*	28	Cows present at paddock near stations 4 and 5.
#######	13	14	11	21	38	101	102	28	*	50	Water appeared very turbid at station #6.
8/7/2001	14	12	5	43	1994	296	75	25	*	70	Cows observed in the water at station #5 bypass. Water very cloudy and turbid downstream and at station #6.
#######	260	9	1	33	1024	267	14	5	*	39	Water at station #10 appeared very turbid, windy. Cows in bypass/station #5 (photos taken to document).
#######	117	1	1	33	1720	212	10	31	*	10	Cows observed in the water at station #5 bypass. Water cloudy and turbid downstream and at station #6.
#######	2	1	51	22	300	21	11	40	*	12	Cows observed in bypass in a.m., but not at time of sampling. Water still fairly turbid downstream.
#######	5	1	2	15	228	274est	78	17	*	95	No cows observed at station #5 bypass.
9/5/2001	4	7	1	22	57	54	66	73	*	11	Flow in bypass is greater than in main UTR channel.
#######	9	2	3	4	83	84	11	13	*	9	Flow in bypass is greater than in main UTR channel, beaver activity observed above station #1.
#######	0	0	31	8	90	14	24	1	*	5	Flow in main channel greater than bypass again.
#######	7	3	33	51	299	446	36	243	*	13	Rained day before sampling.
#######	7	1	4	5	29	12	8	3	*	2	Bird and fresh feces observed at station #3.

* Station number 9 is not accessible due to low water level and sampling on foot. No samples will be taken at this station during summer 2001.

= cows no longer present (as of 9/6/01)

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform Monitoring Data
Summer 2001

From	30-d	Upper Xmas Valley		30-day log mean	HWY 50 Meyers		30-day log mean	Airport		30-day log mean	Upper Barton Main		30-day log mean	Upper Barton Bypass		30-day log mean
Date	To Date	Stn 1	log FC	Lmean1	Stn 2	log FC	Lmean2	Stn 3	log FC	Lmean3	Stn 4	log FC	Lmean4	Stn 5	log FC	Lmean5
6/4/2001	07/03/01	1	0	**2**	3	1.0986	**4**	0	1E-07	**3**	2	0.6931	**6**	25	3.2189	**3**
#######	07/10/01	1	0	**3**	6	1.7918	**6**	7	1.9459	**4**	8	2.0794	**12**	3	1.0986	**3**
#######	07/13/01	0	1E-07	**4**	1	0	**6**	1	0	**4**	6	1.7918	**14**	0	1E-07	**3**
#######	07/24/01	8	2.0794	**10**	7	1.9459	**4**	6	1.7918	**3**	14	2.6391	**16**	7	1.9459	**13**
#######	07/25/01	2	0.6931	**10**	6	1.7918	**4**	6	1.7918	**2**	6	1.7918	**16**	1	0	**15**
#######	08/08/01	13	2.5649	**15**	24	3.1781	**5**	5	1.6094	**3**	75	4.3175	**24**	14	2.6391	**61**
#######	08/15/01	17	2.8332	**24**	5	1.6094	**4**	1	0	**2**	15	2.7081	**21**	11	2.3979	**126**
#######	08/18/01	15	2.7081	**33**	0	1E-07	**3**	3	1.0986	**2**	9	2.1972	**24**	103	4.6347	**292**
#######	08/22/01	17	2.8332	**24**	1	0	**3**	1	0	**4**	20	2.9957	**28**	45	3.8067	**349**
#######	08/23/01	13	2.5649	**26**	14	2.6391	**4**	11	2.3979	**5**	21	3.0445	**29**	38	3.6376	**525**
8/7/2001	09/05/01	14	2.6391	**16**	12	2.4849	**3**	5	1.6094	**3**	43	3.7612	**26**	1994	7.5979	**489**
#######	09/11/01	260	5.5607		9	2.1972		1	0		33	3.4965		1024	6.9315	
#######	09/14/01	117	4.7622		1	0		1	0		33	3.4965		1720	7.4501	
#######	09/20/01	2	0.6931		1	0		51	3.9318		22	3.091		300	5.7038	
#######	09/27/01	5	1.6094		1	0		2	0.6931		15	2.7081		228	5.4293	
9/5/2001	10/04/01	4	1.3863		7	1.9459		1	0		22	3.091		57	4.0431	
#######		9	2.1972		2	0.6931		3	1.0986		4	1.3863		83	4.4188	
#######		0	1E-07		0	1E-07		31	3.434		8	2.0794		90	4.4998	
#######		7	1.9459		3	1.0986		33	3.4965		51	3.9318		299	5.7004	
#######	9/6/2001	7	1.9459	**5**	1	0	**2**	4	1.3863	**11**	5	1.6094	**10**	29	3.3673	**90**

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform Monitoring Data
Summer 2001

From	30-d	Upper Xmas Valley		30-day log mean	HWY 50 Meyers		30-day log mean	Airport		30-day log mean	Upper Barton Main		30-day log mean	Upper Barton Bypass		30-day log mean
Date	To Date	Stn 1	log FC	Lmean1	Stn 2	log FC	Lmean2	Stn 3	log FC	Lmean3	Stn 4	log FC	Lmean4	Stn 5	log FC	Lmean5

* Station number 9 is not accessible due to low water level and sampling on foot. No samples will be taken at this station during summer 2001.

= cows no longer present (as of 9/6/01)

TABLE 1: Upper Tı
Summer 2001

From	30-d	HWY 50 SLT		30-day log mean	Trout Cr. @ HWY 50		30-day log mean	Lower Barton Beach		30-day log mean	Lower Trout Cr.		30-day log mean
Date	To Date	Stn 6	log FC	Lmean6	Stn 7	log FC	Lmean7	Stn 8	log FC	Lmean8	Stn 10	Lmean10	log mean
6/4/2001	07/03/01	2	0.6931	**6**	6	1.7918	**22**	7	1.9459	**7**	25	3.218876	**7**
#######	07/10/01	3	1.0986	**11**	19	2.9444	**29**	15	2.7081	**11**	3	1.098612	**7**
#######	07/13/01	14	2.6391	**15**	26	3.2581	**32**	0	1E-07	**10**	2	0.693147	**8**
#######	07/24/01	8	2.0794	**19**	53	3.9703	**31**	17	2.8332	**24**	19	2.944439	**11**
#######	07/25/01	11	2.3979	**22**	35	3.5553	**27**	11	2.3979	**26**	6	1.791759	**10**
#######	08/08/01	40	3.6889	**49**	22	3.091	**39**	52	3.9512	**30**	17	2.833213	**19**
#######	08/15/01	14	2.6391	**67**	35	3.5553	**36**	43	3.7612	**21**	10	2.302585	**22**
#######	08/18/01	17	2.8332	**106**	11	2.3979	**29**	63	4.1431	**19**	3	1.098612	**22**
#######	08/22/01	49	3.8918	**110**	52	3.9512	**29**	8	2.0794	**18**	28	3.332205	**28**
#######	08/23/01	101	4.6151	**129**	102	4.625	**26**	28	3.3322	**21**	50	3.912023	**28**
8/7/2001	09/05/01	296	5.6904	**132**	75	4.3175	**29**	25	3.2189	**24**	70	4.248495	**26**
#######	09/11/01	267	5.5872		14	2.6391		5	1.6094		39	3.663562	
#######	09/14/01	212	5.3566		10	2.3026		31	3.434		10	2.302585	
#######	09/20/01	21	3.0445		11	2.3979		40	3.6889		12	2.484907	
#######	09/27/01	274	5.6131		78	4.3567		17	2.8332		95	4.553877	
9/5/2001	10/04/01	54	3.989		66	4.1897		73	4.2905		11	2.397895	
#######		84	4.4308		11	2.3979		13	2.5649		9	2.197225	
#######		14	2.6391		24	3.1781		1	0		5	1.609438	
#######		446	6.1003		36	3.5835		243	5.4931		13	2.564949	
#######	9/6/2001	12	2.4849	**50**	8	2.0794	**17**	3	1.0986	**10**	2	0.693147	**6**

TABLE 1: Upper Tı
Summer 2001

From	30-d	HWY 50 SLT		30-day log mean	Trout Cr. @ HWY 50		30-day log mean	Lower Barton Beach		30-day log mean	Lower Trout Cr.		30-day log mean
Date	To Date	Stn 6	log FC	Lmean6	Stn 7	log FC	Lmean7	Stn 8	log FC	Lmean8	Stn 10	Lmean10	log mean

* Station number 9 i

= cows no longer p

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform
Summer 2000

	STATION										
	Upper Xmas Valley	HWY 50 Meyers	Airport	Upper Barton Main	Upper Barton Bypass	HWY 50 SLT	Trout Cr. @ HWY 50	Lower Barton Beach	Lower Barton Midway	Lower Trout Cr.	
Date	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**NOTES**
#######	ns	ns	ns	ns	ns	ns	ns	63	3	8	Many birds present on beach near stn #8
#######	0	0	0	0	0	1	1	8	0	2	Some birds present on beach near stn #8
#######	3	0	0	5	5	17	7	59	14	13	Many birds present on beach near stn #8
#######											Cattle on Upper Barton Meadows
#######	8	17	2	17	26	19	3	74	21*	36	* sampled at edge of inundated area
7/3/2000	5	4	5	9	4	5	12	151	0	5	Many Canadian Geese near stn #8
7/6/2000	4	5	6	6	6	4	4	30	0	8	Some Sea Gulls on beach only near stn #8
#######	11	2	6	23	8	25	21	10	0	46	Cattle on lower Barton Meadow
#######											cattle observed standing in Trout Creek--no cowboy present to herd away from surface waters
#######	8	26	14	21	11	80	8	10	4	37	
#######	8	4	6	12	27	53	19	7	1	200	Cattle present along Trout Cr.--upper meadow
#######	8	8	21	66	41	55	313	4	5	110	Dog observed upstream from station #5, Cows present in water throughout Truckee Marsh (#8, #9, #10)
#######	6	16	29	19	18	17	48	6	5	500	
#######	16	25	5	11	16	19	6	1	2	238	Cows present at station #5, much algae floating in water
#######	13	14	21	24	35	23	29	7	5	950	
8/3/2000	14	20	8	25	54	26	27	16	26	540	
8/7/2000	10	5	11	50	75	57	30	37	2	80	Dogs swimming in water prior to sampling at station #3, cows present at station #8
#######	5	6	3	82	62	5800	9	18	36	72	Cattle in paddock nearest HWY 50 above Station 6 - in river at watering location (fenced across river - photos to doc), many birds present at station #8
#######	11	17	16	56	230	130	13	7	7	86	Cattle not in paddock nearest HWY 50 above Station 6, many birds bathing in water upstream prior to sampling at station #4, water st station #5 barely flowing, large number of birds present at station #8
#######	3	17	11	36	40	54	20	79	16	180	Cows present at station #10, many birds present at station #8, floating fecal matter from cows observed in Trout Creek
#######	7	13	25	25	72	22	7	12	190	4	No flow at station #5 bypass
#######	17	28	20	24	41	28	37	53	4	350	No flow at station #5 bypass

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform
Summer 2000

	STATION										
	Upper Xmas Valley	HWY 50 Meyers	Airport	Upper Barton Main	Upper Barton Bypass	HWY 50 SLT	Trout Cr. @ HWY 50	Lower Barton Beach	Lower Barton Midway	Lower Trout Cr.	
Date	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**NOTES**
#######	22	21	70	50	325	94	14	14	1	250	No flow at station #5 bypass, many birds present at station #8, cows present near station #8 between Lake Tahoe and Truckee Marsh, evidence of dog/human in river at station #3 prior to sampling
#######	6	6	18	20	300	13	6	64	12	380	cows present and in water upstream from station #10, dog in water near station #8 while sampling, no flow at station #5
9/5/2000	2	1	21	27	150	32	10	47	18	210	No flow at station #5 bypass, many birds present at Truckee Marsh
9/7/2000	3	5	15	55	320	62	7	21	20	310	Station #5 bypass is flowing, Truckee River level is slightly up,cows are present upstream from sample location #5 bypass
#######	3	0	8	40	4200	652	0	65	6	106	Station #5 non-BMP bypass cloudy water, cattle in paddock with bypass, cloudy water downstream at station #6, no cows present at station #10.
#######	2	1	7	32	3850	520	3	22	16	117	Cows present upstream from station #5, water is very cloudy, station #6 water is cloudy, station #1 very little flow, no cows present at station #10
#######	1	1	5	2	7900	700	5	105	22	195	Cows present upstream from statin #10, water is cloudy at bypass station #5, little flow at station #5
#######	2	8	49	14	1950	180	5	16	34	260	Cows present upstream from station #10
#######	1	0	12	28	1000	30	2	38	96	100	Fencing is down below station #5, no cows present near Upper Truckee River, Cows present upstream from station #10
#######	2	3	10	13	270	60	5	65	5	110	Fencing is still down downstream from station #5, no cows present at Trout or U.Truckee
#######	0	8	33	20	26	2	2	5	9	2	No cows present, fencing remains down
#######	0	390	270	490	5600	510	2	20	1	200	*sampling was preceded by 3 days of light snow, no cows present
#######	0	53	8	18	430	80	2	38	1	330	
#######	0	29	7	14	560	60	5	58	34	420	*sampling was preceded by a storm event.
#######	0	5	23	17	133	95	4	55	32	78	

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform
Summer 2000

	STATION										
	Upper Xmas Valley	HWY 50 Meyers	Airport	Upper Barton Main	Upper Barton Bypass	HWY 50 SLT	Trout Cr. @ HWY 50	Lower Barton Beach	Lower Barton Midway	Lower Trout Cr.	
Date	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**NOTES**
											= cows no longer present (as of 10/3/00)

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform Monitoring Data Summer 2000

From	30-d	Upper Xmas Valley		30-day log mean	HWY 50 Meyers		30-day log mean	Airport		30-day log mean	Upper Barton Main		30-day log mean	Upper Barton Bypass	
Date	To Date	Stn 1	log FC	Lmean1	Stn 2	log FC	Lmean2	Stn 3	log FC	Lmean3	Stn 4	log FC	Lmean4	Stn 5	log FC
#######	07/15/00	ns			ns			ns			ns			ns	
#######	07/18/00	0	1E-07	5	0	1E-07	4	0	1E-07	4	0	1E-07	8	0	1E-07
#######	07/21/00	3	1.098612	6	0	1E-07	5	0	1E-07	5	5	1.6094	14	5	1.6094
#######	07/29/00	8	2.079442	8	17	2.8332	8	2	0.6931	8	17	2.8332	16	26	3.2581
7/3/2000	08/01/00	5	1.609438	8	4	1.3863	8	5	1.6094	10	9	2.1972	17	4	1.3863
7/6/2000	08/04/00	4	1.386294	9	5	1.6094	10	6	1.7918	10	6	1.7918	19	6	1.7918
#######	08/08/00	11	2.397895	10	2	0.6931	10	6	1.7918	11	23	3.1355	24	8	2.0794
#######	08/11/00	8	2.079442	9	26	3.2581	11	14	2.6391	10	21	3.0445	27	11	2.3979
#######	08/15/00	8	2.079442	9	4	1.3863	11	6	1.7918	11	12	2.4849	30	27	3.2958
#######	08/18/00	8	2.079442	8	8	2.0794	13	21	3.0445	11	66	4.1897	34	41	3.7136
#######	08/22/00	6	1.791759	9	16	2.7726	14	29	3.3673	12	19	2.9444	30	18	2.8904
#######	08/25/00	16	2.772589	9	25	3.2189	14	5	1.6094	11	11	2.3979	32	16	2.7726
#######	08/29/00	13	2.564949	10	14	2.6391	14	21	3.0445	15	24	3.1781	38	35	3.5553
8/3/2000	09/01/00	14	2.639057	9	20	2.9957	13	8	2.0794	15	25	3.2189	37	54	3.989
8/7/2000	09/05/00	10	2.302585	7	5	1.6094	9	11	2.3979	16	50	3.912	37	75	4.3175
#######	09/08/00	5	1.609438	6	6	1.7918	9	3	1.0986	17	82	4.4067	38	62	4.1271
#######	09/12/00	11	2.397895	6	17	2.8332	9	16	2.7726	21	56	4.0254	34	230	5.4381
#######	09/15/00	3	1.098612	6	17	2.8332	7	11	2.3979	19	36	3.5835	33	40	3.6889
#######	09/19/00	7	1.94591	5	13	2.5649	5	25	3.2189	18	25	3.2189	32	72	4.2767
#######	09/22/00	17	2.833213	4	28	3.3322	3	20	2.9957	15	24	3.1781	23	41	3.7136

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform Monitoring Data
Summer 2000

From	30-d	Upper Xmas Valley		30-day log mean	HWY 50 Meyers		30-day log mean	Airport		30-day log mean	Upper Barton Main		30-day log mean	Upper Barton Bypass	
Date	To Date	Stn 1	log FC	Lmean1	Stn 2	log FC	Lmean2	Stn 3	log FC	Lmean3	Stn 4	log FC	Lmean4	Stn 5	log FC
#######	09/26/00	22	3.091042	**3**	21	3.0445	**3**	70	4.2485	**16**	50	3.912	**22**	325	5.7838
#######	09/29/00	6	1.791759	**2**	6	1.7918	**2**	18	2.8904	**13**	20	2.9957	**20**	300	5.7038
9/5/2000	10/04/00	2	0.693147	**2**	1	0	**2**	21	3.0445	**12**	27	3.2958	**19**	150	5.0106
9/7/2000	10/06/00	3	1.098612	**2**	5	1.6094	**2**	15	2.7081	**13**	55	4.0073	**19**	320	5.7683
#######	10/13/00	3	1.098612	**1**	0	1E-07	**4**	8	2.0794	**19**	40	3.6889	**24**	4200	8.3428
#######	10/17/00	2	0.693147	**1**	1	0	**7**	7	1.9459	**19**	32	3.4657	**22**	3850	8.2558
#######	10/20/00	1	0	**1**	1	0	**9**	5	1.6094	**21**	2	0.6931	**21**	7900	8.9746
#######	10/24/00	2	0.693147	**1**	8	2.0794	**13**	49	3.8918	**27**	14	2.6391	**31**	1950	7.5756
#######	10/27/00	1	0	**1**	0	1E-07	**16**	12	2.4849	**20**	28	3.3322	**31**	1000	6.9078
#######	#######	2	0.693147		3	1.0986		10	2.3026		13	2.5649		270	5.5984
#######		0	1E-07		8	2.0794		33	3.4965		20	2.9957		26	3.2581
#######		0	1E-07		390	5.9661		270	5.5984		490	6.1944		5600	8.6305
#######		0	1E-07		53	3.9703		8	2.0794		18	2.8904		430	6.0638
#######		0	1E-07		29	3.3673		7	1.9459		14	2.6391		560	6.3279
#######	#######	0	1E-07	1	5	1.6094	20	23	3.1355	22	17	2.8332	29	133	4.8903

TABLE 1: Upper Truckee/Trout Creek Non-Point Source Fecal Coliform Monitoring Data
Summer 2000

From	30-d	Upper Xmas Valley		30-day log mean	HWY 50 Meyers		30-day log mean	Airport		30-day log mean	Upper Barton Main		30-day log mean	Upper Barton Bypass	
Date	To Date	Stn 1	log FC	Lmean1	Stn 2	log FC	Lmean2	Stn 3	log FC	Lmean3	Stn 4	log FC	Lmean4	Stn 5	log FC

= cows no longer present (as of 10/3/00)

30-day log mean	HWY 50 SLT		30-day log mean	Trout Cr. @ HWY 50		30-day log mean	Lower Barton Beach		30-day log mean	Lower Barton Midway		30-day log mean	Lower Trout Cr.		30-day log mean
Lmean5	Stn 6	log FC	Lmean6	Stn 7	log FC	Lmean7	Stn 8	log FC	Lmean8	Stn 9	log FC	Lmean9	Stn 10	log FC	Lmean10
	ns			ns			63	4.1431	39	3	1.0986	5	8	2.0794	9
7	1	0	13	1	0	7	8	2.0794	24	0	1E-07	2	2	0.6931	18
11	17	2.8332	21	7	1.9459	13	59	4.0775	22	14	2.6391	3	13	2.5649	30
14	19	2.9444	21	3	1.0986	15	74	4.3041	12	21	3.0445	3	36	3.5835	57
14	5	1.6094	21	12	2.4849	19	151	5.0173	9	0	1E-07	2	5	1.6094	82
19	4	1.3863	25	4	1.3863	21	30	3.4012	7	0	1E-07	3	8	2.0794	138
25	25	3.2189	34	21	3.0445	27	10	2.3026	7	0	1E-07	3	46	3.8286	178
32	80	4.382	63	8	2.0794	24	10	2.3026	8	4	1.3863	5	37	3.6109	187
44	53	3.9703	66	19	2.9444	26	7	1.9459	8	1	0	5	200	5.2983	206
46	55	4.0073	66	313	5.7462	26	4	1.3863	10	5	1.6094	7	110	4.7005	204
48	17	2.8332	55	48	3.8712	18	6	1.7918	13	5	1.6094	10	500	6.2146	154
54	19	2.9444	63	6	1.7918	16	1	0	14	2	0.6931	11	238	5.4723	135
75	23	3.1355	76	29	3.3673	18	7	1.9459	19	5	1.6094	10	950	6.8565	136
96	26	3.2581	71	27	3.2958	15	16	2.7726	25	26	3.2581	11	540	6.2916	123
107	57	4.0431	73	30	3.4012	14	37	3.6109	28	2	0.6931	10	80	4.382	111
126	5800	8.6656	73	9	2.1972	12	18	2.8904	26	36	3.5835	13	72	4.2767	129
137	130	4.8675	42	13	2.5649	12	7	1.9459	27	7	1.9459	12	86	4.4543	138
198	54	3.989	52	20	2.9957	9	79	4.3694	36	16	2.7726	12	180	5.193	142
350	22	3.091	69	7	1.9459	7	12	2.4849	31	190	5.247	12	4	1.3863	135
629	28	3.3322	106	37	3.6109	7	53	3.9703	40	4	1.3863	9	350	5.8579	219

30-day log mean	HWY 50 SLT		30-day log mean	Trout Cr. @ HWY 50		30-day log mean	Lower Barton Beach		30-day log mean	Lower Barton Midway		30-day log mean	Lower Trout Cr.		30-day log mean
Lmean5	Stn 6	log FC	Lmean6	Stn 7	log FC	Lmean7	Stn 8	log FC	Lmean8	Stn 9	log FC	Lmean9	Stn 10	log FC	Lmean10
1019	94	4.5433	**134**	14	2.6391	**5**	14	2.6391	**35**	1	0	**12**	250	5.5215	**211**
1173	13	2.5649	**116**	6	1.7918	**4**	64	4.1589	**39**	12	2.4849	**20**	380	5.9402	**188**
1158	32	3.4657	**141**	10	2.3026	**4**	47	3.8501	**39**	18	2.8904	**18**	210	5.3471	**161**
930	62	4.1271	**99**	7	1.9459	**3**	21	3.0445	**30**	20	2.9957	**17**	310	5.7366	**90**
1330	652	6.48	**129**	0	1E-07	**3**	65	4.1744	**30**	6	1.7918	**12**	106	4.6634	**85**
1000	520	6.2538	**100**	3	1.0986	**3**	22	3.091	**28**	16	2.7726	**9**	117	4.7622	**98**
825	700	6.5511	**79**	5	1.6094	**3**	105	4.654	**31**	22	3.091	**9**	195	5.273	**96**
566	180	5.193	**55**	5	1.6094	**3**	16	2.7726	**29**	34	3.5264	**7**	260	5.5607	**85**
460	30	3.4012	**45**	2	0.6931	**3**	38	3.6376	**31**	96	4.5643	**7**	100	4.6052	**92**
	60	4.0943		5	1.6094		65	4.1744		5	1.6094		110	4.7005	
	2	0.6931		2	0.6931		5	1.6094		9	2.1972		2	0.6931	
	510	6.2344		2	0.6931		20	2.9957		1	0		200	5.2983	
	80	4.382		2	0.6931		38	3.6376		1	0		330	5.7991	
	60	4.0943		5	1.6094		58	4.0604		34	3.5264		420	6.0403	
329	95	4.5539	55	4	1.3863	3	55	4.0073	30	32	3.4657	6	78	4.3567	

30-day log mean	HWY 50 SLT		30-day log mean	Trout Cr. @ HWY 50		30-day log mean	Lower Barton Beach		30-day log mean	Lower Barton Midway		30-day log mean	Lower Trout Cr.		30-day log mean
Lmean5	Stn 6	log FC	Lmean6	Stn 7	log FC	Lmean7	Stn 8	log FC	Lmean8	Stn 9	log FC	Lmean9	Stn 10	log FC	Lmean10

NOTES
Many birds present on beach near stn #8
Some birds present on beach near stn #8
Many birds present on beach near stn #8
* sampled at edge of inundated area
Many Canadian Geese near stn #8
Some Sea Gulls on beach only near stn #8
Cattle on lower Barton Meadow
Cattle present along Trout Cr.--upper meadow
Dog observed upstream from station #5, Cows present in water throughout Truckee Marsh (#8, #9, #10)
Cows present at station #5, much algae floating in water
Dogs swimming in water prior to sampling at station #3, cows present at station #8
Cattle in paddock nearest HWY 50 above Station 6 - in river at watering location (fenced across river - photos to doc), many birds present at station #8
Cattle not in paddock nearest HWY 50 above Station 6, many birds bathing in water upstream prior to sampling at station #4, water st station #5 barely flowing, large number of birds present at station #8
Cows present at station #10, many birds present at station #8, floating fecal matter from cows observed in Trout Creek
No flow at station #5 bypass
No flow at station #5 bypass

NOTES
No flow at station #5 bypass, many birds present at station #8, cows present near station #8 between Lake Tahoe and Truckee Marsh, evidence of dog/human in river at station #3 prior to sampling
cows present and in water upstream from station #10, dog in water near station #8 while sampling, no flow at station #5
No flow at station #5 bypass, many birds present at Truckee Marsh
Station #5 bypass is flowing, Truckee River level is slightly up,cows are present upstream from sample location #5 bypass
Station #5 non-BMP bypass cloudy water, cattle in paddock with bypass, cloudy water downstream at station #6, no cows present at station #10.
Cows present upstream from station #5, water is very cloudy, station #6 water is cloudy, station #1 very little flow, no cows present at station #10
Cows present upstream from statin #10, water is cloudy at bypass station #5, little flow at station #5
Cows present upstream from station #10
Fencing is down below station #5, no cows present near Upper Truckee River, Cows present upstream from station #10
Fencing is still down downstream from station #5, no cows present at Trout or U.Truckee
No cows present, fencing remains down
*sampling was preceded by 3 days of light snow, no cows present
*sampling was preceded by a storm event.

NOTES

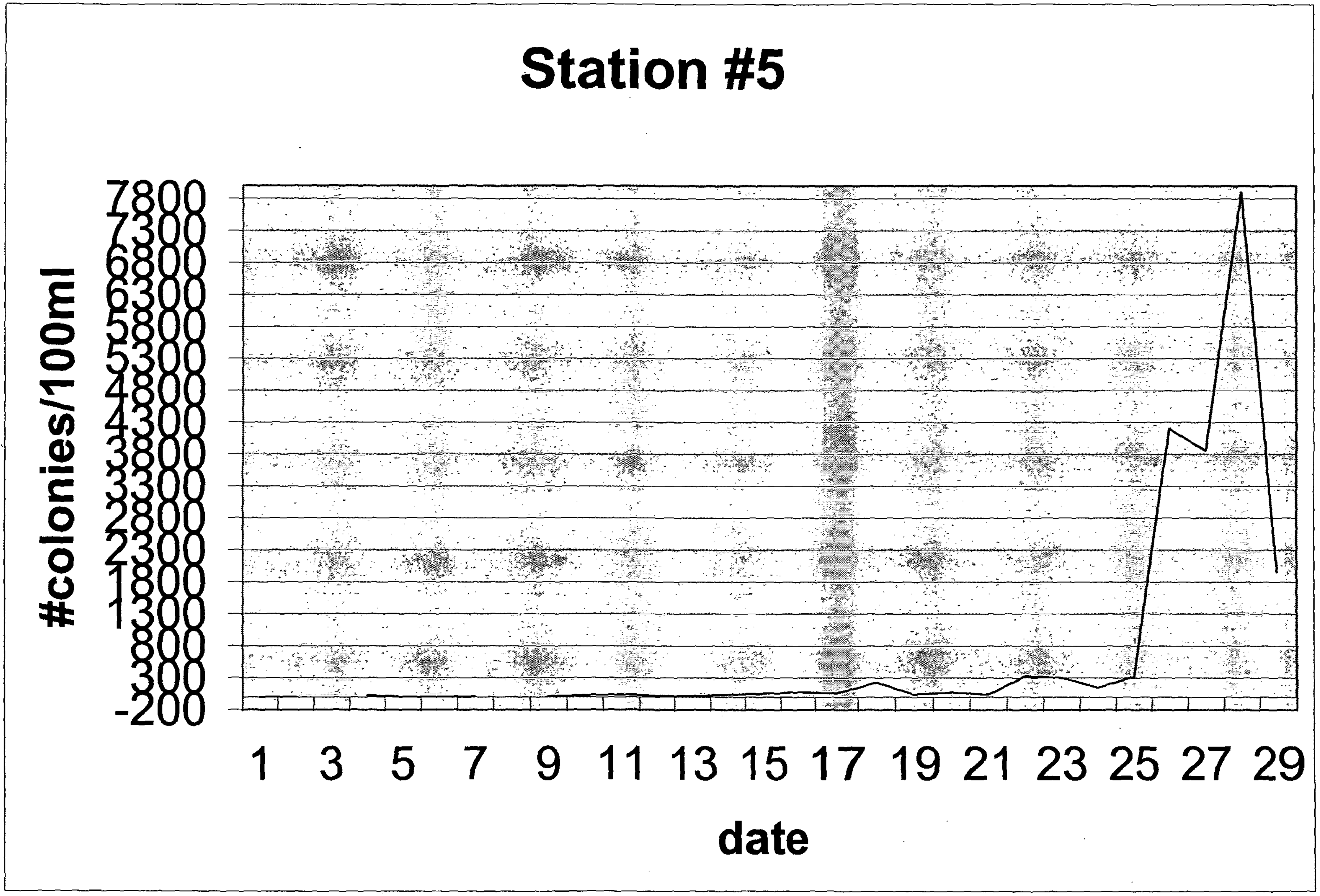

Station #5
#colonies/100ml
7800
7300
6800
6300
5800
5300
4800
4300
3800
3300
2800
2300
1800
1300
800
300
-200
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
date

TABLE 2: USFS Meiss Meadows Fecal Coliform Monitoring Data
Summer 2000

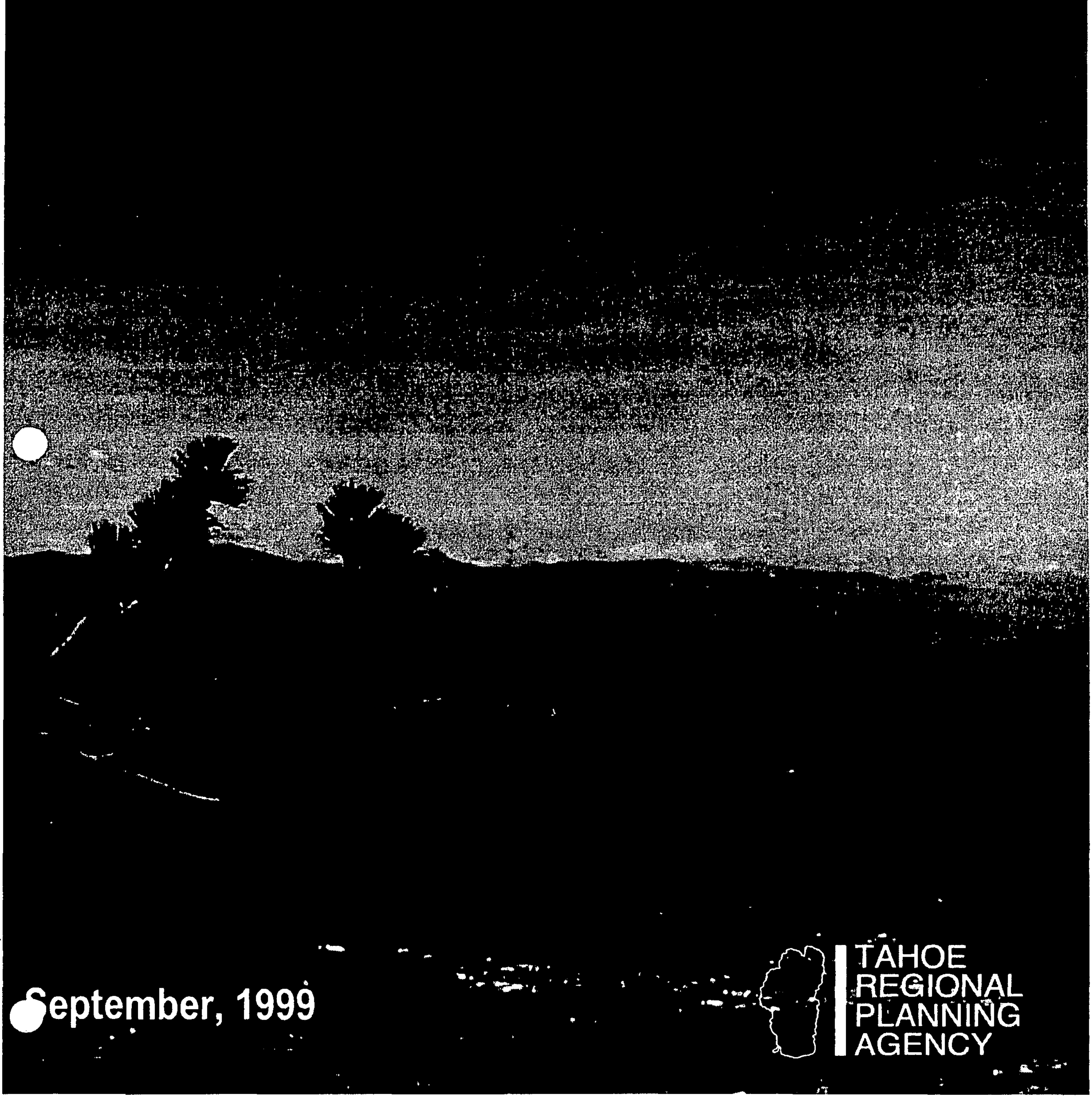
	Big Meadows			Meiss			Baldwin		Trout			
	lower allotment boundary	mid allotment after enclosure	upper allotment	lower allotment boundary	center of Meiss allotment	upstream Upper Truckee R	lower	upper	lower	mid	upper	
Date	**BM-1**	**BM-2**	**BM-3**	**M-1**	**M-2**	**M-3**	**B-1**	**B-2**	**T-1**	**T-2**	**T-3**	**NOTES**
5/2/2000	0	3	1									
#######	93	49	0				13	26				
6/1/2000	0	0	0				33	15				
6/6/2000	0	3	2									
6/8/2000							24	6				
#######	2	1	0									
#######									6	2	3	
#######				0	1	0						
#######	20	22	6						3	6	2	
#######							20	0				
#######	6	0	210									
#######									27	2	3	
#######				5	7	1						
7/6/2000	33	37	94									
7/7/2000							28	9	19	4	3	
#######	280	96	33				2	8				
#######				6	0	0						
#######									39	19	23	
#######				22	5	0						
#######	34	36	31									
#######				68	0	32						Lahontan QA/QC
8/3/2000	20	18	10	74	2	38						Lahontan QA/QC
#######				0	46	4						Lahontan QA/QC
#######	20	12	8	10	0	8						Lahontan QA/QC
9/7/2000	6	24	16	10	2	8						Lahontan QA/QC
#######	1	5	0	0	1	0						Lahontan QA/QC
*10/2/00	0	0	1	0	0	10						*Holding time expired

Additional field notes and data

Date	m-FC CFU/100mL Fenceline Background	UTR Grass Lake Rd.
6/16/2000	5	
6/19/2000	9	0

	South Upper Truckee/Trout Creek Non-Point Source Monitoring Stations, Summer 2000		
STN #	**Station Location**	**Station Type/Function**	**Station Field ID**
1	South Upper Truckee River (SUTR) in Christmas Valley at Bridge near USGS gauging station near Hawley Grade.	Upstream Station	SUTR Bridge @ Hawley Gr.
2	SUTR @ Highway 50 bridge , Meyers.	Downstream Christmas Valley to assess residential impacts including small grazing (Celio Ranch) and backyard livestock grazers.	SUTR @ HWY 50 (Meyers)
3	SUTR at lower end of Lake Tahoe Airport at concrete crossing	Upstream of Upper Barton Meadows; downstream Meyers and Tahoe Paradise + Lake Tahoe Golf Courses	Airport - Cement Crossing
4	SUTR below fenced portion before confluence with bypass	Monitor influence of BMP implementation	SUTR Main Channel - fenced (just above junction with bypass)
5	SUTR below unfenced bypass (beavers) in Upper Barton Meadows	Monitor impacts of livestock in unfenced (no BMPs) portion	SUTR Bypass Channel - unfenced (just above junction with main)
6	SUTR at Highway 50 Bridge near Carrows Resturant	Downstream Upper Barton Meadows to get cumulative impacts and Upstream for Lower Barton Meadows.	SUTR @ HWY 50 - SLT
7	Trout Creek at Highway 50 Bridge	Upstream of Trout Creek portion of Lower Barton Meadow	Trout Cr. @ HWY 50 Bridge
8	Lower Barton Meadow Inundated Area near beach, spit adjoining Lake Tahoe	Livestock Impacts if present in lower 1/3 portion (inundated area near Lake Tahoe)	Barton Meadows inundated area - cow pie beach
9	Lower Barton Meadow Inundated Area middle	Background sources from water fowl, etc.	Barton Meadows inundated area - background mid-meadow
10	Trout Creek at Lower Barton Meadow across from El Dorado/San Francisco Streets before River Reaches inundated area of Lower Barton Meadow	Downstream of livestock area	Trout Cr. - lower

Annual Water Quality Report



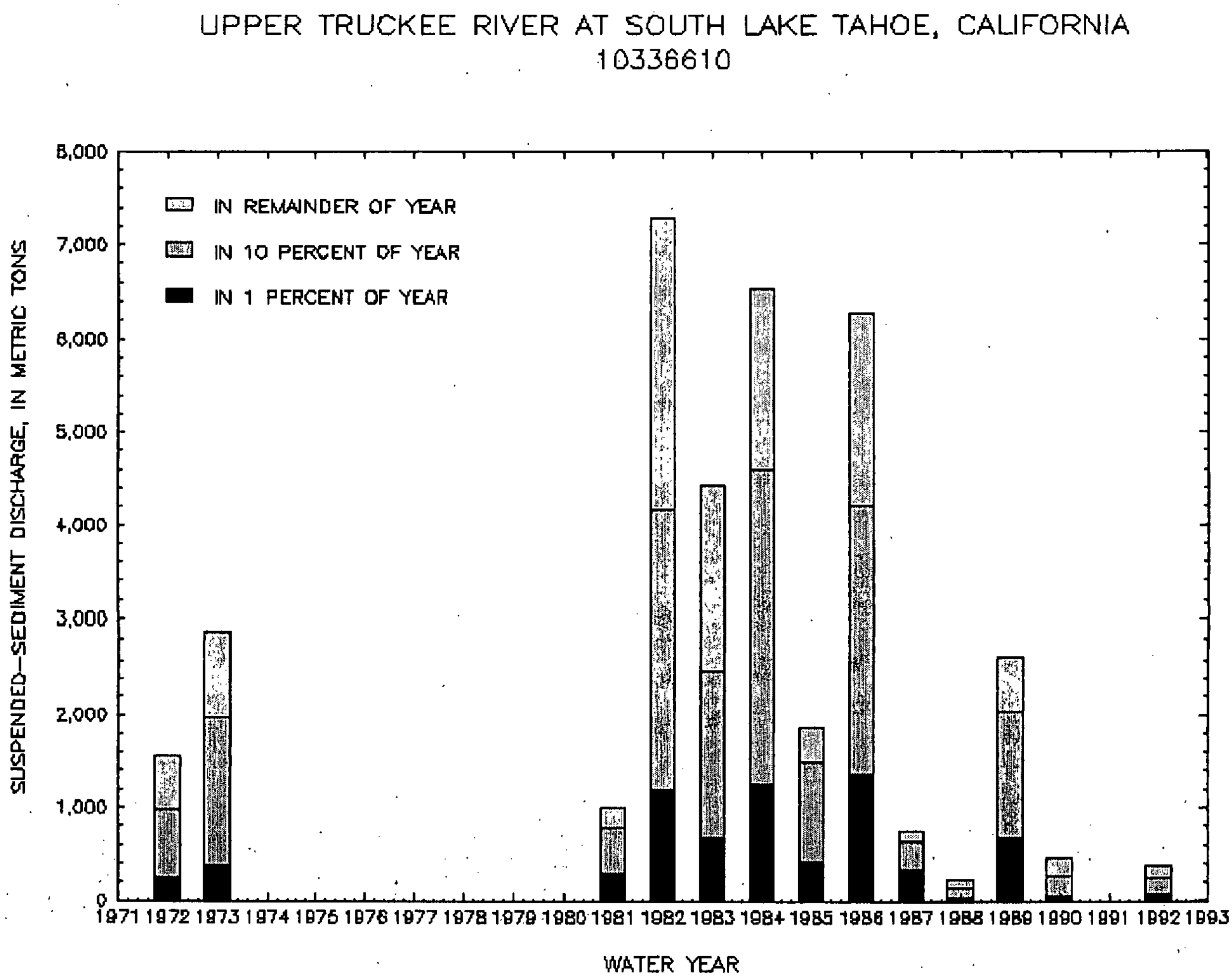
September, 1999

TAHOE
REGIONAL
PLANNING
AGENCY

able 8. Annual Average Concentrations, CA and NV Tributaries

		WY80	WY81	WY82	WY83	WY84	WY85	WY86	WY87	WY88	WY89	WY90	WY91	WY92	WY93	WY 94	WY 95	WY 96
ALIFORNIA																		
	Trout Creek	0.025	0.030	0.051	0.056	0.037	0.035				0.042	0.040	0.032	0.031	0.045	0.036	0.058	0.053
	Upper Truckee	0.021	0.040	0.029	0.036	0.035	0.029	0.044	0.023	0.022	0.043	0.044	0.037	0.024	0.040	0.027	0.052	0.045
otal P (mg/l)	Blackwood Creek	0.031	0.032	0.051	0.045	0.021	0.016	0.053	0.014	0.015	0.056	0.037	0.051	0.031	0.059	0.027	0.071	0.126
	Ward Creek	0.027	0.036	0.044	0.026	0.027	0.018	0.034	0.013	0.014	0.032	0.035	0.039	0.033	0.055	0.076	0.069	0.125
	General Creek		0.019	0.023	0.020	0.013	0.013	0.016	0.011	0.011	0.018	0.021	0.021	0.017	0.023	0.017	0.027	0.031
	Trout Creek										0.223	0.160	0.168	0.235	0.258	0.152	0.275	0.249
	Upper Truckee										0.271	0.204	0.204	0.212	0.278	0.146	0.281	0.192
otal N (mg/l)	Blackwood Creek										0.197	0.137	0.218	0.161	0.255	0.103	0.293	0.270
	Ward Creek										0.167	0.126	0.181	0.172	0.205	0.197	0.244	0.235
	General Creek										0.166	0.131	0.161	0.145	0.169	0.123	0.231	0.195
	Trout Creek										0.573	0.444	0.393	0.525	0.641	0.472	0.880	0.994
	Upper Truckee										0.329	0.392	0.515	0.366	0.528	0.286	0.849	0.752
otal Fe (mg/l)	Blackwood Creek										0.419	0.355	0.875	0.579	1.121	0.296	1.182	1.990
	Ward Creek										0.254	0.220	0.357	0.278	0.518	0.826	0.720	1.690
	General Creek										0.154	0.10	0.102	0.086	0.204	0.084	0.298	0.385
	Trout Creek	48	5	44	43	34	20				7	5	7	5	11	11	50	27
otal Suspended	Upper Truckee	49	24	42	24	48	31	55	23	8	34	9	31	12	26	11	46	39
ediment (mg/l)	Blackwood Creek	85	14	152	38	26	15	125	12	4	14	7	18	9	67	11	86	146
	Ward Creek	16	9	171	30	18	8	55	6	2	6	4	10	8	43	59	69	177
	General Creek		4	42	8	8	4	25	3	2	4	3	4	3	12	8	17	26
NEVADA																		
	Third Creek									0.0051	0.0144	0.0100	0.0108	0.0105	0.0094	0.012	0.012	0.0094
Soluble	Incline Creek									0.0101	0.0145	0.0141	0.0110	0.0122	0.0139	0.014	0.014	0.013
Reactive	Logan House Creek									0.0015	0.0050	0.0050	0.0031	0.0037	0.0042	0.004	0.005	0.0031
Phosphorus (mg/l)	Glenbrook Creek									0.0095	0.0114	0.0100	0.0151	0.0142	0.0122	0.013	0.014	0.021
	Edgewood Creek											0.0200	0.0184	0.0244	0.0119	0.012	0.013	0.014
	Third Creek									0.0409	0.0319	0.0223	0.0259	0.028	0.035	0.010	0.033	0.020
Total Soluble	Incline Creek									0.0772	0.0487	0.0391	0.0404	0.042	0.037	0.027	0.035	0.029
Inorganic Nitrogen	Logan House Creek									0.0474	0.0155	0.0250	0.0373	0.037	0.014	0.016	0.012	0.011
(mg/l)	Glenbrook Creek									0.0537	0.0274	0.0200	0.0200	0.014	0.124	0.006	0.029	0.016
	Edgewood Creek											0.0625	0.0359	0.055	0.036	0.021	0.035	0.035
	Third Creek		13	105	48	28	27			16	8	80	447	332	1141	60	491	73
Total Suspended	Incline Creek									44	82	40	37	27	73	34	124	39
Sediment	Logan House Creek									3	10	5	3	7	10	5	43	19
(mg/l)	Glenbrook Creek									5	11	6	5	6	11	22	29	21
	Edgewood Creek											14	11	13	11	5	9	16

Source: TRPA, 1996


UPPER TRUCKEE RIVER AT SOUTH LAKE TAHOE, CALIFORNIA
10336610
IN REMAINDER OF YEAR
IN 10 PERCENT OF YEAR
IN 1 PERCENT OF YEAR
SUSPENDED-SEDIMENT DISCHARGE, IN METRIC TONS
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993
WATER YEAR

Wildlife

Range Management

Grazing of domestic livestock on National Forest System lands is one of the multiple uses managed by the Forest Service in the Lake Tahoe Basin. Grazing of cattle, horses, and sheep in the Basin began sometime in the late 1860's. This unregulated grazing resulted in overstocked and degraded rangelands. Around the turn of the century, Forest Reserves were created. Also grazing allotments were created on these reserves in order to partition the landscape into manageable units of land. These allotments were permitted to livestock operators to graze a specified type and number of animals for a given time period. Photographs show the condition and use levels of the Basin's rangelands in the early 1900's. Until the 1960's, livestock outnumbered humans in the Basin. As the Basin became more developed for human activities, livestock numbers declined.

In the 1990's, grazing on Forest Service managed lands within the Basin is limited to four active grazing allotments. These allotments are located primarily in the South Shore area. The Baldwin Allotment is located along Tallac Creek near the Baldwin and Ski Beach recreation areas. It encompasses approximately *210* acres and *50* horses/mules are permitted to graze from July 1 to December 1. The Cold Creek Allotment Is located at the headwaters of Cold Creek north of Freel Peak. The area is commonly known as "High Meadows" due to the large meadow that is privately owned within the allotment boundary. The

Site Index

Contact Us

allotment encompasses about *5,000* acres and 20 cow/calf pairs are permitted to graze from July 15 to October 15. The Meiss (pronounced "mice") Allotment is located along the headwaters of the Upper Truckee River at the southern end of Lake Tahoe's watershed near Carson Pass. Grazing is permitted on *11,275* acres from July 1 to September 25 for 200 cows and their calves. The Trout Creek Allotment is located at the headwaters of Trout Creek. The allotment is about *15,000* acres and 60 cow/calf pairs are permitted to graze from July 15 to September 15. Other forms of grazing are permitted within the Basin under our Special Uses program, these include: horse stables, special use pastures, and outfitter guide permits.

The emphasis of the Basin's range program is on maintaining healthy, functioning ecosystems and improving at risk ecosystems. This is achieved through planning, designing, and implementing proper livestock management practices. Forest Service resource staff have developed a variety of environmental indicators to be implemented that will help resources achieve desired condition on all of our allotments. Planning is used to bring all interested individuals together to discuss what resource problems exist, what is and isn't working with current management, and what options exist to improve resources and management. Designing a proper management practice requires an understanding of resource, livestock, and human needs in order to be successful. This usually involves Forest Service staff, interested individuals, and livestock operators. Implementation becomes the responsibility of the Forest Service and the rancher. This involves following the direction of the management plan and monitoring.

Monitoring is two fold and focuses on implementation (annual) and effectiveness (5-10yr) monitoring. Monitoring is done by Basin staff, grazing permittees, and other Forest Service staff. If monitoring indicates that resources aren't improving or management isn't properly implemented then adaptive management is used to improve conditions.

Current management of the Basin's rangelands has led to a steady improvement of natural resources affected by grazing. Recent photographs show a positive trend in the recovery of degraded areas. The goal of the Forest Service in Lake Tahoe is to continue to improve at risk and maintain healthy rangelands so that all present and future users may benefit.

Last updated: Thursday, October 04, 2001

TAHOE BASIN MONITORING

07/09/00

Site	Date	ID	Location	Depth msl	Temp C	pH	EC umhos	Cl mg/L	COD mg/L	NO3-N mg/L	Comment
Buried Sludge Monitoring											
MW11	06/20/00	20000620-13	Sludge Pond	6267.8	8.1	6.79	77	0.8	< 5.0	0.076	
MW12	06/20/00	20000620-14	Sludge Pond	6266.0	8.6	6.22	147	1.9	< 5.0	0.119	
MW13	06/20/00	20000620-15	Sludge Pond	6257.2	7.1	6.83	729	2.6	16.3	1.520	
ERB Monitoring											
CONTROL	06/20/00	20000620-06	At Post Office	6282.9	9.8	7.01	175	6.9	< 5.0	2.490	
MW01.5	06/20/00	20000620-07	SW corner of ERB	6268.8	10.4	7.25	170	2.9	< 5.0	0.630	
MW02-50	06/20/00	20000620-08	Black Bart side of ERB	6268.6	11.0	6.87	408	38.9	< 5.0	8.820	
MW03-50	06/20/00	20000620-09	Black Bart side of ERB	6268.6	11.0	6.56	375	33.4	< 5.0	3.490	
MW04-50	06/20/00	20000620-10	Hank Monk side of ERB	6268.7	8.8	6.67	75	4.9	< 5.0	0.057	
MW07-50	06/20/00	20000620-11	North side of ERB	6279.3	8.8	6.30	261	26.7	< 5.0	0.649	
Heavenly Valley Creek											
HVC-1	06/02/00	20000602-06	Downstream of Pioneer		5.8	7.62	33	0.6	< 5.0	0.015	
HVC-2	06/02/00	20000602-07	250' upstream of Pond #2		5.4	7.40	35	0.7	< 5.0	< 0.010	
HVC-3	06/02/00	20000602-08	25' downstream of Johnson Blvd		5.4	7.44	36	0.9	< 5.0	0.015	
HVC-4	06/02/00	20000602-09	Effluent of drain from Lower Shop		9.4	7.41	115	0.7	< 5.0	0.071	
HVC-5	06/02/00	20000602-HVC5	Effluent of drainage pipe along Jo								Dry
Treatment Plant Monitoring											
MW08-25	06/20/00	20000620-12	SW side of Pond #1	6247.4	10.1	6.30	1031	50.6	85.2	< 0.010	

Loads and Yields of Suspended Sediment and Nutrients for Selected Watersheds in the Lake Tahoe Basin, California and Nevada

Timothy G. Rowe, Hydrologist

U.S. Geological Survey

Abstract

The U.S. Geological Survey, in cooperation with the Tahoe Regional Planning Agency, has monitored tributaries in the Lake Tahoe Basin since 1988 to determine streamflow and concentrations of sediment and nutrients contributing to loss of clarity in Lake Tahoe. Loads and yields of suspended sediment and nutrients for 10 selected watersheds totaling nearly half the area tributary to Lake Tahoe (152 square miles [mi^2]) are described. The size of the watersheds ranges from 2.15 mi^2 (Logan House Creek) to 56.5 mi^2 (Upper Truckee River).

The Upper Truckee River had the largest median loads of sediment (7.2 tons per day [ton/d]) and nutrients, in pounds per day (lb/d): total ammonia plus organic nitrogen (TKN), 110; dissolved nitrite plus nitrate (NO_2+NO_3), 7.7; total phosphorus (TP), 31; and total bioreactive iron (Fe), 400 lb/d. Logan House Creek had the smallest loads of sediment (<0.01 ton/d) and nutrients (TKN, 0.26; NO_2+NO_3, 0.02; TP, 0.02; and Fe, 0.09 lb/d).

Third Creek had the largest yield for sediment (0.32 (ton/d)/mi^2) and Fe (13 lb/d/mi^2), Ward Creek for TKN (3.4 lb/d/mi^2) and TP (1.1 lb/d/mi^2), and Blackwood Creek for NO_2+NO_3 (0.68 lb/d/mi^2). Logan House Creek had the smallest yield for sediment (<0.01 ton/d/mi^2) and nutrients (TKN, 0.12; NO_2+NO_3, 0.01; TP, 0.01; and Fe, 0.04 lb/d/mi^2).

Introduction

Lake Tahoe is an outstanding natural resource and famous for its alpine setting and deep, clear waters. Protection of this renowned clarity has become very important in the past half century, as the clarity has been decreasing by about 1 foot per year (Goldman and Byron 1986). This decrease is due mainly to human activities, which have increased dramatically in the Lake Tahoe Basin since 1960.

Increased nutrient concentrations within Lake Tahoe are considered the primary cause of algal growth, and thereby loss of clarity, in the lake. Suspended sediment also is of concern, because nutrients attach to and are transported by sediment particles. Within the Lake Tahoe Basin, stream discharge is suspected of being one of the major pathways for nutrient and sediment transport to the lake. Increased development has accelerated this transport through urbanization of wetland areas, added erosion from development of steep mountain sides, and discharge by septic and sewage systems within the basin.

Public concern for the clarity of Lake Tahoe also has increased over the years. As an example, voters in Nevada passed bond acts in 1986 and 1996 to fund construction projects in Nevada to reduce erosion and the transport of nutrients and sediments to Lake Tahoe.

The Tahoe Regional Planning Agency (TRPA), the U.S. Geological Survey (USGS), the Tahoe Research Group of the University of California, Davis (TRG), and State and local agencies have been monitoring the Lake Tahoe Basin for nutrients and sediments since the 1970's. One cooperative program, a tributary-monitoring study by the USGS and TRPA, began in the 1988 water year. The primary purpose of the study was to provide a long-term data base for monitoring local water-quality thresholds and estimating the loads of nutrients and sediment from selected Lake Tahoe tributaries. This study initially included four Lake Tahoe Basin watersheds and has expanded over the years. The current network includes 32 stream sites in 14 of the 63 Lake Tahoe watersheds where sediment, nutrient, and streamflow data are collected (fig. 1 and Boughton et al 1997).

This paper presents findings from the cooperative study for 10 near-mouth sampling sites in 10 watersheds of the Lake Tahoe Basin during water years 1988-96. For this report, the period of record for four sites is 1988-96, and for six sites is 1993-96, although the data-collection effort is ongoing. All years referred to are water years—October 1 through September 30.

Nutrients sampled are total ammonia plus organic nitrogen (TKN), dissolved nitrite plus nitrate (NO_2+NO_3), total phosphorus (TP), and total bioreactive iron (Fe) (iron that is biologically available to phytoplankton). Suspended-sediment and nutrient data used in this report are from instantaneous samples collected during the day throughout the entire water year.

Description of Study Area

Lake Tahoe, the highest lake of its size in the United States, with an average lake-surface altitude of 6,225 ft above sea level, is about 22 miles (mi) long and 12 mi wide. The average depth of the lake is about 1,000 ft and the deepest part is 1,646 ft (fig. 1). The basin area is 506 square miles (mi^2), consisting of 192 mi^2 in lake-surface area and 314 mi^2 in surrounding watershed area (Crippen and Pavelka 1972). The highest altitude in the watershed is in the Trout Creek Basin (10,881 ft).

The 10 watersheds sampled for this study compose nearly half (152 mi^2) the watershed area. The size of the selected watersheds ranges from 2.15 mi^2 (Logan House Creek) to 56.5 mi^2 (Upper Truckee River). The main stream channel lengths range from 3.30 mi (Logan House Creek) to 21.4 mi (Upper Truckee River).

Precipitation, which falls mostly as snow from November into June, varies across the basin, from 30-40 inches per year (in/yr) on the eastern side to 70-90 in/yr on the western side (Crippen and Pavelka 1972). Annual precipitation in the basin was below normal for 6 years (1988-92 and 1994) and above normal during the remaining 3 years (1993, 1995, and 1996) of the study (Dan Greenlee, Natural Resources Conservation Service, oral commun., 1996).

Methods

Streamflow was measured and gaging stations were operated according to USGS guidelines (Buchanan and Somers 1969; Kennedy 1983). All streamflow data are available in USGS electronic data bases and USGS published annual Water Resources Data Reports for Nevada and California.

Drainage areas for sampling sites and total watershed areas (table 1) were reported by Cartier et al (1995), and channel lengths were reported by Jorgensen et al (1978).

Water-quality samples were collected using USGS guidelines (Edwards and Glysson 1988). The samples were analyzed for nutrients and iron by TRG laboratories in Davis and Tahoe City, Calif., according to procedures described by Hunter et al (1993). The samples were analyzed for suspended sediment by the USGS California Sediment Laboratory in Salinas, Calif., using USGS guidelines (Guy 1969). All water-quality data are available in USGS data bases and in published annual Water Resources Data Reports for Nevada and California.

Daily loads of suspended sediment and nutrients were calculated by multiplying the instantaneous nutrient and suspended-sediment concentration values by the instantaneous streamflow value and converting the product to tons per day or pounds per day.

For each watershed, summary statistics were calculated for loads of suspended sediment and the four nutrients using methods described by Helsel and Hirsch (1992) and are shown in figure 3; median daily loads are presented in table 3. Median values were chosen as preferable summary values because they are not strongly influenced by a few extreme values.

Median loads were normalized to a common unit (square miles), and the resulting yields were ranked for each of the 10 sampled watersheds, with a rank of 1 assigned to the highest median yield and 10 to the lowest. Rankings were then summed up for all sediment and nutrients and divided by five to give an overall general ranking of the sampled watersheds for yields.

Results

Instantaneous streamflow at the time of sample-collection visits ranged from 0 cubic feet per second (ft^3/s), at two sites during low base-flow periods in July 1988 and August 1994, to 1,750 ft^3/s at Upper Truckee River during a rain storm at the spring snowmelt-runoff peak in May 1996. The highest median streamflow value for sampling visits was 158 ft^3/s at Upper Truckee River. The lowest median streamflow value was 0.20 ft^3/s at Logan House Creek (table 2).

For periods of record discussed herein, the Upper Truckee River had the highest average annual daily mean streamflow, 123 ft^3/s, and highest average annual runoff, 89,000 acre feet (acre-ft), and Logan House Creek had the lowest at 0.30 ft^3/s and 221 acre-ft, respectively. The highest average annual unit runoff, 2,860 acre-ft/mi^2, was in Blackwood Creek and the lowest, 106 acre-ft/mi^2, was in Logan House Creek.

The hydrograph of daily mean streamflow for Incline Creek (fig. 2*A*) for 1996 shows a seasonal pattern that is typical of streams in the Lake Tahoe Basin. Most runoff is during the April-through-June snowmelt period. Sharp peaks represent fall and early winter rains (December), rain-on-snow storms (February), and summer thunderstorms (May and July).

The longer term hydrograph (fig. 2*B*) for Incline Creek for the 9-year period of record discussed herein clearly shows the effects of drought (water years 1988-92 and 1994), as compared to years in which runoff was above normal (1993, 1995, and 1996). The average annual daily mean streamflow for the 9 years is 6.26 ft^3/s.

Instantaneous measurements of suspended-sediment concentrations from the 10 stream sites ranged from <1 milligrams per liter (mg/L) at many sites during the summer to 3,930 (mg/L) at Third Creek during a rainstorm on snowpack in March 1993 (table 3). Median values ranged from 3.0 mg/L at Logan House

Creek, to 80 mg/L in Third Creek.

Median suspended sediment loads ranged from <0.01 ton per day (ton/d) for Logan House Creek to 7.2 ton/d in the Upper Truckee River. Median yields of sediment showed different results—from 0.01 ton per day per square mile (ton/d/mi^2) for Logan House Creek to 0.32 ton/d/mi^2 for Third Creek. When yields were ranked, Third Creek had the highest rank (1) and Logan House Creek had the lowest (10; table 3).

Instantaneous measurements of nutrient concentrations varied throughout the basin (table 3). For TKN, the range was <0.01 mg/L-24 mg/L, both at Third Creek, with the highest during a summer thunderstorm in July 1990. Median TKN values ranged from 0.12 mg/L in Ward and General Creeks to 0.23 in Third Creek. For NO_2+NO_3, the range was from <0.001mg/L for two sites to 1.25 mg/L at Glenbrook Creek during a rainstorm on snowpack in March of 1993. Median $NO_2 + NO_3$ values ranged from 0.005 mg/L in General Creek to 0.031 mg/L in Incline Creek. For TP, the range was from <0.001 mg/L at Logan House Creek to 9.42 mg/L at Third Creek during the summer thunderstorm in July 1990. Median TP values ranged from 0.020 mg/L in Logan House Creek to 0.052 mg/L in Incline Creek. For Fe, the range was from 8 micrograms per liter (μ g/L) to 33,900 μ g/L, both at Ward Creek, with the highest during a rainstorm in October 1994. Median Fe values ranged from 74.5 μ g/L in Logan House Creek to 1,360 μ g/L in Third Creek.

The Upper Truckee River had the largest median daily load of all nutrients (TKN, 110; NO_2+NO_3, 7.7; TP, 31; and Fe, 400 lb/d), whereas Logan House Creek had the smallest (TKN, 0.26; NO_2+NO_3, 0.02; TP, 0.02; and Fe, 0.09 lb/d). Summary statistics for sampled loads for the 10 watershed sites are depicted by box plots in figure 3.

Median daily yields for TKN ranged from 0.12 lb/d/mi^2 at Logan House Creek to 3.4 lb/d/mi^2 at Ward Creek. NO_2+NO_3 ranged from 0.01 lb/d/mi^2 at Logan House Creek to 0.68 lb/d/mi^2 at Blackwood Creek. TP ranged from 0.01 lb/d/mi^2 at Logan House Creek to 1.1 lb/d/mi^2 at Ward Creek. Fe ranged from 0.04 lb/d/mi^2 at Logan House Creek to 13 lb/d/mi^2 at Third Creek.

Median daily yields were ranked for each constituent by watershed. These rankings represent degree of potential constituent contribution to Lake Tahoe, per unit area of watershed, with 1 indicating the highest contribution and 10 the lowest. For TKN, Ward Creek ranked highest and Logan House Creek the lowest; for NO_2+NO_3, Blackwood Creek was the highest and Logan House Creek the lowest; for TP, Ward Creek was highest and Logan House Creek the lowest; and for Fe, Third Creek was the highest and Logan House Creek the lowest. When the ranks of yields for suspended sediment and the four nutrients were averaged, Blackwood Creek was highest and Logan House Creek lowest. The overall ranking, from highest to lowest, (fig. 3), was Blackwood Creek, Ward Creek, Third Creek, Upper Truckee River, Incline Creek, General Creek, Trout Creek, Edgewood Creek, Glenbrook Creek, and Logan House Creek.

Discussion

Concentrations of suspended sediment and nutrients varied widely in the sampled watersheds of the Lake Tahoe Basin. This variation is largely due to differences in weather patterns, precipitation amounts, and natural conditions across the basin. For example, more precipitation falls on the western side of Lake Tahoe, and the streamflow runoff and sediment and nutrient loads reflect that. The years of drought conditions also reduced both nutrient and sediment loads in the watersheds.

When the concentrations are flow-weighted and loads are calculated, the largest loads are in the Upper Truckee River watershed. This is solely because the Upper Truckee River is the largest watershed and delivers the greatest annual runoff to Lake Tahoe. The smallest loads are from Logan House Creek, which is the smallest of the 10 sampled watersheds and delivers the least annual runoff to the lake.

Third Creek has the highest sediment and Fe yield, which is due to the exposed soil caused by the large snow and rock avalanche of February 17, 1986, in the upper reach (Bill Quesnel, Incline Village General Improvement District, oral commun., 1992). Ward Creek had the highest yield for TKN and TP and Blackwood Creek the highest for NO_2+NO_3, possibly because of human activities in the area.

The ordered ranks show that the largest yields of sediment and nutrients were in Blackwood Creek, followed by Ward Creek, Third Creek, Upper Truckee River, and Incline Creek. The watersheds with the smallest yields are Glenbrook and Logan House Creeks. This ranking agrees with a suspended-sediment study on nine Lake Tahoe Basin watersheds (eight of which are included here) between 1981-85 by Hill and Nolan (1988). They found that the highest annual suspended-sediment yields were from Blackwood Creek, Ward Creek, Upper Truckee River, and Third Creek.

For the 10 selected watersheds, the higher yields were from six watersheds on Lake Tahoe's western, southern, and northern sides, all of which receive greater precipitation and are more developed and affected by human activities. The lower yields were from four watersheds on the eastern side, which receive less precipitation and are somewhat less developed.

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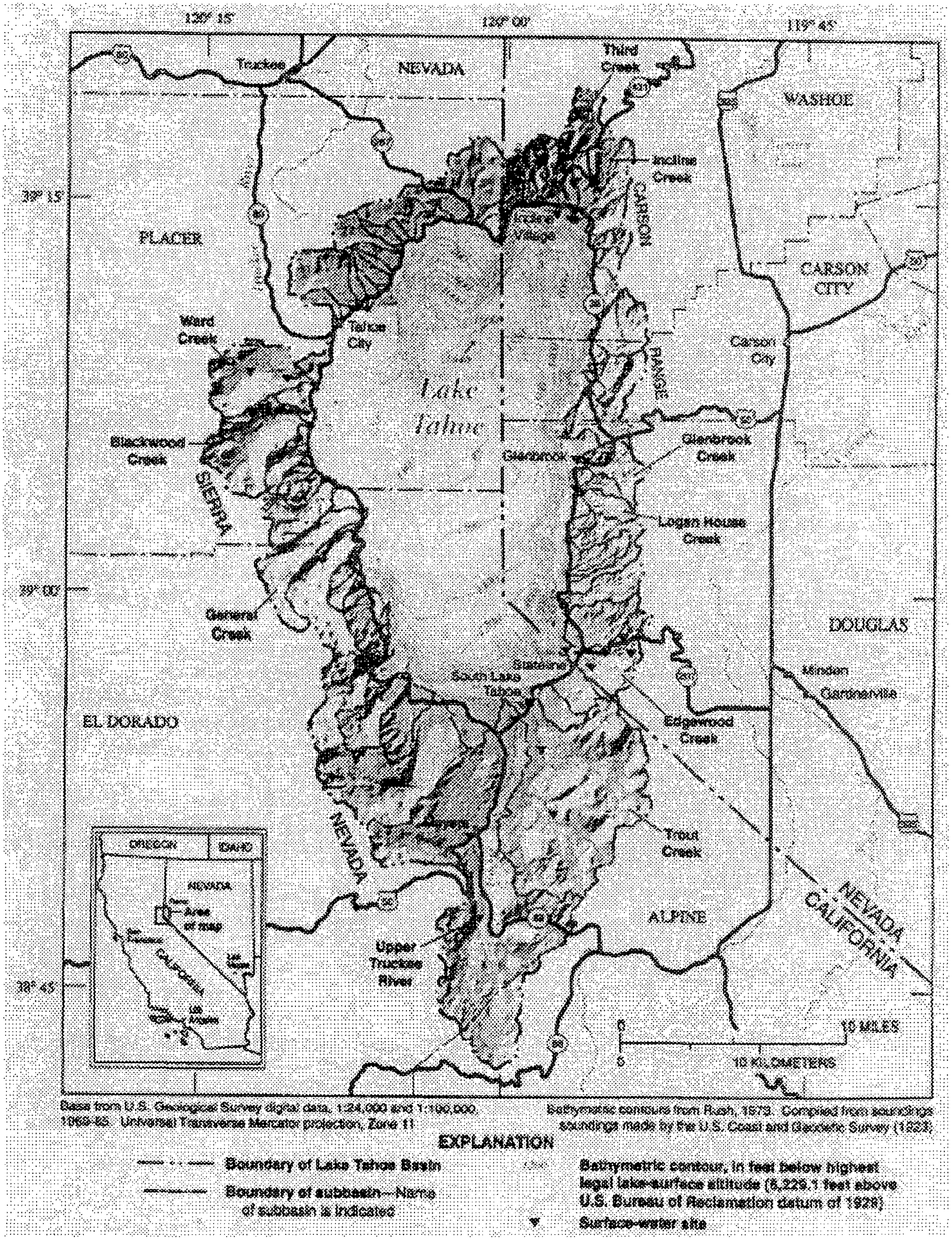

1. Geographic setting, hydrologic basins, bathymetry, surface-water sampling sites, and selected watersheds in the Lake Tahoe Basin (modified from Rowe and Stone 1997).

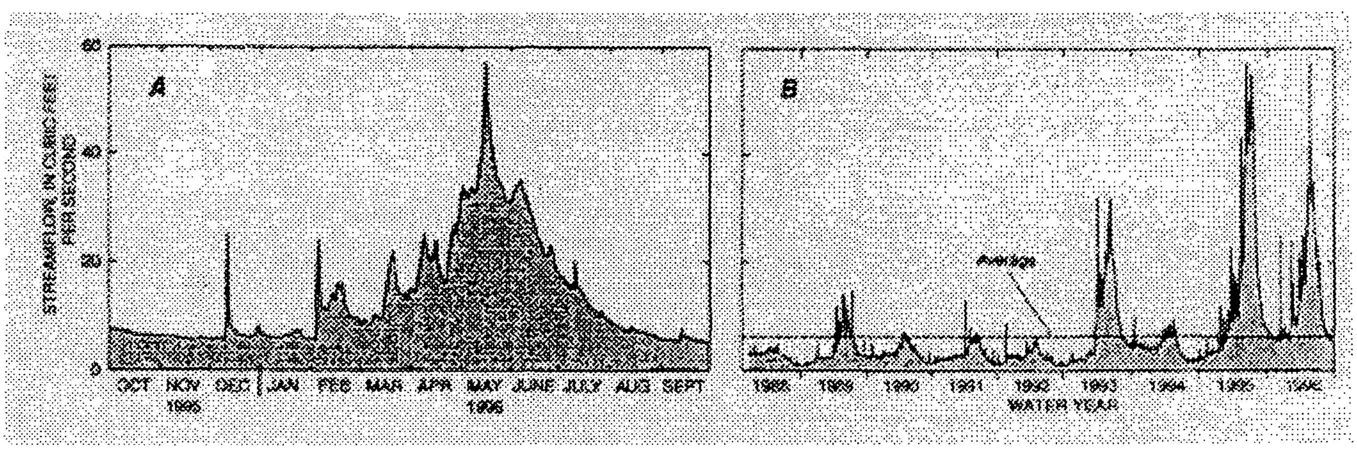

Figure 2. (A) Daily mean streamflow for Incline Creek during 1996 water year, a representative stream in the Lake Tahoe Basin; (B) Daily mean streamflow for Incline Creek, 1988-96 water years, representing years of drought and above-normal runoff.

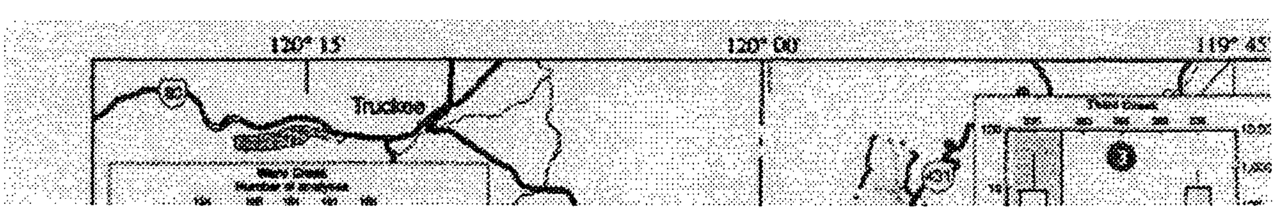

Figure 3. Daily suspended-sediment and nutrient loads depicted by box plots and yield ranks for selected surface-water sampling sites in the Lake Tahoe Basin, 1988-96 (modified from Boughton et al 1997).

Table 1. Sampling-Site Information for Selected Lake Tahoe Basin Watersheds

Sampling site (figure 1)	Total watershed drainage area (square miles)[a]	Sampling-site drainage area (square miles)	Main channel length(miles)[b]
Third Creek near Crystal Bay, Nev.		6.02	7.05
Incline Creek near Crystal Bay, Nev.	6.05	6.69	4.66
Glenbrook Creek at Glenbrook, Nev.	6.70	4.10	3.92
Logan House Creek near Glenbrook, Nev.	4.11	2.09	3.30
Edgewood Creek at Stateline, Nev.	2.15	5.61	5.53
	6.64		
Trout Creek at South Lake Tahoe, Calif.	41.2	40.4	10.7
Upper Truckee River at South Lake Tahoe, Calif.	56.5	54.0	21.4
General Creek near Meeks Bay, Calif.	7.63	7.39	9.17
Blackwood Creek near Tahoe City, Calif.	11.2	11.1	6.20
Ward Creek near Tahoe Pines, Calif.	9.75	9.73	5.90

[a]From Cartier et al 1995.

[b]From Jorgensen et al 1978.

Table 2. Streamflow Information for Selected Lake Tahoe Basin Watersheds

[Abbreviations: acre-ft, acre-feet; ft^3/s, cubic feet per second; ft, feet; mi^2, square miles.]

Sampling site	Range and median of sampled streamflow[a] (ft^3/s)	Period of record (water years)	Average annual mean daily streamflow (ft^3/s)	Average annual runoff (acre-ft)	Average annual yield[b] (acre-ft/mi^2)
Third Creek		1988-96	6.68	4,830	802
Incline Creek	0.93 - 118 (6.0)	1988-96	6.26	5,040	753
Glenbrook Creek	.56 - 71 (5.7)	1988-96	1.30	943	230
Logan House Creek	0 - 35 (0.88)	1988-96	.30	221	106
Edgewood Creek	0 - 7.9 (0.20)	1993-96	3.72	2,690	480
	1.1 - 25 (3.6)				
Trout Creek	3.2 - 305 (49.5)	1993-96	44.8	32,400	802
Upper Truckee River	.70 - **1,750**[c] **(158)**	1993-96	**123**	**89,000**	1,650
General Creek	.41 - 559 (30.5)	1993-96	20.2	14,700	1,990
Blackwood Creek	1.1 - 936 (60.0)	1993-96	44.0	31,800	**2,860**
Ward Creek	.22 - 950 (47.5)	1993-96	32.1	23,200	2,380

[a]Median, in parentheses, equals 50-percent value.

[b]Yield is annual runoff divided by sampling-site drainage area.

[c]**Bold** indicates highest value.

Table 3. Suspended-Sediment and Nutrient Information for Selected Lake Tahoe Basin Watersheds

[Nutrient concentrations from Tahoe Research Group, University of California, Davis (1996). Abbreviations: mg/L, milligrams per liter; ton/d, tons per day; ton/d/mi^2, tons per day per square mile; lb/d, pounds per day; lb/d/mi^2, pounds per day per square mile; mg/L, micrograms per liter]

A. Suspended sediments				
Sampling site	Instantaneous measurement	Median load[b] (ton/d)	Median yield[c] (ton/d/mi^2)	Yield rank[d]

	Concentration range (mg/L)	Median concentration[a] (mg/L)			
Third Creek	1 - **3,930**[e]	**80**	1.9	**0.32**	**1**
Incline Creek	1 - 1,840	26	.62	.09	5
Glenbrook Creek	1 - 606	6.0	.02	.01	9
Logan House Creek	<1 - 388	3.0	<.01	.01	10
Edgewood Creek	1 - 130	5.0	.08	.01	8
Trout Creek	2 - 335	14	2.5	0.06	6
Upper Truckee River	1 - 458	15	**7.2**	.13	4
General Creek	<1 - 404	7.0	.43	.06	7
Blackwood Creek	1 - 1,080	16	2.6	.23	2
Ward Creek	<1 - 3,000	10	1.3	.14	3

B. Nitrogen and Phosphorus

Sampling site	Instantaneous measurement		Median load[b] (lb/d)	Median yield[c] (lb/d/mi²)	Yield rank[d]
	Concentration range (mg/L)	Median concentration[a] (mg/L)			
Total ammonia plus organic nitrogen					
Third Creek	<0.01- **24**	**0.23**	12	2.0	5
Incline Creek	.01 - 3.0	.21	9.6	1.4	7
Glenbrook Creek	.06 - 6.0	.20	1.1	.27	9
Logan House Creek	.03 - 1.7	.20	.26	.12	10
Edgewood Creek	.04 - 1.1	.21	4.8	.86	8
Trout Creek	0.03 - 2.1	0.21	69	1.7	6
Upper Truckee River	.05 - 1.2	.17	**110**	2.1	4
General Creek	.04 - .51	.12	22	2.9	3
Blackwood Creek	.02 - 1.7	.13	36	3.3	2
Ward Creek	.01 - 1.2	.12	33	**3.4**	**1**
Dissolved nitrite plus nitrate					

Third Creek	<0.001 - 0.439	0.014	0.60	0.10	6
Incline Creek	.003 - .330	**.031**	1.1	.17	3
Glenbrook Creek	<.001 - **1.25**	.010	.06	.02	9
Logan House Creek	.002 - .072	.013	.02	.01	10
Edgewood Creek	.002 - .070	.019	.45	.08	7
Trout Creek	0.002 – 0.060	0.008	3.1	0.08	8
Upper Truckee River	.002 - .050	.012	**7.7**	.14	5
General Creek	.002 - .033	.005	1.2	.16	4
Blackwood Creek	.002 - .086	.016	7.6	**.68**	**1**
Ward Creek	.001 - .072	.010	2.8	.29	2

(continued)

Table 3 (continued)

B. Nitrogen and Phosphorus (continued)

Sampling site	Instantaneous measurement		Median load[b] (lb/d)	Median yield[c] (lb/d/mi²)	Yield rank[d]
	Concentration range (mg/L)	Median concentration[a] (mg/L)			
Total phosphorus					
Third Creek	0.002 - **9.42**	0.051	2.2	0.37	5
Incline Creek	.004 - 1.12	**.052**	2.0	.29	7
Glenbrook Creek	.008 - 1.98	.039	.15	.04	9
Logan House Creek	<.001 - .160	.020	.02	.01	10
Edgewood Creek	.008 - .507	.041	1.2	.21	8
Trout Creek	0.003 - 0.393	0.041	15	0.36	6
Upper Truckee River	.004 - .222	.030	**31**	.57	3
General Creek	.007 - .275	.021	2.9	.39	4
Blackwood Creek	.010 - .994	.031	9.5	.86	2
Ward Creek	.008 - 2.02	.032	11	**1.1**	**1**

C. Total bioreactive iron

Sampling site	Instantaneous measurement		Median load[b] (lb/d)	Median yield[c] (lb/d/mi^2)	Yield rank[d]
	Concentration range (mg/L)	Median concentration[a] (mg/L)			
Third Creek	219 - 33,300	**1,360**	77	**13**	**1**
Incline Creek	226 - 28,500	1,060	65	9.8	3
Glenbrook Creek	43 - 27,700	504	3.7	.89	9
Logan House Creek	18 - 2,750	74.5	.09	.04	10
Edgewood Creek	34 - 6,540	607	15	2.7	7
Trout Creek	137 - 8,750	620	230	5.6	5
Upper Truckee River	53 - 4,210	394	**400**	7.4	4
General Creek	32 - 7,650	101	15	2.1	8
Blackwood Creek	103 - 14,800	440	110	10	2
Ward Creek	8 - **33,900**	159	44	4.5	6

[a] Median equals 50-percent value.

[b] Median load equals 50-percent value. Load = concentration x streamflow x load factor (0.0027 for ton/d; 5.394 for lb/day).

[c] Median yield is median load divided by sampling-site drainage area.

[d] Rank from 1 to 10: 1 indicates highest contribution of constituent and 10 lowest contribution. Overall rank for all constituents: (1) Blackwood Creek, (2) Ward Creek, (3) Third Creek, (4) Upper Truckee River, (5) Incline Creek, (6) General Creek, (7) Trout Creek, (8) Edgewood Creek, (9) Glenbrook Creek, and (10) Logan House Creek. See Figure 3.

[e] **Bold** indicates highest value.

Water Resources skip navigation Data Category: Geographic Area:

Water Quality Samples for California

USGS 10336610 UPPER TRUCKEE RIVER AT SOUTH LAKE TAHOE CALIF

El Dorado County, California
Hydrologic Unit Code 16050101
Latitude 38°55'22", Longitude 119°59'23" NAD27
Drainage area 54.90 square miles
Gage datum 6,229.04 feet above sea level NGVD29

Output formats

- Parameter Group data summary
- Inventory of available water-quality data
- Inventory of water-quality data with retrieval
- Tab-separated ASCII file, serial order
- Tab-separated ASCII file, wide order
- Reselect output format

SAMPLE DATETIME	MEDIUM CODE	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS TOTAL (MG/L AS P) (00665)
1996-10-01 10:30	9	.1471	.0107	.0228
1996-11-05 12:40	9	.3291	.0094	.0169
1996-11-18 15:30	9	.269	.0201	.105
1996-11-19 13:35	9	.2758	.0183	.0665
1996-12-05 13:15	9	.0761	.0108	.1439
1996-12-09 14:30	9	.1872	.0168	.0197
1996-12-12 14:00	9	.2041	.01	.0736
1996-12-13 13:00	9	.1726	.0056	.0474
1996-12-31 15:45	9	.3389	.0123	.078
1997-01-01 17:00	9	.3965	.0119	.2303
1997-01-02 16:40	9	.2146	.0049	.2222
1997-01-03 11:45	9	.1587	.0092	.0985
1997-01-08 12:30	9	.2258	.02	.036
1997-03-13 13:10	9	.1827	.0185	.0328

1997-03-27 11:00	9	.0973	.0397	.0347
1997-04-09 12:45	9	.2941	.016	.0184
1997-05-02 10:30	9	.2059	.0093	.0182
1997-05-08 09:30	9	.2209	.0061	.0173
1997-05-15 15:10	9	.1147	.0057	.0421
1997-05-16 07:45	9	.1669	.0025	.0497
1997-05-22 13:20	9	.2075	.0397	.033
1997-05-30 11:20	9	.0932	.0058	.0271
1997-06-06 14:00	9	.126	.0065	.0293
1997-06-13 12:15	9	.085	.01	.0363
1997-06-20 15:50	9	.0739	.0085	.0428
1997-06-27 13:15	9	.1471	.0101	.0217
1997-07-23 12:40	9	.0677	.0166	.0363
1997-08-19 12:40	9	.1482	.0117	.0428
1997-08-19 13:05	9	≤ .2	≤ .09	≤ .01
1997-09-17 11:45	9	.0701	.0081	.0235
1997-10-21 11:30	9	.1085	.0165	.0169
1997-11-25 11:40	9	.1012	.009	.0179
1997-12-15 13:10	9	.1031	.0255	.0381
1998-01-16 13:30	9	.4571	.0261	.1114
1998-01-22 15:30	9	.2083	.0321	.0204
1998-02-25 12:00	9	.1398	.0406	.024
1998-03-18 12:30	9	.1647	.0218	.0261
1998-03-25 13:30	9	.4653	.0293	.0639
1998-04-21 14:20	9	.1208	.0153	.0278
1998-04-30 13:15	9	.1512	.0159	.0242
1998-05-05 13:30	9	.1013	.0119	.0187
1998-05-13 12:00	9	.2009	.0196	.0235
1998-05-20 12:40	9	.0912	.0148	.0263
1998-05-28 14:50	9	.0977	.0137	.0208
1998-06-03 12:55	9	.1152	.0135	.0305
1998-06-07 14:15	9	.2109	.0138	.0707

1998-06-11 14:15	9	.1566	.0095	.0606
1998-06-17 11:20	9	.1158	.0074	.0426
1998-06-23 15:40	9	.2262	.0034	.0357
1998-06-30 16:10	9	.1447	.0104	.0491

SAMPLE DATETIME	MEDIUM CODE	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)
1998-07-15 15:15	9	.0847	.0092	.0331
1998-07-29 10:30	9	.0813	.0118	.0343
1998-08-13 12:45	9	.0488	.006	.024
1998-09-09 15:30	9	.1516	.0034	.0292
1998-09-29 14:15	9	.1292	.0094	.0184
1998-10-28 09:50	9	.1139	.0153	.0151
1998-11-30 10:30	9	.3196	.0223	.0528
1998-12-22 11:30	9	.1406	.0321	.0207
1999-01-22 11:10	9	.2546	.0416	.0676
1999-02-26 16:30	9	.1799	.0404	.0291
1999-03-18 16:20	9	.1543	.0213	.0276
1999-03-24 11:20	9	.1734	.0231	.0225
1999-04-16 09:45	9	.1721	.0293	.0234
1999-04-21 13:20	9	.1916	.0279	.0391
1999-04-28 14:05	9	.1027	.0307	.016
1999-05-07 09:10	9	.2161	.0143	.0391
1999-05-10 17:00	9	.1169	.022	.0269
1999-05-13 14:40	9	.5937	.0163	.048
1999-05-20 14:00	9	.205	.0162	.0263
1999-05-26 11:00	9	.241	.0165	.0657
1999-06-03 12:40	9	.128	.0057	.0325
1999-06-09 09:50	9	.0826	.013	.0205
1999-06-14 08:05	9	.1042	.0039	.0549

1999-06-21 11:30	9	.0836	.0075	.0271
1999-07-07 11:00	9	.1251	.0132	.0277
1999-08-19 10:50	9	.0846	.0145	.0257
1999-09-21 10:00	9	.062	.0189	.0266

Water Quality Remark Code	Description
<	Actual value is known to be less than the value shown.

Questions about data gs-w-ca_NWISWeb_Data_Inquiries@usgs.gov
Feedback on this website gs-w-ca_NWISWeb_Maintainer@usgs.gov

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Water Quality Samples for California: Sample Data
http://water.usgs.gov/ca/nwis/qwdata?

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USGS Water Resources of California
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3.5 0.94

From: Robert Erlich
To: Unsicker, Judith
Date: 10/12/01 5:50PM
Subject: Re: Fwd: Upper Truckee R. & Snow Creek /303(d) listing

Language (modified) is generally from May 1999 NOA for Snow Ck

The project area is the 100-year floodplain of Snow Creek, a tributary to Lake Tahoe, which adjoins State Route 28 (SR28) in the commounity of Tahoe Vista, California. The California Tahoe Conservancy owns the project area and is coordinating restoration activities with the Placer County Department of Public Works, who has overseen construction of the project and mainatain the improvements during the initial establishment period (first three years). The project involves activities to restore and enhance approximately 4 acres of SEZ, wetlands and other waters of the State, removal of waste earthen materials (approximately 22,000 cubic yards), and highway culvert modifications to reduce flooding.

Following fill removal, the existing constructed pond was be made smaller and reconfigured as a seasonal meadow wetlands. Channels were reconfigured to promote more frequent inundation of the meadow areas, and the area was revegetated with a variety of wetland and riparian plant species. Approximately 75% of the the project area had been occupied by sparsely vegetated earthen fill. The project revegeates and restores approximately 2.4 acres of SEZ and naturally functioning wetlands.

CC: Kemper, Lauri

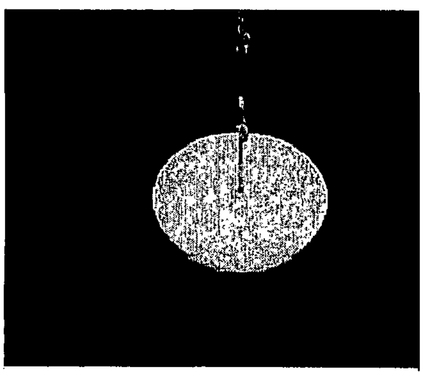
UC DAVIS TAHOE RESEARCH GROUP

Changes in Water Clarity at Lake Tahoe

Alan D. Jassby, Charles R. Goldman, John E. Reuter and Robert C. Richards
Department of Environmental Science & Policy, University of California, Davis, California 95616, USA

The optical clarity of water plays an important role in our casual judgments about water quality. Clarity is often used by the layperson as a basis for judging potability as well as the safety of water contact. In pristine water bodies, both freshwater and marine, optical clarity can also be an important aesthetic characteristic.

The *Secchi depth* is one common measure of optical clarity in lakes and the oceans. It is simply the depth at which an 8 or 10-inch white disc disappears from view at the surface when lowered into the water. Secchi depth measurements have been collected from many locations around the world for more than a century. Because of its apparent simplicity, the Secchi disk is sometimes dismissed as an "archaic" instrument by the novice. Quite to the contrary, it has a number of important and desirable features. First, Secchi depth is a reproducible measurement of clarity when carefully executed, more precise in fact than some electronic measures of light scattering. Second, the physics of Secchi depth measurement is well understood and Secchi depth can therefore be incorporated into rigorous predictive models. Third, Secchi depth quantifies clarity as perceived by the human visual system and is accordingly a highly suitable management endpoint for lakes. Finally, it is the only consistent optical measurement made in Lake Tahoe (and many other water bodies) that dates back several decades and can therefore be used to detect trends.

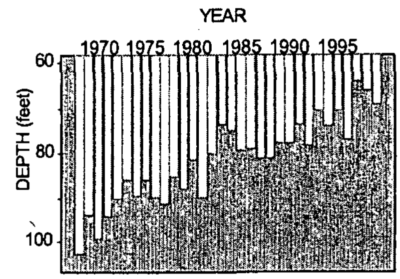


A Secchi disk just below the water surface, on its way down to check water clarity

Large clarity declines have occurred over the last few decades in some of our most transparent water bodies, including Lake Tahoe. Secchi depths of over 120 feet were recorded in the early years of the measurement program at Lake Tahoe and still occasionally exceed 90 feet. The long-term decline, though, is a matter of great concern. Overall, the decrease in Secchi depth regardless of season has averaged almost one foot per year. Because of Tahoe's unique beauty, protection of its water clarity has become an issue of pressing concern for watershed residents and the millions of annual recreational visitors.

Lake Tahoe waters have been losing transparency at an average of about one foot each year since the late 1960s.

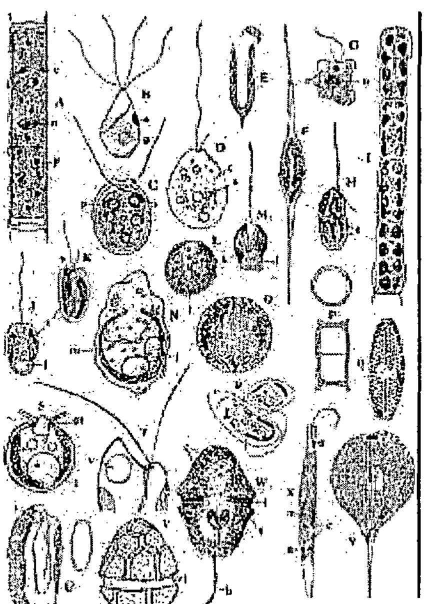
The decline in transparency is due to increases in both algae and mineral particles. Attached algae around the lake margins has proliferated over the past few decades, and microscopic drifting algae called *phytoplankton* living in the open waters has also increased. These increases have been fueled by nitrogen and phosphorus falling on the lake from the atmosphere and washing in from the watershed. In addition to these nutrients, clay and silt particles are also carried in by streams. These mineral particles, like the phytoplankton, cause light to scatter and decrease water clarity. The relative roles of phytoplankton and mineral particles are important because they determine whether the focus should be on controlling phytoplankton growth, mineral particles, or both.



The depth at which a white disk can be seen from the surface changes from year to year but generally has become shallower over the decades.

Transparency declines are due to both phytoplankton increases and to clay and silt particles washed in from the watershed.

The long time series of Secchi depth for Lake Tahoe not only records trends in water clarity but enables us to distinguish the underlying causes. Secchi depth has been measured in Lake Tahoe an average of every 12 days since July 1967. There is a marked seasonal pattern with a minimum (i.e., low clarity) in June and in December. The June low is due to accumulation of mineral particles carried in by the melting snow pack; a spring increase of phytoplankton also contributes. Generally speaking, the larger the snow pack, the bigger the decline in clarity. The December low results from the deeper and deeper mixing of the lake that starts in autumn. As the waters mix, layers of phytoplankton and other particles far below the surface are carried into upper waters where they lower the transparency. This December drop in clarity was almost nonexistent when measurements began in 1967 but it has become stronger over the years as phytoplankton growth and mineral particle inputs have increased. It is not yet fully understood how much of this long-term decrease is due to phytoplankton and how much to clay and silt. Based on the available measurements and physical considerations, both categories probably play a significant role of roughly similar magnitude.



Source: F.E. Fritsch

Microscopic phytoplankton take many unique and beautiful forms. Their exact contribution to the clarity decrease depends on their size, shape, and chemical composition, as well as their abundance.

Because of the large funds to be spent in the Tahoe Basin for protecting water quality, the relative importance of phytoplankton and mineral particles needs to be resolved more precisely. Management strategies to control algae and to control soil erosion are quite different. In addition, the size distribution of particles entering and within the lake needs to be determined. Long-term clarity losses due to mineral particles are dependent on a certain size fraction, namely the fraction that will be retained in the lake and contribute to a buildup of light-scattering particles. It will be of no help to control 99% of erosion if the microscopic particles most responsible for the clarity decline are still entering the lake. Finally, the time it takes for mineral particles to clear from the lake – their *residence time* – needs to be determined. Insofar as mineral particles contribute to the long-term loss of clarity, the recovery time for the lake is dependent on this residence time. All of these issues are part of the current focus of the Tahoe Research Group at UC Davis.

The relative importance of phytoplankton and mineral particles needs to be resolved for an effective management strategy.

Additional scientific information can be found in the following publications:

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Acknowledgments:

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CHANGES IN MTBE AND BTEX CONCENTRATIONS IN LAKE TAHOE, CA-NV

FOLLOWING IMPLEMENTATION OF A BAN ON SELECTED

2-STROKE MARINE ENGINES

Brant C. Allen & John E. Reuter

Tahoe Research Group

University of California, Davis

Davis, CA 95616

INTRODUCTION

Discovery of the fuel oxygenate methyl tert-butyl ether (MTBE) in groundwater, lakes and reservoirs used for drinking water has raised considerable concern among health officials and water suppliers. The U.S. EPA has classified MTBE as a possible human carcinogen. Recent legislation in California has established primary and secondary drinking water standards at 13 µg/L and 5 µg/L, respectively. Since 1997, the Lake Tahoe basin has received considerable state and national attention with regards to MTBE contamination of both groundwater drinking supplies and the lake itself.

Protection of the lake from controllable sources of pollution is required under its designation as an Outstanding National Water Resource (ONWR) as part of the federal Clean Water Act. Lake samples collected by the University of California, Davis - Tahoe Research Group (TRG), University of Nevada Reno (UNR), and the U.S. Geological Survey during the summers of 1997 and 1998 showed detectable levels of MTBE and the BTEX fuel constituents (benzene, toluene, ethylbenzene, and xylene), lake wide (e.g. Allen et al. 1998, Boughton and Lico 1998). Concentrations were shown to vary with the level of motorized watercraft traffic. However, at specific locations, levels exceeded not only the California drinking water standards but the higher U.S. EPA advisory value of 35 µg/L. Samples from the open water in the middle of the lake, where little summer boating occurs, revealed the presence of fuel constituents to a depth of 10 m, but at concentrations near or below the analytical levels of detection (mean value of

0.3 µg/L; Allen et al. 1998).

Along the shoreline of the lake where motorized watercraft activity is more common, fuel constituent concentrations were found to be about an order of magnitude higher (2.6 µg/L, mean value for MTBE). These shoreline concentrations were still below the established drinking water standards. In areas where motorized watercraft traffic is considered to be exceptionally high (marinas and fueling facilities), mean concentrations for both MTBE and benzene, during certain times of the summer boating season, exceeded primary drinking water standards. Further investigation by the California Air Resources Board (CARB) and UNR into the direct contribution of fuel constituents from various engine technologies revealed that the carbureted two stroke engines were contributing a disproportionate share of the fuel load to Lake Tahoe (Glenn Miller, University of Nevada, Reno, unpub. data). In fact, Allen et al. (1998) calculated that while using only 11-12% of the total fuel used for Lake Tahoe boating, these engines contributed 90% of the MTBE to the water. In contrast the 4-stroke engines consumed 87% of the fuel and but were responsible for only 8% of the estimated MTBE loading to the lake from all marine engines.

The results of these cumulative studies resulted in regulations imposed by the Tahoe Regional Planning Agency (TRPA), banning certain two stroke engine technologies. This ban took effect on June 1, 1999. Additionally, several large oil companies began producing gasoline without MTBE and delivering it to the south end of the lake. With both programs to abate MTBE loading to the lake and groundwater in place by late spring of 1999, the summer boating season was expected to produce lower levels of in-lake fuel constituents. The TRG began sampling in August to evaluate the effectiveness of these changes, i.e. comparison of lake concentrations of MTBE and BTEX in the summer of 1999 relative to 1997 and 1998.

METHODS

Sampling locations were selected to describe changes in MTBE and BTEX concentration in Lake Tahoe that may have resulted from the policy decisions above. Therefore, our sampling focused on locations which had positive results during the 1997 and 1998 monitoring. Site selection was separated into three categories; 1) an open water, midlake location where boating is minimal, 2) nearshore, at 10 locations around the perimeter of the lake, where the majority of boat occurs, and 3) 10 locations on the south shore where boat traffic is concentrated ("hot spots"), often associated with launch ramps, refueling facilities, marinas or a combination of the above. Within each category, specific sites were chosen, whenever possible, to replicate those sampled in previous years.

The timing of the sampling, late August and the Labor Day weekend in September, coincided with the peak of the summer boating season. Three sampling dates were chosen, mid-week (Wednesday and Thursday, 25 and 26 August, respectively). Weekend samples were collected on Monday (30 August), and the Labor Day weekend was represented by samples taken on the Tuesday after the holiday (7 September).

At all locations, with the exception of mid-lake, water samples were taken by hand at a depth of 0.5 m. Our previous sampling at Lake Tahoe showed this to be a representative depth for the nearshore stations. The closed VOA vials were submerged to the sampling depth and then opened and allowed to fill completely. The cap was replaced while submerged. Samples were checked to ensure no air space remained within the VOA vial before they were placed on ice in a cooler. The mid-lake samples were collected using a 1.2 L, stainless Kemmerer well sampler with Teflon end caps. The sampler was lowered to depth and closed with a messenger. Water was then transferred to the VOA vial and filled so that no air spaces remained. All samples were kept on ice from collection through transport to Lawrence Livermore National Laboratories (LLNL). All analytical determinations were made by LLNL staff at their facilities (C. Koester, pers. comm.)

RESULTS

Open water and nearshore samples showed a significant decrease in MTBE concentration when compared to data collected in 1997 and 1998. Generally, ambient concentrations decreased by a factor of 10 with samples around the north end of the lake (Homewood to Glenbrook) at or below the 0.06 µg/L level of detection. Samples collected in the vicinity of the south end of the lake (Zephyr Cove to Emerald Bay) showed a similar drop in concentration from previous years, but remained above the level of detection at a few tenths of a part per billion (µg/L). Ambient concentrations of the BTEX compounds (benzene, toluene, ethylbenzene, and xylene) at the nearshore locations were also found to be lower than levels recorded in the past two years of monitoring (Table 1).

Samples from the "hot spot" locations had greater MTBE levels than the nearshore and open water areas; four concentrations approached or exceeded drinking water standards. The remaining six "hot spots" had fuel concentrations similar to nearshore areas sampled during the 1997 and 1998 monitoring. At the four "hot spots" where fuel constituent concentrations neared or exceeded drinking water standards, MTBE and BTEX concentrations were highly variable. MTBE concentrations ranged from 0.46 µg/L up to 56.5 µg/L. This high value is over four times the primary drinking water standard of 13 µg/L. The dramatic difference in results between these "hot spots" and the remainder of the lake suggests source contamination has not been completely eliminated by actions to date, but that inputs to the lake were significantly reduced in the summer of 1999.

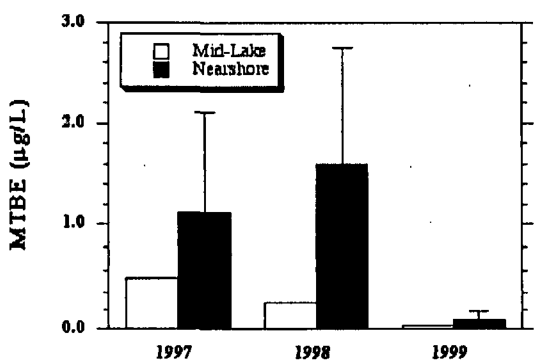
DISCUSSION

The sampling dates selected during this study were at the end of the summer boating season during the month of August and after the Labor Day weekend early in September. Allen et al. (1998) showed this period representative of high MTBE and BTEX concentrations in Lake Tahoe. With the exception of a few of the "hot spots", the data collected during this study showed little variation between sampling dates.

Comparisons of data collected during this study with that of previous years shows a dramatic decrease in MTBE concentration at both offshore and nearshore locations (86.7% and 95.8%, respectively)(Figure 1). This demonstrates that programs to eliminate MTBE from Lake Tahoe are having an effect. The offshore and most of the nearshore locations around the lake had MTBE concentrations at or near the analytical level of detection (LOD) throughout the sampling period

The sampling of "hot spots" around the south end of Lake Tahoe resulted in highly variable results (MTBE range <0.06 to 56.5 µg/L). MTBE samples collected at Ski Run Marina exceeded the California primary drinking water standard of 13 µg/L by four-fold on two separate sampling dates. Additionally the California drinking water standard for benzene (0.1 µg/L) was surpassed on the post Labor Day sampling, 7 September. These samples stand out from the rest as being extremely high even for the "hot spot" locations. The reasons may be due to above average concentration of boats per unit area or some problem with operations at the facilities. The two other locations where measured concentrations of MTBE approached or exceeded California drinking water standards where associated with boat launch ramps. Since neither location is in the immediate proximity of fueling facilities it is expected that the fuel constituents came from the boats themselves. While it is unclear how the fuel entered the water, any number of human errors and boat malfunctions could have contributed. One distinct possibility associated with launch ramps is the draining of the bilge upon removal of the boat from the water. Either the intentional removal of boat plugs to allow draining while on the incline ramp or the automatic operation of electrical bilge pumps when water rushes to the back of the boat will cause fuel laden water to flow directly into the lake in the vicinity of the ramp.

CONCLUSION



On the whole, fuel constituent concentrations in Lake Tahoe are down dramatically from previous years. This could be the result of the TRPA regulation banning certain two cycle engine technologies or as a byproduct of some service stations within the Tahoe basin selling MTBE-free fuel. A comparison of the decreases in ambient MTBE and toluene concentrations was done to determine which corrective action was having the greatest impact on Tahoe water quality. If the MTBE-free fuel was having the greatest impact, the ambient MTBE concentrations would be expected to decrease while toluene concentrations in the lake remained near the levels recorded in

1997 and 1998. If the new boating regulations were having the greatest impact, both MTBE and toluene concentrations could be expected to drop. Indeed both mean MTBE and mean toluene concentrations drop significantly (95.8% and 88.3% respectively) indicating that the elimination of the highly polluting two cycle engines is having a clear impact on water quality.

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PC11 Human Activities and Aquatic Ecosystems
Date: Thursday, February 15, 2001
Location: Southwest Hall

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SEASONAL SIGNIFICANCE OF ATMOSPHERIC DEPOSITION OF PHOSPHORUS AND THE SOURCES OF DEPOSITION FOR LAKE TAHOE, CA-NV

Increases in nutrient inputs, especially phosphorus, into Lake Tahoe are contributing to the rapid decrease of the Lake's famous clarity. Atmospheric deposition is estimated to be responsible for 20-30% of the annual external phosphorus inputs into Lake Tahoe. Seasonally, atmospheric fallout is more significant because the deposition of phosphorus can increase during the dry months when stream flows are very low. This phosphorus source also falls directly on the water surface into the photic zone, increasing its availability to algae. Bulk deposition measurements along Lake Tahoe's north shore were collected from July through September 2000. Preliminary analysis reveals that during this period, atmospheric deposition (predominantly dry) provided several times more phosphorus than streams. Approximately 50% of the total phosphorus was immediately biologically available. The phosphorus collected this summer may be slightly higher than long-term deposition data at Ward Creek, possibly due to collection differences. Future analysis of this summer's samples by electron microscopy will give clues to the sources of fallout materials and their relative importance. Road dust and wind-blown soil are predicted to be major summer sources.

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LOADS AND YIELDS OF SUSPENDED SEDIMENT FOR SELECTED WATERSHEDS IN THE LAKE TAHOE BASIN, CALIFORNIA AND NEVADA

By Timothy G. Rowe, Hydrologist, U.S. Geological Survey, Carson City, Nevada

Abstract:The U.S. Geological Survey, in cooperation with the Tahoe Regional Planning Agency, has monitored tributaries in the Lake Tahoe Basin since 1988 to determine streamflow and concentrations of sediment and nutrients contributing to loss of clarity in Lake Tahoe. Loads and yields of suspended sediment for 10 selected watersheds totaling nearly half the area tributary to Lake Tahoe (152 square miles [mi^2]) are described. The size of the watersheds ranges from 2.15 mi^2 (Logan House Creek) to 56.5 mi^2 (Upper Truckee River).

The Upper Truckee River had the largest median loads of sediment (7.2 tons per day [ton/d]), Logan House Creek had the smallest loads of sediment (<0.01 ton/d). Third Creek had the largest yield for sediment (0.32 (ton/d)/mi^2), Logan House Creek had the smallest yield for sediment (<0.01 ton/d/mi^2).

INTRODUCTION

Lake Tahoe is an outstanding natural resource and famous for its alpine setting and deep, clear waters. Protection of this renowned clarity has become very important in the past half century, as the clarity has been decreasing by about 1 foot per year (Goldman and Byron 1986). This decrease is due mainly to human activities, which have increased dramatically in the Lake Tahoe Basin since 1960.

Increased nutrient concentrations within Lake Tahoe are considered the primary cause of algal growth, and thereby loss of clarity, in the lake. Suspended sediment also is of concern, because nutrients attach to and are transported by sediment particles. Within the Lake Tahoe Basin, stream discharge is suspected of being one of the major pathways for nutrient and sediment transport to the lake. Increased development has accelerated this transport through urbanization of wetland areas, added erosion from development of steep mountain sides, and discharge by septic and sewage systems within the basin.

Public concern for the clarity of Lake Tahoe also has increased over the years. As an example, voters in Nevada passed bond acts in 1986 and 1996 to fund construction projects in Nevada to reduce erosion and the transport of nutrients and sediments to Lake Tahoe.

The Tahoe Regional Planning Agency (TRPA), the U.S. Geological Survey (USGS), the Tahoe Research Group of the University of California, Davis (TRG), and State and local agencies have been monitoring the Lake Tahoe Basin for nutrients and sediments since the 1970's. One cooperative program, a tributary-monitoring study by the USGS and TRPA, began in the 1988 water year. The primary purpose of the study was to provide a long-term data base for monitoring local water-quality thresholds and estimating the loads of nutrients and sediment from selected Lake Tahoe tributaries. This study initially included four Lake Tahoe Basin watersheds and has expanded over the years. The current network includes 32 stream sites in 14 of the 63 Lake Tahoe watersheds where sediment, nutrient, and streamflow data are collected (fig. 1 and Boughton et al 1997).

This paper presents findings from the cooperative study for 10 near-mouth sampling sites in 10 watersheds of the Lake Tahoe Basin during water years 1988-96. For this report, the period of record for four sites is 1988-96, and for six sites is 1993-96, although the data-collection effort is ongoing. All years referred to are water years—October 1 through September 30.

Suspended-sediment used in this report are from instantaneous samples collected during the day throughout the entire water year.

DESCRIPTION OF STUDY AREA

Lake Tahoe, the highest lake of its size in the United States, with an average lake-surface altitude of about 6,225 ft above sea level, is about 22 miles (mi) long and 12 mi wide. The average depth of the lake is about 1,000 ft and the deepest part is about 1,636 ft. The basin area is 506 square miles (mi^2), consisting of 192 mi^2 in lake-surface area and 314 mi^2 in surrounding watershed area (Crippen and Pavelka 1972). The highest altitude in the watershed is in the Trout Creek Basin (10,881 ft).

The 10 watersheds sampled for this study compose nearly half (152 mi^2) the watershed area. The size of the selected watersheds ranges from 2.15 mi^2 (Logan House Creek) to 56.5 mi^2 (Upper Truckee River). The main stream channel lengths range from 3.30 mi (Logan House Creek) to 21.4 mi (Upper Truckee River).

Precipitation, which falls mostly as snow from November into June, varies across the basin, from 30-40 inches per year (in/yr) on the eastern side to 70-90 in/yr on the western side (Crippen and Pavelka 1972). Annual precipitation in the basin was below normal for 6 years (1988-92 and 1994) and above normal during the remaining 3 years (1993, 1995, and 1996) of the study (Dan Greenlee, Natural Resources Conservation Service, oral commun., 1996).

METHODS

Streamflow was measured and gaging stations were operated according to USGS guidelines (Buchanan and Somers 1969; Kennedy 1983). All streamflow data are available in USGS electronic data bases and USGS published annual Water Resources Data Reports for Nevada and California.

Drainage areas for sampling sites and total watershed areas (table 1) were reported by Cartier et al (1995), and channel lengths were reported by Jorgensen et al (1978).

Suspended sediment samples were collected using USGS guidelines (Edwards and Glysson 1988). The samples were analyzed by the USGS California Sediment Laboratory in Salinas, Calif., using USGS guidelines (Guy 1969). All suspended sediments data are available in USGS data bases and in published annual Water Resources Data Reports for Nevada and California .

Daily loads of suspended sediment were calculated by multiplying the instantaneous suspended-sediment concentration values by the instantaneous streamflow value and converting the product to tons per day.

For each watershed, summary statistics were calculated for loads of suspended sediment using methods described by Helsel and Hirsch (1992); median daily loads are presented in table 3. Median values were chosen as preferable summary values because they are not strongly influenced by a few extreme values.

Median loads were normalized to a common unit (square miles), and the resulting yields were ranked for each of the 10 sampled watersheds, with a rank of 1 assigned to the highest median yield and 10 to the lowest.

RESULTS

Instantaneous streamflow at the time of sample-collection visits ranged from 0 cubic feet per second (ft^3/s), at two sites during low base-flow periods in July 1988 and August 1994, to 1,750 ft^3/s at Upper Truckee River during a rain storm at the spring snowmelt-runoff peak in May 1996. The highest median streamflow value for sampling visits was 158 ft^3/s at Upper Truckee River. The lowest median streamflow value was 0.20 ft^3/s at Logan House Creek (table 2).

For periods of record discussed herein, the Upper Truckee River had the highest average annual daily mean streamflow, 123 ft^3/s, and highest average annual runoff, 89,000 acre feet (acre-ft), and Logan House Creek had the lowest at 0.30 ft^3/s and 221 acre-ft, respectively. The highest average annual unit runoff, 2,860 acre-ft/mi^2, was in Blackwood Creek and the lowest, 106 acre-ft/mi^2, was in Logan House Creek.

The hydrograph of daily mean streamflow for Incline Creek (fig. 2*A*) for 1996 shows a seasonal pattern that is typical of streams in the Lake Tahoe Basin. Most runoff is during the April-through-June snowmelt period. Sharp peaks represent fall and early winter rains (December), rain-on-snow storms (February), and summer thunderstorms (May and July).

The longer term hydrograph (fig. 2*B*) for Incline Creek for the 9-year period of record discussed herein clearly shows the effects of drought (water years 1988-92 and 1994), as compared to years in which runoff was above normal (1993, 1995, and 1996). The average annual daily mean streamflow for the 9 years is 6.26 ft^3/s.

Instantaneous measurements of suspended-sediment concentrations from the 10 stream sites ranged from <1 milligrams per liter (mg/L) at many sites during the summer to 3,930 (mg/L) at Third Creek during a rainstorm on snowpack in March 1993 (table 3). Median values ranged from 3.0 mg/L at Logan House Creek, to 80 mg/L in Third Creek.

Median suspended sediment loads ranged from <0.01 ton per day (ton/d) for Logan House Creek to 7.2 ton/d in the Upper Truckee River. Median yields of sediment showed different results—from 0.01 ton per day per square mile ($ton/d/mi^2$) for Logan House Creek to 0.32 $ton/d/mi^2$ for Third Creek (fig. 3). When yields were ranked, Third Creek had the highest rank (1) and Logan House Creek had the lowest (10; table 3).

DISCUSSION

Concentrations of suspended sediment varied widely in the sampled watersheds of the Lake Tahoe Basin. This variation is largely due to differences in weather patterns, precipitation amounts, and natural conditions across the basin. For example, more precipitation falls on the western side of Lake Tahoe, and the streamflow runoff and sediment loads reflect that. The years of drought conditions also reduced sediment loads in the watersheds.

When the concentrations are flow-weighted and loads are calculated, the largest loads are in the Upper Truckee River watershed. This is solely because the Upper Truckee River is the largest watershed and delivers the greatest annual runoff to Lake Tahoe. The smallest loads are from Logan House Creek, which is the smallest of the 10 sampled watersheds and delivers the least annual runoff to the lake.

Third Creek has the highest sediment yield, which is due to the exposed soil caused by the large snow and rock avalanche of February 17, 1986, in the upper reach (Bill Quesnel, Incline Village General Improvement District, oral commun., 1992). The next largest yields of sediment were in Blackwood Creek, followed by Ward Creek, Upper Truckee River, and Incline Creek. The watersheds with the smallest yields are Glenbrook and Logan House Creeks. This ranking agrees with a suspended-sediment study on nine Lake Tahoe Basin watersheds (eight of which are included here) between 1981-85 by Hill and Nolan (1988). They found that the highest annual suspended-sediment yields were from Blackwood Creek, Ward Creek, Upper Truckee River, and Third Creek.

For the 10 selected watersheds, the higher yields were from six watersheds on Lake Tahoe's western, southern, and northern sides, all of which receive greater precipitation and are more developed and affected by human activities. The lower yields were from four watersheds on the eastern side, which receive less precipitation and are somewhat less developed.

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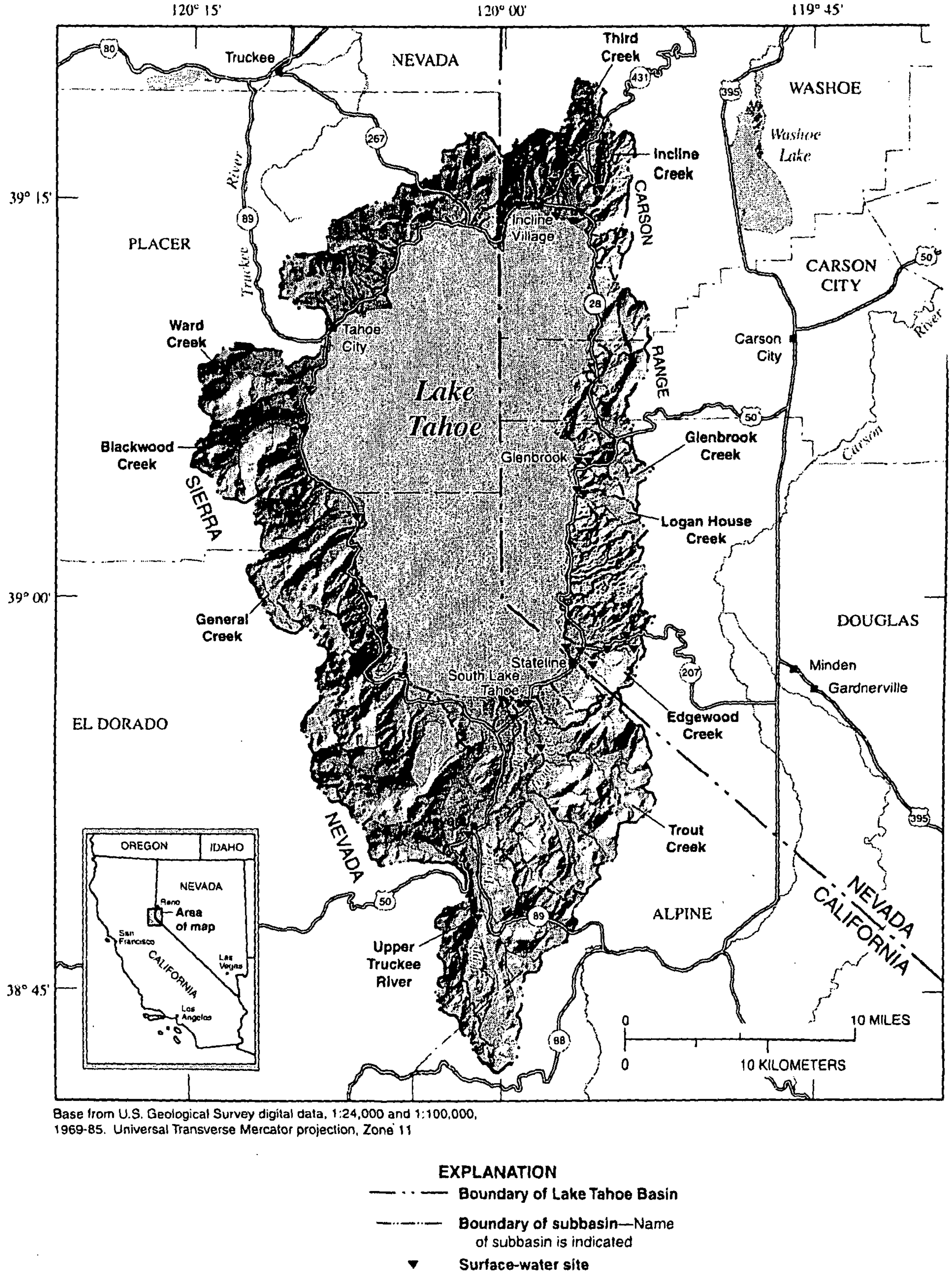


Figure 1. Geographic setting, hydrologic basins, bathymetry, surface-water sampling sites, and selected watersheds in the Lake Tahoe Basin (modified from Rowe and Stone 1997).

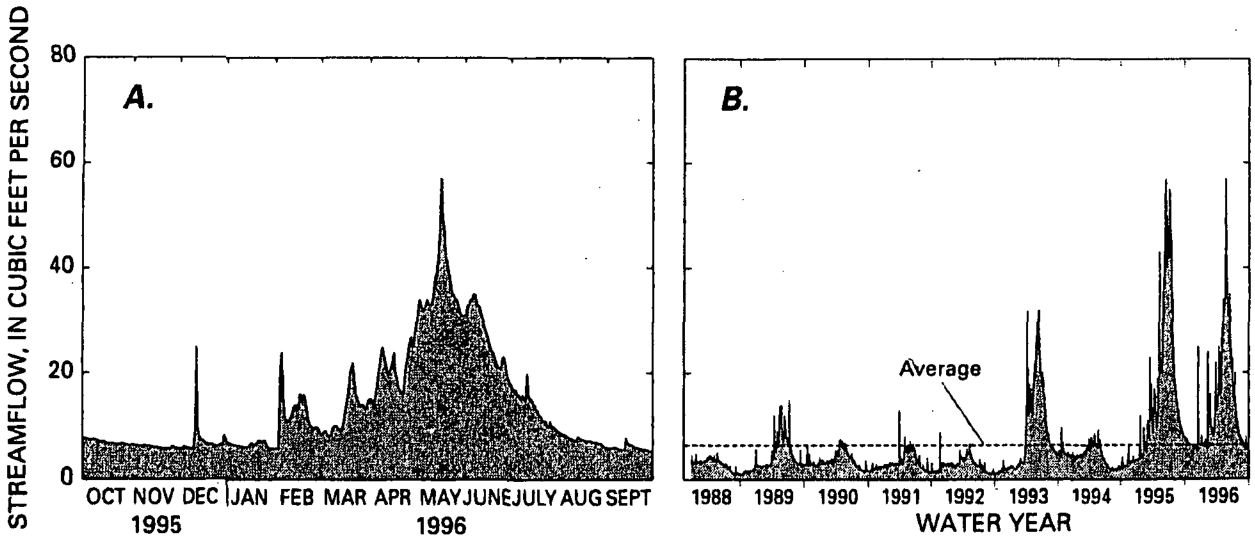


Figure 2. (*A*) Daily mean streamflow for Incline Creek during 1996 water year, a representative stream in the Lake Tahoe Basin, and (*B*) daily mean streamflow for Incline Creek, 1988-96 water years, representing years of drought and above-normal runoff.

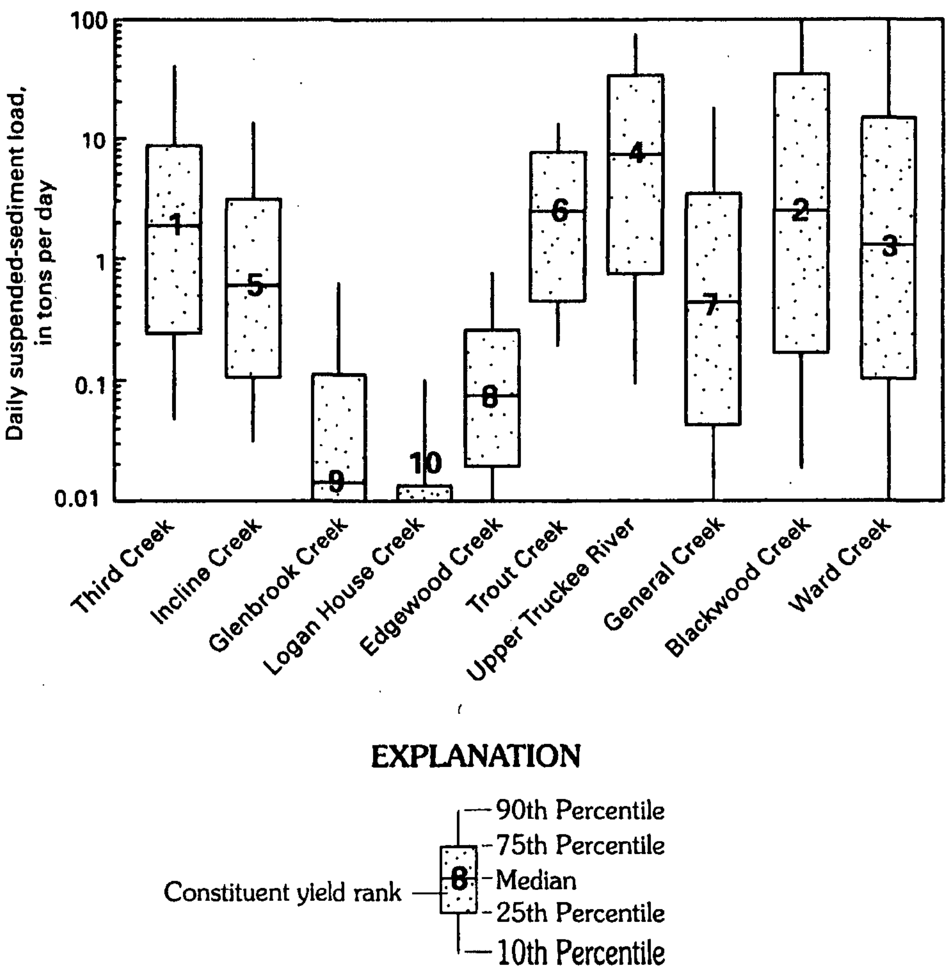


Figure 3. Suspended-sediment loads depicted by box plots and yeild ranks for selected surface-water sampling sites in the Lake Tahoe Basin, 1988-96.

Table 1. Sampling-site information for selected Lake Tahoe watersheds

Sampling site (figure 1)	Total watershed drainage area (square miles)[a]	Sampling-site drainage area (square miles)	Main channel length (miles)[b]
Third Creek near Crystal Bay, Nev.	6.05	6.02	7.05
Incline Creek near Crystal Bay, Nev.	6.70	6.69	4.66
Glenbrook Creek at Glenbrook, Nev.	4.11	4.10	3.92
Logan House Creek near Glenbrook, Nev.	2.15	2.09	3.30
Edgewood Creek at Stateline, Nev.	6.64	5.61	5.53
Trout Creek at South Lake Tahoe, Calif.	41.2	40.4	10.7
Upper Truckee River at South Lake Tahoe, Calif.	56.5	54.0	21.4
General Creek near Meeks Bay, Calif.	7.63	7.39	9.17
Blackwood Creek near Tahoe City, Calif.	11.2	11.1	6.20
Ward Creek near Tahoe Pines, Calif.	9.75	9.73	5.90

[a] From Cartier et al 1995

[b] From Jorgensen et al 1978

Table 2. Streamflow information for selected Lake Tahoe Basin watersheds

[Abbreviations: acre-ft, acre-feet; ft^3/s, cubic feet per second; ft, feet; mi^2, square miles]

Sampling site	Range and median of sampled streamflow[a] (ft^3/s)	Period of record (water years)	Average annual mean daily streamflow (ft^3/s)	Average annual runoff (acre-ft)	Average annual yield[b] (acre-ft/mi^2)
Third Creek	0.93 - 118 (6.0)	1988-96	6.68	4,830	802
Incline Creek	.56 - 71 (5.7)	1988-96	6.26	5,040	753
Glenbrook Creek	0 - 35 (0.88)	1988-96	1.30	943	230
Logan House Creek	0 - 7.9 (0.20)	1988-96	.30	221	106
Edgewood Creek	1.1 - 25 (3.6)	1993-96	3.72	2,690	480
Trout Creek	3.2 - 305 (49.5)	1993-96	44.8	32,400	802
Upper Truckee River	.70 - **1,750**[c] **(158)**	1993-96	**123**[c]	**89,000**[c]	1,650
General Creek	.41 - 559 (30.5)	1993-96	20.2	14,700	1,990
Blackwood Creek	1.1 - 936 (60.0)	1993-96	44.0	31,800	**2,860**[c]
Ward Creek	.22 - 950 (47.5)	1993-96	32.1	23,200	2,380

[a] Median, in parentheses, equals 50-percent value.

[b] Yield is annual runoff divided by sampling-site drainage area.

[c] **Bold** indicates highest value.

Table 3. Suspended-sediment and nutrient information for selected Lake Tahoe Basin watersheds

[Abbreviations: mg/L, milligrams per liter; ton/d, tons per day; ton/d/mi², tons per day per square mile]

Sampling site	Concentration range (mg/L)	Median concentration[a] (mg/L)	Median load[b] (ton/d)	Median yield[c] (ton/d/mi²)	Yield rank[d]
Third Creek	**1 - 3,930**[e]	**80**[e]	1.9	**0.32**[e]	**1**[e]
Incline Creek	1 - 1,840	26	.62	.09	5
Glenbrook Creek	1 - 606	6.0	.02	.01	9
Logan House Creek	<1 - 388	3.0	<.01	.01	10
Edgewood Creek	1 - 130	5.0	.08	.01	8
Trout Creek	2 - 335	14	2.5	0.06	6
Upper Truckee River	1 - 458	15	**7.2**[e]	.13	4
General Creek	<1 - 404	7.0	.43	.06	7
Blackwood Creek	1 - 1,080	16	2.6	.23	2
Ward Creek	<1 - 3,000	10	1.3	.14	3

[a] Median equals 50-percent value.
[b] Median load equals 50-percent value. Load = concentration x streamflow x load factor (0.0027 for ton/d).
[c] Median yield is median load divided by sampling-site drainage area.
[d] Rank from 1 to 10: 1 indicates highest contribution of constitutent and 10 Lowest contribution.
[e] **Bold** indicates highest value.

Concentrations and Distribution of Manmade Organic Compounds in the Lake Tahoe Basin, Nevada and California, 1997-99

By Michael S. Lico and Nyle Pennington

Water-Resources Investigations Report 99-4218

Abstract

The U.S. Geological Survey, in cooperation with the Tahoe Regional Planning Agency and the Lahontan Regional Water-Quality Control Board, sampled Lake Tahoe, major tributary streams to Lake Tahoe, and several other lakes in the Lake Tahoe Basin for manmade organic compounds during 1997-99.

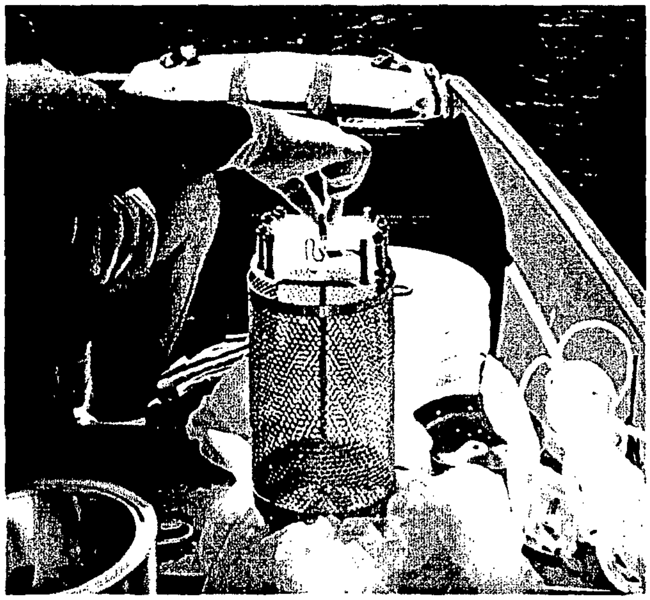
Gasoline components were found in all samples collected from Lake Tahoe during the summer boating season. Methyl *tert*-butyl ether (MTBE), benzene, toluene, ethylbenzene, and xylenes (BTEX) were the commonly detected compounds in these samples. Most samples from tributary streams and lakes with no motorized boating had no detectable concentrations of gasoline components. Motorized boating activity appears to be directly linked in space and time to the occurrence of these gasoline components. Other sources of gasoline components to Lake Tahoe, such as the atmosphere, surface runoff, and subsurface flow, are minor compared to the input by motorized boating. Water sampled from Lake Tahoe during mid-winter, when motorized boating activity is low, had no MTBE and only one sample had any detectable BTEX compounds.

Soluble pesticides rarely were detected in water samples from the Lake Tahoe Basin. The only detectable concentrations of these compounds were in samples from Blackwood and Taylor Creeks collected during spring runoff. Concentrations found in these samples were low, in the 1 to 4 nanograms per liter range.

Organochlorine compounds were detected in samples collected from semipermeable membrane devices (SPMD's) collected from Lake Tahoe, tributary streams, and Upper Angora Lake. In Lake Tahoe, SPMD samples collected offshore from urbanized areas contained the largest number and highest concentrations of organochlorine compounds. The most commonly detected organochlorine compounds were cis- and trans-chlordane, *p,p'*-DDE, and hexachlorobenzene. In tributary streams, SPMD samples collected during spring runoff generally had higher combined concentrations of organochlorine compounds than those collected during baseflow conditions. Upper Angora Lake had the fewest number of organochlorine compounds detected of all lake samples. Dioxins and furans were not detected in SPMD samples from two sites in Lake Tahoe or from two tributary streams.

The number of polycyclic aromatic hydrocarbon (PAH) compounds and their combined concentrations generally were higher in samples from Lake Tahoe than those from tributary streams. Areas of high-motorized boating activity at Lake Tahoe had the largest number and highest concentrations of PAH's. PAH compounds were detected in samples from SPMD's in four of six tributary streams during spring runoff, all tributary streams during baseflow conditions, and at all lake sites. The most commonly detected PAH's in tributary streams during spring runoff were phenanthrene, fluoranthene, pyrene, and chrysene, and during baseflow conditions were phenanthrene, 1-methylphenanthrene, diethylnaphthalene, and pyrene. Upper Truckee River, which has an urban area in its drainage basin, had the largest number and highest combined concentration of PAH's of all stream samples.

Diver retrieving semipermeable membrane device from Lake Tahoe, near Glenbrook, Nev. Photograph by R.J. Hoffman, U.S. Geological Survey, August 1998.



Semipermeable membrane sampling device, Upper Angora Lake, Calif., July 1998. Photograph by K.J. Hill, Tahoe Regional Planning Agency.

Bottom-sediment from Lake Tahoe had detectable concentrations of p-cresol, a phenol, in all but one sample. A sample collected near Chambers Lodge contained phenol at an estimated concentration of 4 micrograms per kilogram (µg/kg). Bottom-sediment samples from tributary streams had no detectable concentrations of organochlorine or PAH compounds. Several compounds were detected in bottom sediment from Upper Angora Lake at high concentrations. These compounds and their concentrations were *p,p'*-DDD (10 µg/kg), *p,p'*-DDE (7.4 µg/kg), 2,6-dimethylnaphthalene (estimated at 190 µg/kg), pentachlorophenol (3,000 µg/kg), and p-cresol (4,400 µg/kg).

INTRODUCTION

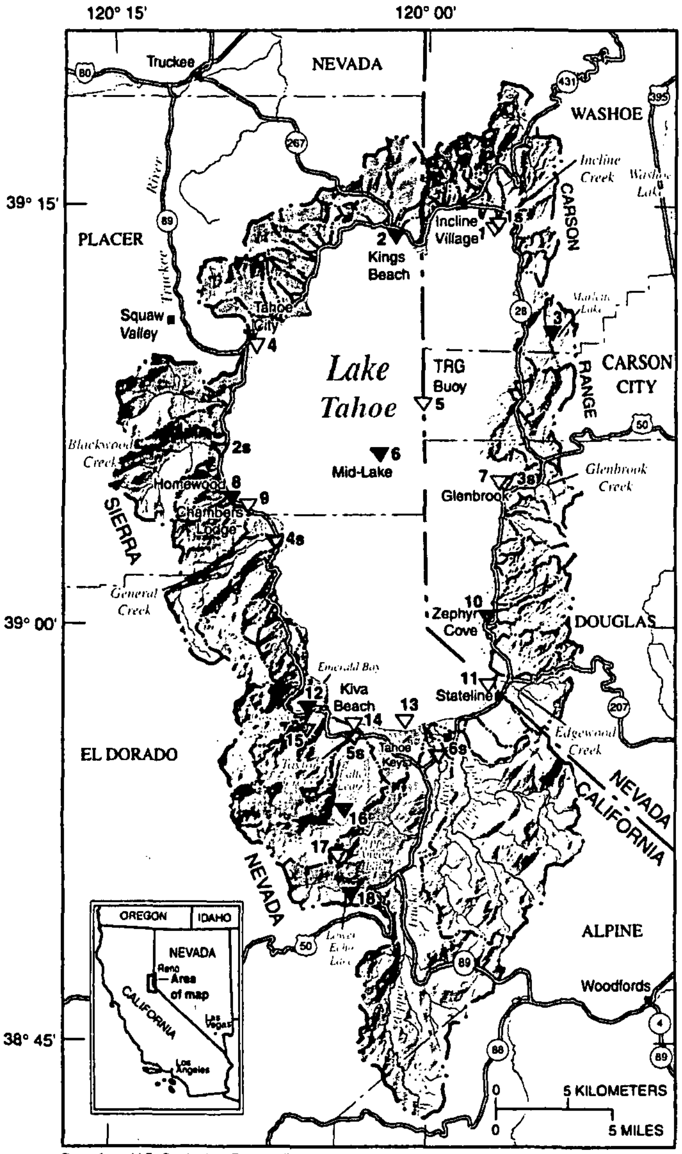
Lake Tahoe is a high alpine lake renowned for its clear, deep waters and has been designated an Outstanding National Resource Water. The lake is a destination for outdoor sporting enthusiasts who visit the lake throughout the year. Its proximity to the San Francisco Bay Area, about 240 kilometers (km) to the west, and setting in the Sierra Nevada make it one of the premier summer vacation spots in the country. In recent years, the clarity of Lake Tahoe has been decreasing at a rate that will make it a lake less extraordinary in appearance within the next 30 years (Goldman and others, 1998). The cause of this loss of clarity is due to increased algae populations within the lake. Scientists and regulators require more information that would allow them to make appropriate decisions on remedial actions needed to reverse this trend. All sewage effluent has been exported from the Lake Tahoe Basin since the mid-1970's. Other more recently enacted regulations in the Tahoe Basin include prohibition of most two-stroke engines and controlling sediment, and thus nutrient, input into the lake. Increased urbanization and its associated activities may be an important contributor to the reduction of Lake Tahoe's clarity. Pesticide and fertilizer use, leaking underground fuel storage tanks, and atmospheric deposition can all be important sources of manmade compounds that could upset the natural ecological systems within the lake.

Before 1997, little was known about the concentrations of manmade organic compounds in Lake Tahoe and its tributary streams. During 1997, the U.S. Geological Survey (USGS) in cooperation with the Tahoe Regional Planning Agency and the University of California, Davis, Tahoe Research Group (TRG) collected the first data documenting the presence of the gasoline components benzene, toluene, ethylbenzene, xylenes, methyl *tert*-butyl ether (MTBE), and *tert*-amyl methyl ether (TAME) in the lake (Boughton and Lico, 1998). Every sample taken from the lake during the summer months had detectable concentrations of MTBE. The findings of this study (Boughton and Lico, 1998) prompted a more detailed investigation, the results of which are reported herein.

Purpose and Scope

This report documents the occurrence and distribution of selected manmade organic compounds in water and bottom sediment from Lake Tahoe, its major tributaries, and other Lake Tahoe Basin lakes. Organic compounds investigated during this study include gasoline components (VOC's), soluble pesticides, and semivolatile compounds (including organochlorine compounds, PAH's, dioxins, and furans). Locations of sampling sites are shown in figure 1. Ancillary data collected as part of this study can be found in a report by Preissler and others (1999, p. 508-520). The results of this study are documented to provide a useful benchmark from which future comparisons can be made.

Lake Tahoe was sampled at 10 locations during August 1998 for VOC's and soluble pesticides. Samples for VOC's were taken from Lake Tahoe at five sites during January 1999. Semipermeable membrane sampling devices (SPMD's) were deployed to sample hydrophobic organic compounds at eight locations at Lake Tahoe (July-August 1998). Water samples were obtained from six tributary streams during spring runoff (May 1998) and during baseflow (October 1998) conditions. SPMD's were deployed in the tributary streams for two periods of approximately 8 weeks each (May-June 1998 and November-December 1998) to sample the hydrophobic organic compounds. Lists of analytes for the several classes of compounds can be found in tables 1-4 and in the following reports—Connor and others (1998), Foreman and others (1995), Furlong and others (1996),



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000,1969-85.
Universal Transverse Mercator projection, Zone 11

EXPLANATION

Boundary of Lake Tahoe Basin

Boundary of subbasin

Tributary stream site, number, and type of data collected

▼ 1s VOC's, pesticides, SPMD, and bottom sediment

Lake site, number, and type of data collected

▼ 10 VOC's

▽ 4 VOC's, pesticides, and bottom sediment

▽ 13 VOC's, pesticides, SPMD, and bottom sediment

Figure 1. Lake and tributary stream sampling sites in Lake Tahoe Basin, Nevada and California.

and Zaugg and others (1995). In Upper Angora Lake, about 8 km southwest of Lake Tahoe, water samples were taken for VOC's and soluble pesticides during August 1998, and hydrophobic organic compounds (using SPMD's) during July-August 1998. Bottom sediment was collected for analysis of hydrophobic organic compounds at seven sites from Lake Tahoe, six tributary streams, and Upper Angora Lake during August 1998. Two other lakes, Fallen Leaf Lake and Lower Echo Lake, were sampled for VOC's during August 1998. Upper Angora Lake has no motorized boats and nearby automobile traffic is minor. Fallen Leaf and Lower Echo Lakes have substantial boating traffic during the summer months. Analytical results of water samples collected during 1997 and reported by Boughton and Lico (1998) are included in the discussion section of this report.

Sample Collection and Analysis

Water samples for VOC's were collected using methods described by Shelton (1997). A stainless-steel sampler, described by Shelton (1997), was lowered to the desired depth on a stainless-steel cable connected to a calibrated reel. The sampler contained four 40-milliliter (mL) vials. Each vial was flushed with seven volumes of sample and the final 40 mL remained in the vial. Although this sampler was designed for suburban streams, its ability to allow sample vials to be purged ensures the water sample in the vials is representative. Approximate flushing volumes at 3- and 30-meter (m) depths are 260 and 230 mL, respectively (R.J. Hoffman, U.S. Geological Survey, written commun., 1999). Immediately upon retrieval and before opening, the sampler was placed in a preservation chamber (Shelton, 1994) to minimize contamination of the samples by atmospheric sources. Samples were removed from the sampler, preserved with 1:1 hydrochloric acid, capped, placed on ice, and sent overnight to the USGS National Water Quality Laboratory (NWQL) in Arvada, Colo. VOC's were analyzed using gas chromatography-mass spectrometry as described by Connor and others (1998). Sampler performance was documented by Halde and others (1999). Quality-assurance samples for VOC's included sampler blanks (a measure of potential contamination by the sampler) and ambient blanks (a measure of potential contamination from the atmosphere).

Water samples for soluble pesticides were collected using the same stainless-steel sampler used for VOC's with the exception that no vials were in the sampler. Water from the sampler was collected and composited in a 3-liter teflon bottle. The water sample was filtered through a glass fiber filter, placed on ice, and sent overnight to the NWQL. Soluble pesticides (86 compounds) were extracted from water samples using solid-phase extraction procedures outlined by Sandstrom and others

Table 1. Volatile organic compounds in water samples collected at Lake Tahoe, other nearby alpine lakes, and tributary streams, July 1997-January 1999

[Concentrations in micrograms per liter; <, less than; --, not determined]

Site number (fig. 1)	Depth (meters below land surface)	Date	Benzene [1]	Toluene [1]	Ethyl-benzene [1]	Ortho-xylene [1]	Meta- and para-xylene [1]	Methyl *tert*-butyl ether [1] (MTBE)	*Tert*-amyl methyl ether [1] (TAME)
				Lake Tahoe Samples					
1	3	09/03/1997	E0.5	0.13	E0.02	E0.03	E0.09	0.45	E0.05
1	3	08/11/1998	.17	1.0	.24	.42	1.0	.84	.10
1	3	01/13/1999	<.10	<.05	<.03	<.064	<.064	<.17	<.11
2	3	09/03/1997	.13	.68	.12	.20	.52	1.7	.14
4	3	07/29/1997	.15	.58	E.09	.16	.42	1.5	E.09
4	3	08/02/1997	.33	1.9	.39	.60	1.6	4.2	.20
4	3	08/12/1998	.11	.56	.097	.17	.44	1.3	.15
5	30	07/29/1997	<.032	<.04	<.03	<.064	<.064	.19	E.02
5	3	08/02/1997	<.06	E.04	<.03	<.064	E.03	.59	E.04
5	10	08/02/1997	<.06	<.07	<.03	<.064	E.04	.61	<.11
5	30	08/02/1997	<.032	<.04	<.03	<.064	<.064	.26	<.11
5	3	08/11/1998	<.10	E.08	<.03	<.064	<.064	.45	<.11
5	30	08/11/1998	<.10	<.05	<.03	<.064	<.064	.22	<.11
5	3	01/13/1999	<.10	<.05	<.03	<.064	<.064	<.17	<.11
5	30	01/13/1999	<.10	<.05	<.03	<.064	<.064	<.17	<.11
6	3	09/03/1997	E.04	E.09	<.03	<.064	E.05	.42	E.05
6	30	09/03/1997	E.02	E.04	<.03	<.064	<.064	.18	<.11
7	3	09/02/1997	E.04	E.1	E.01	<.064	E.06	.30	E.04
7	3	08/11/1998	<.10	.27	E.06	.099	.26	.47	<.11
7	3	01/13/1999	<.10	<.05	<.03	<.064	<.064	<.17	<.11
8	3	09/02/1997	E.05	.15	E.02	E.04	E.1	.45	E.05
9	3	08/12/1998	<.10	.27	E.04	E.07	.19	.78	.13
10	3	09/02/1997	.15	.70	.12	.23	.52	1.0	.14
10	3	08/11/1998	.61	4.4	1.1	2.0	4.7	1.3	.17
10	3	01/13/1999	<.10	E.02	<.03	<.064	E.02	<.17	<.11
11	3	08/12/1998	.21	1.0	.18	.36	.94	2.4	.45
12	3	08/12/1998	.44	1.5	.20	.59	1.5	4.0	.85
13	3	09/02/1997	E.07	.26	E.04	E.06	E.2	.68	E.07
13	3	08/12/1998	.18	.91	.17	.28	.72	2.0	.34
13	3	01/13/1999	<.10	<.05	<.03	<.064	<.064	<.17	<.11
14	3	08/12/1998	.17	.78	.12	.23	.58	1.8	.34
				Tributary Stream Samples					
1s	--	05/13/1998	E.004	<.038	<.03	<.064	<.064	<.11	<.11
1s	--	10/27/1998	<.10	E.02	<.03	<.064	<.064	E.06	<.11
2s	--	05/121998	<.032	<.038	<.03	<.064	<.064	<.11	<.11
2s	--	10/27/1998	<.10	<.05	<.03	<.064	<.064	<.17	<.11
3s	--	05/13/1998	<.032	<.038	<.03	<.064	<.064	<.11	<.11
3s	--	10/28/1998	<.10	<.05	<.03	<.064	<.064	<.17	<.11
4s	--	05/12/1998	<.032	<.038	<.03	<.064	<.064	<.11	<.11
4s	--	10/27/1998	<.10	E.04	<.03	<.064	<.064	<.17	<.11
5s	--	05/13/1998	<.032	<.038	<.03	<.064	<.064	<.11	<.11
5s	--	10/28/1998	<.10	<.05	<.03	<.064	<.064	<.17	<.11

Table 1. Volatile organic compounds in water samples collected at Lake Tahoe, other nearby alpine lakes, and tributary streams, July 1997-January 1999—Continued

Site number (fig. 1)	Depth (meters below land surface)	Date	Benzene[1]	Toluene[1]	Ethyl-benzene[1]	Ortho-xylene[1]	Meta- and para-xylene[1]	Methyl *tert*-butyl ether[1] (MTBE)	*Tert*-amyl methyl ether[1] (TAME)
6s	--	05/13/1998	<0.032	<0.038	<0.03	<0.064	<0.064	<0.11	<0.11
6s	--	10/28/1998	<.10	E.01	<.03	<.064	<.064	<.17	<.11
				Other Nearby Lake Samples[2]					
3	3	09/05/1997	<.032	<.04	<.03	<.064	<.064	<.11	<.11
3	9.1	09/05/1997	<.032	E.01	<.03	<.064	<.064	<.11	<.11
15	3	09/04/1997	<.032	E.04	<.03	<.064	E.02	<.11	<.11
15	15	09/04/1997	<.032	E.02	<.03	<.064	<.064	<.11	<.11
16	3	08/10/1998	<.10	.11	<.03	<.064	E.08	.78	.14
17	3	09/04/1997	<.032	E.02	<.03	<.064	<.064	<.11	<.11
17	10	09/04/1997	<.032	<.04	<.03	<.064	<.064	<.11	<.11
17	3	08/13/1998	<.10	<.054	<.03	<.064	<.064	<.17	<.11
17	6	08/13/1998	<.10	<.054	<.03	<.064	<.064	<.17	<.11
18	3	08/10/1998	.40	3.5	.71	1.1	1.5	7.7	2.2

[1] When an "E" is reported, the compound has passed all criteria used to identify its presence, and only the concentration is estimated (Connor and others, 1998).

[2] Lake sites 3 and 17 have no motorized boating activity.

(1992) and Zaugg and others (1995) and then analyzed by gas or high-performance liquid chromatography. Sampler blanks were collected for quality-assurance purposes.

Bottom-sediment samples were collected and processed using protocols developed for the National Water-Quality Assessment Program (Shelton and Capel, 1994). Sediment samples were sent overnight to the NWQL. The sediment samples were extracted and analyzed for organochlorine compounds (28 compounds), PAH's (79 compounds), and PCB's (total) by gas chromatography (Foreman and others, 1995; Furlong and others, 1996). Sediment samples from two tributary streams and two sites at Lake Tahoe were sent to a contract laboratory for determination of dioxins and furans (25 compounds) using methods described by U.S. Environmental Protection Agency (1986).

Detection of semivolatile compounds in water is problematic because of their low concentrations and transient nature. Semipermeable membrane devices (SPMD's) were used to sample for these compounds in the water column. SPMD's are devices that contain triolein in a low-density polyethylene tube (Huckins and others, 1990). These devices are effective in sequestering dissolved organic compounds from water and are useful in assessing their potential bioavailability (Bevans and others, 1996). For quality-assurance purposes, a blank (SPMD's transported to the sampling sites and opened to the atmosphere at the sites) was collected during each round of SPMD deployment. Compounds are recovered from the SPMD's by dialysis and gel-permeation chromatography and analyzed by gas chromatography-mass spectrometry. Models exist to estimate water concentrations of organic compounds from SPMD concentrations (Huckins and others, 1993; Ellis and others, 1995).

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OCCURRENCE OF MANMADE ORGANIC COMPOUNDS

Water

During the summers of 1997 and 1998, water samples from 13 sites in Lake Tahoe were collected and analyzed for gasoline components (table 1). All summer samples from Lake Tahoe had detectable concentrations of the oxygenate MTBE and most samples had measurable concentrations of BTEX (benzene, toluene, ethylbenzene, and xylene) compounds (table 2). MTBE concentrations ranged from 0.18 to 4.2 micrograms per liter (µg/L), with the highest concentrations found in samples from near Tahoe City (site 4) and in Emerald Bay (site 12). Another gasoline oxygenate, TAME, was found in 19 of 25 samples at concentrations as great as 0.85 µg/L (in Emerald Bay). One other gasoline oxygenate, ethyl *tert*-butyl ether (ETBE), was not detected in any sample at a reporting level of 0.11 µg/L. BTEX compounds were detected in 88 percent of the samples collected from Lake Tahoe. The highest concentrations of BTEX compounds were measured in samples collected from Zephyr Cove (site 10), Emerald Bay (site 12), and near Tahoe City (site 4). The most commonly detected BTEX compound was toluene (found in 84 percent of the samples) with a maximum concentration of 4.4 µg/L found in a sample from Zephyr Cove. Benzene was detected in 68 percent of the samples collected and the maximum concentration (0.61 µg/L) was in a sample from Zephyr Cove. Ethylbenzene was detected in 68 percent of the samples and had a maximum concentration of 1.1 µg/L in a sample from Zephyr Cove. Xylenes were detected in 64 percent (ortho isomer) and 80 percent (meta and para isomers) of the samples collected. The maximum concentration for total xylene was 6.7 µg/L in a sample from Zephyr Cove.

During January 1999, samples were collected from five locations (sites 1, 5, 7, 10, and 13) in Lake Tahoe and analyzed for the same gasoline components discussed above. MTBE, TAME, and most BTEX compounds were not detected in these samples. Toluene and meta-and para-xylene were detected in a sample from Zephyr Cove (site 10) at estimated concentrations of 0.02 and 0.02 µg/L, respectively.

Water samples collected from six tributaries to Lake Tahoe had only a few detections of manmade organic compounds (tables 1 and 3). During spring runoff, benzene was detected in a sample from Incline Creek (site 1s) at an estimated concentration of 0.004 µg/L. Two pesticides were detected in a sample from Blackwood Creek (site 2s)—simazine estimated at 0.0038 µg/L and atrazine estimated at 0.0031 µg/L. One pesticide was detected in a sample from Taylor Creek (site 5s)—DCPA estimated at 0.0012 µg/L. During the fall baseflow period, VOC's were detected at low concentrations in three samples. Toluene was detected at estimated concentrations of 0.01, 0.02, and 0.04 µg/L in the Upper Truckee River (site 6s), Incline Creek (site 1s), and General Creek (site 4s), respectively. MTBE was detected in a sample from Incline Creek at an estimated concentration of 0.06 µg/L. No pesticides were detected in water samples collected from tributary streams during baseflow conditions.

Other Tahoe Basin lakes sampled for gasoline components during this study were Lower Echo (site 18), Fallen Leaf (site 16), Cascade (site 15), Marlette (site 3), and Upper Angora (site 17) Lakes. Of these lakes, Upper Angora and Marlette Lakes have no motorized boating activity, Cascade Lake has limited motorized boating activity, and Lower Echo and Fallen Leaf Lakes have considerable motorized boating activity. Samples from Upper Angora and Marlette Lakes had no detectable concentrations of MTBE, ETBE, TAME, and BTEX compounds,

Table 2. Percent detection and concentration ranges of gasoline components in water samples from Lake Tahoe and other nearby lakes

[Abbreviations: E, estimated concentration [1]; MTBE, methyl *tert*-butyl ether; TAME, *tert*-amyl methyl ether]

Compound	Lake Tahoe				Other nearby lakes [2]			
	Percent detection		Concentration range of detection		Percent detection		Concentration range of detection	
	Summer	Winter	Summer	Winter	Motorized boats	No motorized boats	Motorized boats	No motorized boats
Benzene	68	0	E0.02-0.61	--	25	0	0.40	--
Toluene	84	17	E0.02-4.4	E0.02	100	33	E0.02-3.5	E0.01-E0.02
Ethylbenzene	68	0	E0.01-1.1	--	25	0	0.71	--
Ortho-xylene	64	0	E0.03-2.0	--	25	0	1.1	--
Meta- and para-xylenes	80	17	E0.03-4.7	E0.02	75	0	E0.02-1.5	--
MTBE	100	0	0.18-4.2	--	50	0	0.78-7.7	--
TAME	76	0	E0.02-0.85	--	50	0	0.14-2.2	--

[1] When an "E" is reported, the compound has passed all criteria used to identify its presence, and only the concentration is estimated (Connor and others, 1998).

[2] Categories represent motorized boats, all types of motorized boats are allowed on the lakes; and no motorized boats, no motorized boats are allowed on the lakes.

Table 3. Soluble pesticides in water samples and semivolatile organic compounds in semipermeable membrane sampling devices detected in tributaries to Lake Tahoe, Nevada and California

Site (fig. 1)	Compounds detected	
	Soluble pesticides (concentrations in micrograms per liter)	Semivolatile compounds
1s Incline Creek		
Spring runoff	none detected	cis-and trans-chlordane, chrysene, fluoranthene, hexachlorobenzene, pentachloroanisole, phenanthrene, pyrene
Baseflow	none detected	trans-chlordane, *p,p'*-DDE
2s Blackwood Creek		
Spring runoff	simazine (E0.0038 [1]), atrazine (E0.0031)	none detected
Baseflow	none detected	trans-chlordane, *p,p'*-DDE
3s Glenbrook Creek		
Spring runoff	none detected	cis- and trans-chlordane, chrysene, fluoranthene, 1-methylpyrene, pyrene
Baseflow	none detected	trans-chlordane
4s General Creek		
Spring runoff	none detected	cis-and trans-chlordane, fluoranthene, 4,5-methylpyrene, pentachoroanisole, phenanthrene
Baseflow	none detected	trans-chlordane
5s Taylor Creek		
Spring runoff	DCPA (E0.0012)	cis- and trans-chlordane, *p,p'*-DDE, fluoranthene, benzo (g,h,i) perylene
Baseflow	none detected	trans-chlordane, *p,p'*-DDE, pentachloroanisole
6s Upper Truckee River		
Spring runoff	none detected	cis- and trans-chlordane, pentachoroanisole
Baseflow	none detected	cis- and trans-chlordane, *p,p'*-DDE, 1,6-dimethylnaphthalene, naphthalene

[1] When an "E" is reported, the compound has passed all criteria used to identify its presence, and only the concentration is estimated (Connor and others, 1998).

with the exception of an estimated toluene concentration of 0.01 µg/L in a sample from Marlette Lake and an estimated concentration of 0.02 µg/L in a sample from Upper Angora Lake (table 1). An equipment blank from this sample period also contained toluene at an estimated concentration of 0.04 µg/L; thus, these values may be from contamination of the sampler. Lower Echo Lake had the highest measured MTBE and TAME concentrations found during this study. MTBE concentration was 7.7 µg/L and TAME concentration was 2.2 µg/L. BTEX compounds were found at the following concentrations in Lower Echo Lake: benzene, 0.40 µg/L; toluene, 3.5 µg/L; ethylbenzene, 0.71 µg/L; ortho-xylene, 1.1 µg/L; and meta- and para-xylenes, 1.5 µg/L. Fallen Leaf Lake had detectable concentrations of MTBE (0.78 µg/L), TAME (0.14 µg/L), toluene (0.11 µg/L), and meta- and para-xylene (estimated 0.08 µg/L).

Water samples were collected from eight sites in Lake Tahoe and two depths from Upper Angora Lake for soluble pesticide analysis. Soluble pesticides were not detected in any sample from Lake Tahoe or Upper Angora Lake.

Among the most commonly detected classes of semivolatile organic compounds were organochlorines, polycyclic aromatic hydrocarbons (PAH's), and phthalates. Organochlorine compounds were detected in samples from all sites in Lake Tahoe and Upper Angora Lake (table 4). Samples from near Incline Beach (site 1), Chambers Lodge (site 9), near Edgewood Creek (site 11), and Tahoe Keys (site 13) had the greatest number of compounds and the highest combined concentration of organochlorine compounds (fig. 2). Upper Angora Lake (site 17) had the fewest number of organochlorine compounds and was among the lowest combined concentration, as were samples from the TRG buoy (site 5), near Glenbrook (site 7), near Chambers Lodge (site 9), and near Kiva Beach (site 14). Trans- and cis-chlordane and *p,p'*-DDE were detected in all samples from Lake Tahoe. Hexachlorobenzene was detected at four Lake Tahoe sites and had the highest concentration in samples from near Incline Beach and near Edgewood Creek.

PAH's were detected in samples from all locations sampled at Lake Tahoe and Upper Angora Lake (site 17). The number of compounds detected ranged from a low value of 3 (Upper Angora Lake) to an upper value of 23 (near Kiva Beach, site 14). Samples taken near Incline

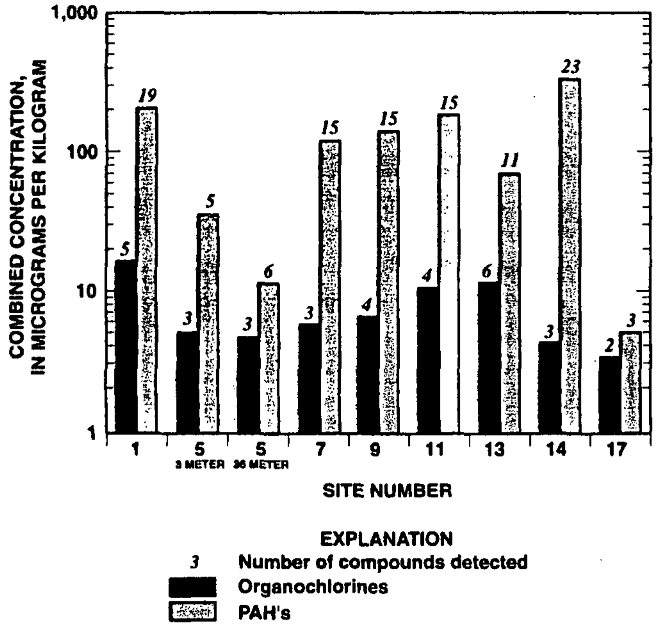

Figure 2. Number and combined concentration of semivolatile organic compounds (organochlorine and polycyclic aromatic hydrocarbon compounds) detected in samples from semipermeable membrane devices placed in Lake Tahoe and Upper Angora Lake, July-August 1998. Sites are shown in figure 1. Site 17 (Upper Angora Lake) is the only lake sampled for semivolatile organic compounds that has no motorized boating activity.

Beach (site 1), near Edgewood Creek (site 11), Glenbrook (site 7), and Chambers Lodge (site 9) had high numbers and large combined concentration of PAH's (fig. 2). Sample sites with low combined concentrations of PAH's were Upper Angora Lake and both depths at the TRG buoy (site 5). The most commonly detected compounds were 9H-fluorene, fluoranthene, 1-methylphenanthrene, acridine, and 1-methyl-9H-fluorene.

The number and combined concentration of organochlorine compounds in the tributaries were greatest in Incline Creek (site 1s), General Creek (site 4s), Taylor Creek (site 5s), and Upper Truckee River (site 6s) during spring runoff (fig. 3). The most commonly detected organochlorine compounds were cis- and trans-chlordane, pentachloroanisole, and hexachlorobenzene (table 4). During baseflow conditions, Taylor Creek, Upper Truckee River, and Incline Creek had the greatest number and combined concentration of organochlorine compounds. Trans-chlordane and *p,p'*-DDE were the most commonly detected compounds during baseflow conditions. Concentrations were generally higher during the spring runoff than the baseflow-sampling period (fig. 4). During spring runoff, PAH's were detected in four of the six tributary streams. Concentrations of PAH's from Blackwood Creek (site 2s) and Upper Truckee River (site 6s) were below detectable levels. Incline (site 1s) and Glenbrook (site 3s) Creeks had the greatest number and combined concentration of PAH's during this period (fig. 4). General Creek (site 4s) had the highest combined concentration of PAH's during the spring runoff period. The most commonly detected PAH's were phenanthrene, fluoranthene, pyrene, and chrysene. During baseflow conditions, PAH's were detected in samples from all six tributary streams. The greatest number of compounds and highest combined concentration were found in samples from Upper Truckee River. Taylor, Blackwood, and General Creeks had the lowest number of compounds and combined concentration. Phenanthrene was detected in samples from all tributary streams. Other commonly detected PAH's were 1-methylphenanthrene, diethylnaphthalene, and pyrene.

Dioxins and furans were analyzed in samples collected from Upper Truckee River (site 6s) and Incline Creek (site 1s) and in Lake Tahoe near Edgewood Creek (site 11) and near Incline Beach (site 1). No dioxins or furans were detected in any of these samples.

Bottom Sediment

Bottom sediment was collected from seven sites at Lake Tahoe, six tributary streams, and one site at Upper Angora Lake during the summer of 1998 (fig. 1). These sediment samples were analyzed for semivolatile compounds (organochlorines, PAH's, PCBs, and phenol), and for two samples, dioxins and furans. Bottom-sediment samples from Lake Tahoe had few detectable manmade organic compounds. One compound, p-cresol, was found in all Lake Tahoe bottom-sediment samples except from near Incline Beach (site 1). Concentrations of p-cresol ranged from an estimated value of 17 µg/kg near Tahoe City (site 4) to 140 µg/kg near Glenbrook (site 7).

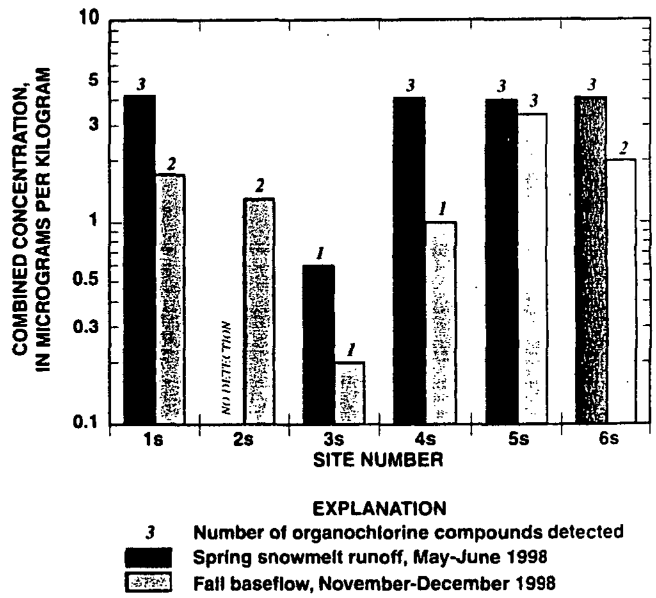

Figure 3. Number and combined concentration of organochlorine compounds detected in semipermeable membrane devices placed in Lake Tahoe Basin streams during spring snowmelt runoff (May-June 1998) and fall baseflow (November-December 1998) periods. Site locations are shown in figure 1.

Table 4. Concentrations of semivolatile organic compounds in Lake Tahoe and Upper Angora Lake. Concentrations were determined on extracts from semipermeable membrane sampling devices. Site numbers correspond to those in figure 1.

[Concentrations in milligrams per kilogram of lipid; all concentrations are estimated. Abbreviations: m, meter; <, less than]

Compound	Site 1 (3 m)	Site 5 (3 m)	Site 5 (36 m)	Site 7 (3 m)	Site 9 (3 m)	Site 11 (3 m)	Site 13 (3 m)	Site 14 (3 m)	Site 17 (3 m)	Blank
Acenaphthalene	6	<100	<100	5	5	<100	5	6	<100	<100
Acenapthene	<100	<100	<100	<100	<100	<100	<100	18	<100	12
Acridine	29	24	<100	24	26	32	24	25	<100	<100
Anthracene	<100	<100	<100	<100	<100	<100	<100	18	<100	<100
Benz(a)anthracene	<100	<100	<100	<100	<100	<100	<100	11	<100	<100
Benzo(b)fluoranthene	28	<100	<100	<100	23	25	<100	24	<100	<100
Benzo(k)fluoranthene	2	<100	<100	<100	<100	.7	<100	2	<100	<100
Benzo(g,h,i)perylene	10	<100	<100	<100	<100	<100	<100	8	<100	<100
9H-Carbazole	<100	<100	<100	<100	16	<100	<100	<100	<100	<100
Chrysene	<100	<100	<100	<100	<100	<100	<100	4	<100	<100
Fluoranthene	41	24	26	27	35	47	24	94	24	23
9H-Fluorene	4	1	1	2	2	3	2	11	1	<100
1-methyl-9H-Fluorene	11	8	<100	8	9	11	9	11	<100	<100
Indeno(1,2,3-cd)pyrene	20	<100	<100	17	17	18	<100	16	<100	<100
Naphthalene	11	4	6	6	6	6	6	11	4	7
1,2-dimethylnaphthalene	5	<100	<100	3	<100	<100	<100	4	<100	<100
1,6-dimethylnaphthalene	14	<100	<100	10	<100	11	10	12	<100	<100
2,6-dimethylnaphthalene	8	<100	<100	6	6	6	5	6	<100	<100
2-ethylnaphthalene	15	<100	<100	12	12	12	11	13	<100	<100
2,3,6-trimethylnaphthalene	4	<100	<100	.2	.8	7	.09	2	<100	<100
Phenanthrene	28	19	27	22	24	20	18	59	21	22
1-methylphenanthrene	27	24	24	24	25	26	24	29	26	23
4,5-methylenephenanthrene	9	<100	<100	2	4	7	3	14	<100	<100
Phenanthridine	<100	<100	<100	22	<100	23	<100	<100	<100	<100
Phenol	13	13	13	14	13	12	13	15	13	13
Pyrene	30	23	24	23	24	24	22	44	23	23
Bis(2-ethylhexyl)phthalate	42	60	51	48	48	43	37	36	48	41
Diethylphthalate	20	22	29	32	33	14	20	23	24	30
Dimethylphthalate	8	<100	<100	<100	<100	<100	<100	<100	<100	7
Di-n-butylphthalate	24	28	29	27	27	25	24	24	24	25
Di-n-octylphthalate	23	24	<100	23	24	23	23	22	24	<100
Hexachlorobenzene	9.5	<5.0	<5.0	<5.0	1	5	1	<5.0	<5.0	<5.0
Cis-chlordane	2	2	1	3	2	2	4	2	2	<5.0
Trans-chlordane	2	2	2	2	2	2	3	2	2	<5.0
p,p'-DDE	1	.9	1	.9	1	.9	1	.8	<5.0	<5.0
Dieldrin	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	1	<5.0	<5.0	<5.0
trans-Nonachlor	1	<5.0	<5.0	<5.0	<5.0	<5.0	1	<5.0	<5.0	<5.0

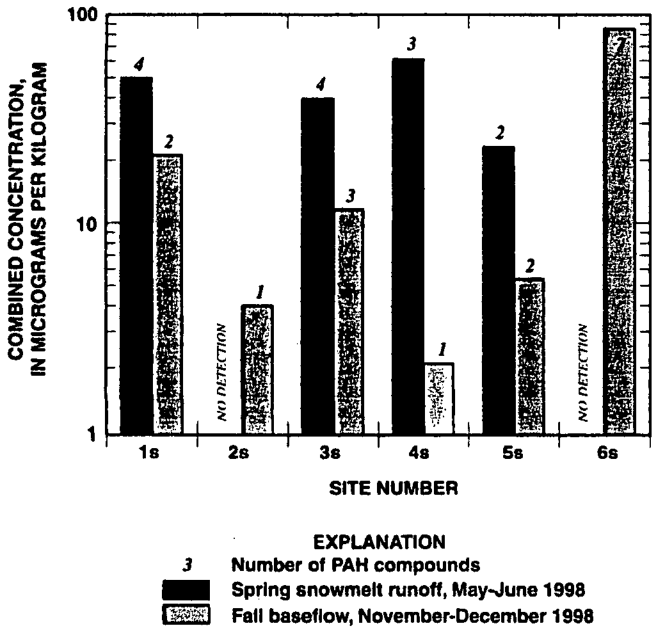

Figure 4. Number and combined concentration of polycyclic aromatic hydrocarbon (PAH) compounds detected in the semipermeable membrane devices placed in Lake Tahoe Basin streams during spring snowmelt runoff (May-June 1998) and fall baseflow (November-December 1998) periods. Site locations are shown in figure 1.

Kiva Beach (site 14) had a concentration of p-cresol (110 µg/kg). Several phthalate esters were detected in these samples and may be the result of contamination during laboratory processing of the samples. Phenol was detected in a sample from near Chambers Lodge (site 9) at an estimated concentration of 4 µg/kg.

A phenol, p-cresol, was detected in bottom sediment from Taylor Creek (site 5s) at an estimated concentration of 22 µg/kg. Several phthalate esters were detected in all samples including the blanks and may be the result of contamination during laboratory preparation of the samples. Three dioxins were detected in a sample from Upper Truckee River (site 6s) at low concentrations. The dioxins found were total heptachlorodibenzo-*p*-dioxin (5.8 ng/kg[1]), 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin (2.5 ng/kg), and octochlorodibenzo-*p*-dioxin (22 ng/kg). A sample from Incline Creek (site 1s) had octochlorodibenzo-*p*-dioxin present at 5.2 ng/kg.

Several compounds were detected in bottom sediment from Upper Angora Lake (site 17) at rather high concentrations. These compounds and their concentrations were *p,p'*-DDD (10 µg/kg), *p,p'*-DDE (7.4 µg/kg), 2,6-dimethylnaphthalene (estimated at 190 µg/kg), pentachlorophenol (3,000 µg/kg), and p-cresol (4,400 µg/kg).

[1] ng/kg is an abbreviation for nanograms per kilogram (equivalent to parts per trillion) and is equal to 0.001 µg/kg.

Discussion of Results

Organic compounds detected in water- and bottom-sediment samples collected from Lake Tahoe Basin indicate human activities have introduced potentially harmful compounds into the Basin. Even though the concentrations of these compounds are low, their presence suggests a need to monitor waters within the Lake Tahoe Basin for manmade organic compounds to ensure no further degradation of its waters.

Several lines of evidence suggest that most VOC's detected in water samples from lakes in the Tahoe Basin are the result of motorized watercraft use in the lakes.

- VOC's were found in all water samples collected from lakes where motorized boating occurred (table 2).
- Areas of high boating activity (Emerald Bay, Tahoe City, and Zephyr Cove in Lake Tahoe and Lower Echo Lake) had the highest concentrations of MTBE and BTEX compounds.
- Samples collected during periods of high boating activity (weekends during the summer), as reported by Boughton and Lico (1998), had some of the highest concentrations found in this study.
- Water samples collected at open-water sites, where boating activity is light, had some of the lowest concentrations of MTBE and BTEX found at Lake Tahoe during the boating season.
- Water samples collected during the winter months, when boating activity is low, had no detectable MTBE and minimal BTEX compounds (table 2).
- No MTBE and minimal BTEX compounds were found in lakes (Upper Angora and Marlette Lakes) where motorized watercrafts are prohibited.

The atmosphere, surface drainage of lands, and subsurface drainage within the Lake Tahoe Basin are not the primary source of the high concentrations of VOC's observed in Lake Tahoe during the summer months. Upper Angora and Marlette Lakes did not have any VOC's present at concentrations greater than 0.02 µg/L. This indicates that an atmospheric source for VOC's in the Tahoe Basin is minor, if present at all. Tributary streams sampled during spring runoff and baseflow conditions only had a few detectable concentrations of VOC's, all less than 0.06 µg/L. This indicates that tributary runoff within the basin is not a major source of VOC's. Finally, input of VOC's to Lake Tahoe by subsurface sources appears to be minor, at least in the areas investigated during this study. If a source such as this were present, VOC concentrations would be higher during the winter because the source would not be seasonally dependent.

Soluble pesticides were not commonly detected during this study, although, low concentrations were found in two water samples collected from tributary streams during spring runoff (table 3). No lake sample had a detectable concentration of any pesticide.

Organochlorine compounds are synthetic compounds mostly used as insecticides, fungicides, and wood preservatives. Organochlorine compounds were found in all SPMD and most bottom-sediment samples collected during this study. Although present, the concentration of these compounds in the water column is less than one part per trillion (as calculated using the model developed by Huckins and others, 1990). Chlordane (cis- and trans-isomers) and *p,p'*-DDE were found in all SPMD samples collected from Lake Tahoe. Chlordane and *p,p'*-DDT (which degrades into *p,p'*-DDE) were commonly used insecticides prior to the 1960's and 1970's. The use of these specific compounds was discontinued by the mid-1970's due to their effect on the environment, but, due to their persistence, they are still present. In Lake Tahoe, SPMD samples near urbanized parts of the Lake (sites 1, 11, and 13) had the highest concentration and number of organochlorine compounds suggesting their source may be urban areas. Hexachlorobenzene also was detected in four samples with the highest concentrations being in samples offshore from Incline Beach and Edgewood Creek (sites 1 and 11), both offshore from relatively dense urban development. SPMD samples from the open-water site (site 5) and Upper Angora Lake (site 17) had the lowest concentrations of all lake samples. Bottom-sediment samples from Lake Tahoe had few detectable organochlorine compounds with the exception of p-cresol, which was detected at every site, except site 1. A common ingredient in wood-preservative formulations, p-cresol probably is present in many of the treated piers and pilings in Lake Tahoe. Concentrations of organochlorine compounds in SPMD samples from tributary streams were similar to that from the open-water site in Lake Tahoe. Bottom-sediment samples collected from tributary streams had few detectable concentrations of organochlorine compounds indicating they are not a current source for most of the compounds found in Lake Tahoe.

PAH compounds are produced by high-temperature pyrolytic reactions such as in internal combustion engines, forest fires, and municipal incineration. Their occurrence in aquatic systems is reportedly due to anthropogenic sources (Smith and others, 1988). PAH's were detected in all SPMD samples from Lake Tahoe. Concentrations generally were higher in samples from Lake Tahoe than those from tributary streams. Nearshore samples had the largest number of compounds and highest combined concentrations of PAH's. PAH's are most abundant in areas where the amount of motorized boating activity is high (sites 1 and 14). Offshore from Kiva Beach (site 14), a popular water skiing location, the highest combined concentration of PAH's and the most number of compounds were found. Using the model of Huckins and others (1990), the concentration for fluoranthene is approximately 0.3 ng/kg. Samples from open water on Lake Tahoe (site 5), where motorized boating activity is low, had a low number of compounds and combined concentrations of PAH's. At this site (site 5), a sample from a depth of 36 m had lower combined concentration of PAH's than a sample from a depth of 3 m. Temporal variation in PAH concentrations within Lake Tahoe are not presently known. PAH's were not detected in bottom-sediment samples from Lake Tahoe, indicating little to no accumulation of these compounds on the sediment. PAH's were present in most SPMD samples from tributary streams in the Lake Tahoe Basin. Most of the samples had between two and four compounds, two samples had no compounds, and the sample from Upper Truckee River (site 6s) had seven compounds (fig. 4). Most streams, except Upper Truckee River, had higher combined concentrations and number of compounds during the spring runoff period than during the baseflow period. Actual concentrations of PAH's in the water column generally are less than 1 ng/kg (as calculated using the model developed by Huckins and others, 1990). Upper Angora Lake, where no motorized boating occurs, had the fewest number of compounds and lowest combined concentration of PAH's, indicating atmospheric sources are not the major input into Lake Tahoe Basin lakes (fig. 2). Controlled burning of vegetation within the Lake Tahoe Basin may be a potential source of PAH's but appears to be a minor contribution.

Sampling Incline Creek, Nev., May 1998. Photograph by M.S. Lico, U.S. Geological Survey.

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Atmospheric Lead and Mercury Deposition at Lake Tahoe

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Abstract

Evidence from this study suggests the existence of a significant modern source for atmospheric Hg deposition in the Sierra Nevada. Concentrations of both lead (Pb) and mercury (Hg) in the sediments of Lake Tahoe deposited prior to 1850 are similar to concentrations in the catchment bedrock, but their concentrations in modern sediments have increased six-fold for Pb (average 83 ppm) and five-fold for Hg (average 0.191 ppm). The lake occupies a relatively pristine, non-industrialized subalpine basin, with a watershed to lake surface ratio of only 1.6. Excess accumulation of trace metals in these sediments should closely reflect direct atmospheric deposition. On average, since 1980 there have been approximately 17 mg of Pb and 38 μg of Hg deposited annually per square meter in excess of the baseline flux. While Pb emissions have occurred locally in the Tahoe basin, from combustion of leaded gasoline until about 1985, the deposition of atmospheric Hg must represent a predominately regional to global source of contamination. Ratios of total modern flux to preindustrial flux are 29 for Pb and 24 for Hg. The flux ratio for Pb is somewhat higher than reported from the eastern USA and Canada, but is not atypical. The flux ratio for Hg is much higher than that observed in most other natural aquatic systems without point-source contamination. Both orographic scavenging and cold-condensation processes could enhance the deposition of Hg and other atmospheric pollutants over the Sierra Nevada.

Introduction

Modern industrial processes, product distribution, and material consumption patterns all disperse a wide variety of toxic metals into the environment. Of particular concern is the atmospheric emission of these metals, which can cause significant contamination over large areas. The introduction of alkyl-leaded gasoline in 1923, for example, ultimately produced a global anthropogenic Pb emission rate that exceeded the total contribution from natural sources by a factor of 28 (*1*). Mercury emission rates have also increased over modern times, and Hg is now listed as an EPA priority pollutant, in large part due to concerns about its biomagnification in aquatic food chains.

To date, there have been few studies of atmospheric deposition for trace metals on the U.S west coast. This study looks at the history of atmospheric Hg deposition over Lake Tahoe, a relatively pristine watershed in the Sierra Nevada mountains of California and Nevada. While there has never been any recorded use of Hg in the Tahoe basin, there was a substantial production and consumption of Hg in mining districts of California and Nevada adjacent to the Tahoe basin during the late 1800s. Our objective was to compare the modern rates of Hg deposition to the preindustrial (baseline) rates, as reconstructed from lake sediment cores. We also examined Pb accumulation rates, and compared the results for both Pb and Hg to sediment concentrations and to flux estimates from similar studies in other regions of North America. The sediment concentrations of titanium (Ti), a conservative reference element, were used as correction factors in reconstructing these trace metal deposition rates.

Study Site and Methods

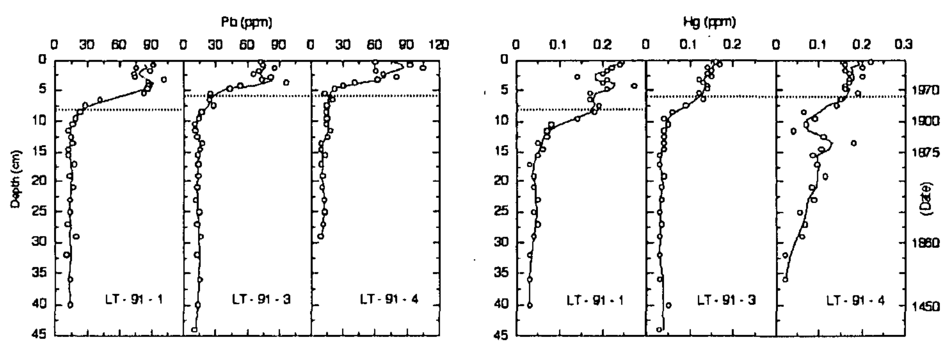
Lake Tahoe occupies a graben in the northern region of the Sierra Nevada mountains, on the border between California and Nevada. Its surface area is 498 km^2, within a natural basin of 1,311 km^2. Less than 8% of the terrestrial area is urbanized. At its natural rim the lake is 1897 meters above sea level, but surrounding mountains extend to over 3000 meters. On its western boundary the Tahoe watershed is delineated by the north-to-south bearing crest of the Sierra Nevada range.

The sediment cores examined in this study were extracted with a Soutar box corer, deployed from the U.C. Davis Research Vessel John LeConte. Two box cores (LT-91-1 and LT-91-3) were extracted from opposite ends of the lake in the profundal zone below 400 meters. A third core (LT-91-4) was taken off the west shoreline on a deep shelf at 300 meters depth.

Concentrations of ^{210}Pb and ^{137}Cs were determined by alpha and gamma spectrometry, respectively, in the laboratory of Dr. David Edgington. The analyses for Pb and Ti were performed by energy dispersive x-ray spectrometry. Samples for Hg analysis were digested in nitric and sulfuric acids, under pressure, then subsequently analyzed for total Hg (THg) using a modified cold vapor atomic absorption (CVAA) micro-technique (*2*).

Results

The concentrations of Pb and Hg in each sediment section of the three cores from Lake Tahoe are shown below, along with the smoothed profiles produced by a three term moving average. The onset horizon of ^{137}Cs is indicated by a horizontal line at the bottom of the deepest sediment section in which ^{137}Cs was detected. This onset horizon is generally interpreted as representing the first appearance (1952—1954) of global fallout from the atmospheric testing of thermonuclear weapons. To facilitate interpretation, approximate dates of sediment deposition are also indicated on the vertical axis.



In all three cores, Hg concentrations increase substantially prior to the ^{137}Cs onset horizon, and prior to equivalent changes in Pb concentrations. Above the ^{137}Cs horizon, however, Hg concentrations increase more slowly, whereas Pb concentrations begin to increase rapidly until they stabilize somewhat in the surficial sediments. In contrast to Pb, the trend of increasing Hg content persists into surficial sediments, which are enriched about five-fold over the baseline concentrations (see sediment enrichment factors listed in Table 1).

Table 1. Concentrations of Pb, Hg and Ti in Lake Tahoe sediment cores; with mean values, relative standard deviations (RSD) and sediment enrichment factors (SEF) calculated for each element.

		Pb (ppm)				**Hg (ppm)**				**Ti (wt %)**			**SEF**
core		**surficial**		**baseline**	**surficial**		**baseline**	**surficial**		**baseline**	**Pb**	**Hg**	**Ti**
LT-91-1		84.7	12.2		0.223	0.030		0.278	0.225		6.0	6.4	0.2
LT-91-3		77.1	12.5		0.157	0.037		0.260	0.259		5.2	3.3	0.0
LT-91-4		85.9	10.5		0.193	0.033		0.306	0.284		7.2	4.8	0.1
mean		82.6	11.7		0.191	0.033		0.281	0.256		6.1	4.9	0.1
RSD (%)		6	9		17	10		8	12		17	32	< 1

Since it has been shown that redox conditions do not appreciably influence the structure of Pb or Hg stratigraphy in most lake sediments (*3*), we interpret these patterns in the Tahoe sediments as representing temporal changes in Pb and Hg loading rates. These patterns do not change significantly when corrected for the contribution of trace metals derived from watershed weathering (normalized by factoring to variation in the content of sediment titanium as a conservative lithogenic element in most depositional environments).

Sediment fluxes of Pb and Hg were calculated as the product of sediment concentration and mass sedimentation rate. These data are summarized for the modern (post 1980) depositional period in Table 2. For modern sediments, with equal weight given to each core, the estimate of excess (normalized) Pb flux is 17 mg m^{-2} y^{-1}. A corresponding estimate for excess Hg flux is 38 µg m^{-2} y^{-1}.

Concise representation of change in deposition rate over time within a system is given by the flux ratio. This is simply the modern flux divided by a baseline, or preindustrial (ante 1850) flux. Like SEF factors this flux ratio must be calculated from the total (i.e., non-normalized) concentrations. Flux ratios are independent of most factors that affect Hg concentrations, such as site conditions, sediment focusing, and site-specific differences in absolute rates of atmospheric Hg deposition. Thus, flux ratios provide a unitless measure for the comparison of changes in Hg deposition between sites and geographic regions. At 47 µg m^{-2} y^{-1} the average modern flux of Hg (uncorrected) to Lake Tahoe sediments is 24 times greater than the baseline flux was prior to 1850 (2.0 µg m^{-2} y^{-1}). This flux ratio is substantially higher than observed in the eastern and midwestern U.S. or in Alaska and Canada (*4*). Neither the modern flux nor the preindustrial flux at Lake Tahoe, however, fall outside the range of results found in other studies. Thus, it appears that high flux ratios for Hg in the Tahoe sediments result from a combination of relatively low preindustrial flux and a comparatively high modern flux.

For Pb, the average modern flux (uncorrected) to Lake Tahoe sediments is 20 mg m^{-2} y^{-1}, and the average preindustrial accumulation rate is 0.7 mg m^{-2} y^{-1}. These values and the resulting flux ratio of 29 are similar to Pb accumulation rates found at other sites around the country (*4*).

Since Hg is known to bioaccumulate in aquatic food chains, and since Hg flux to the sediments of Lake Tahoe has increased substantially over the last 100 years, we obtained measurements of Hg content in the biota (*4*); specifically crayfish (*Pacifastacus leniusculus*), which has been recommended as a reliable indicator of trace metal contamination, and the Mackinaw trout (*Salvelinus namaycush*), which is a top aquatic predator and the basis of an important sport fishery at the lake. Several individuals of each species were collected from about one kilometer off the west shore, just south of Tahoe City. These concentrations are reported in ppm ($\mu g\ g^{-1}$), wet weight. The regressions show a trend of increasing Hg content with size of individuals for both Mackinaw trout and crayfish. All concentrations reported in this study, however, fall below the California state threshold of 0.5 ppm.

Discussion

One of the more interesting findings of this study is that Hg flux on the U.S. continental west coast near the crest of the Sierra Nevada mountains may be equivalent to or greater than rates of Hg deposition observed in the Midwest and eastern U.S. or in Alaska and Canada (*4*). Since there are no significant local sources of Hg emission within the Tahoe Basin, it would appear that air parcels coming off the Pacific Ocean must either carry Hg from distant sources or entrain Hg from regional sources on the west coast.

For Pb there has been a local source of historical emissions at Lake Tahoe, in the form of leaded gasoline consumption. Interestingly, this can provide some validation for the relatively high rate of modern Hg deposition estimated for this site. We have calculated automotive Pb emissions at Lake Tahoe for 1976, using fuel consumption records as estimated by in-basin gasoline sales (*5*). These calculations suggest that sufficient Pb was emitted locally to account for most of the Pb burden measured in recent sediments of the lake. Furthermore, our baseline flux of Pb to Tahoe sediments ($0.7\ mg\ m^{-2}\ y^{-1}$) is quite similar to Pb deposition measured at a remote Sierran site (*6*), and is just slightly greater than the flux of $0.5\ mg\ Pb\ m^{-2}\ y^{-1}$ measured in bulk precipitation over the eastern central (33—48°N) Pacific Ocean (*7*).

The fact that we can accurately account for Pb burden in the Tahoe sediments, along with its general correspondence to loading rates and flux ratios observed in other studies, suggests that our reconstruction of historical sediment and trace metal deposition in this system is reliable. It is likely that Hg has been brought into the basin by prevailing westerly winds, but that Pb has been predominately contributed by automobile emissions distributed around the lake.

The unexpectedly high rate of Hg deposition observed at Tahoe in the modern sediments may occur as a result of efficient orographic scavenging by rain and snow as air parcels travel over the crest of the Sierra Nevada mountain range. Another factor that could significantly enhance Hg deposition over the Tahoe area is a process of cold-condensation, whereby temperature dependent partitioning and transport increase the concentrations of semi-volatile compounds over cooler environments (*8*). It has been shown that these processes and increased precipitation sharply enhance the accumulation of semi-volatile compounds at elevations above 2000 meters (*9*). This could increase the Hg accumulation rates over high altitude environments like Lake Tahoe, especially when there are regional downwind sources of Hg in a warmer climate at lower elevations.

Although USEPA region IX (California, Nevada and Arizona) is the second lowest of all regions in this country for estimated THg emissions (*10*), it is possible that air parcels traveling toward Tahoe could entrain Hg volatilized from the waste of historical gold and silver mining. A tremendous amount of elemental Hg was consumed during the late 1800s at several mining districts regionally close to the Tahoe basin. Somewhat surprisingly, these historical emissions from the western Sierra foothills and from Virginia City in Nevada did not produce an unequivocal signal in Lake Tahoe sediments. Elevated concentrations of Hg are found at depth in the west lake core, but do not appear in the south lake core and are significantly modulated in the north lake core. We suggest that high mass sedimentation rates from Comstock logging in the late 1800s diluted most of this historical Hg signal in the two midlake cores (*4*). For that reason we have focused this study on comparing the preindustrial Hg deposition rates to modern rates.

Much of the Hg lost to mining spoils or deposited locally during the mining era would continue to volatilize from depositional surfaces and may gradually be transported downwind across the landscape. Nriagu (*11*) suggested that re-emission of only 0.2% of Hg lost during the historical mining era in the Sierras would be equivalent to a substantial fraction of current annual anthropogenic emissions in the U.S. This continuous volatilization of Hg° from mining spoils and abandoned Hg mines in the Coastal Range, in conjunction with orographic precipitation, scavenging and cold-condensation, could be contributing to the relatively high rate of modern atmospheric Hg deposition at Lake Tahoe.

We still cannot say yet whether that Hg input derives predominately from regional, perhaps historical, sources on the west coast or from globally distributed atmospheric Hg, but the regional sources are suspect for up to 85% of THg deposition. Obviously, a series of sediment sampling transects or deposition monitoring stations are needed across both elevational and latitudinal gradients in the western U.S. to clarify the relative importance of these sources and processes.

Acknowledgements

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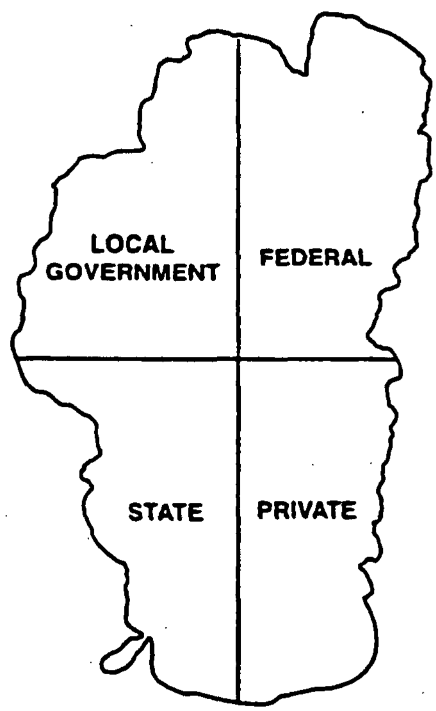
ENVIRONMENTAL IMPROVEMENT PROGRAM
FOR THE LAKE TAHOE REGION

Draft For Initial Adoption



The Cooperative Effort to Preserve, Restore and Enhance the Unique Natural and Human Environment of the Lake Tahoe Region.

February, 1998

TAHOE
REGIONAL
PLANNING
AGENCY

FISHERIES PROGRAM

BACKGROUND

The Fishery resource of the Tahoe Region has always been an integral part of Tahoe's natural environment. The waters of the Tahoe Region once abounded with native Lahontan cutthroat trout and supported a commercial fishery through the early 1900's. Through a variety of cause-and-effect relationships, the native cutthroat trout no longer exist in Lake Tahoe. The last reported spawning run of Lahontan cutthroat trout occurred in 1938. Today, the Tahoe Region supports both a lake and stream fishery. Game fishes include the brook trout, kokanee salmon, rainbow trout, mackinaw (lake trout), brown trout, and mountain whitefish. Of these, only the whitefish is native to the Region. The non-game fish species include Tahoe sucker, Lahontan redside, Lahontan speckled dace, Piute sculpin, and Tui chub. Species composition of the Tahoe fishery has changed greatly over time and the abundance and size are less than historical levels.

Unlike the wildlife threshold that focuses on individual species and their associated habitats, the fisheries thresholds focus almost entirely on habitat. Specifically, stream habitat and lake habitat are evaluated against adopted numerical standards (see Appendix C for numerical standards). In addition, TRPA has been directed to adopt instream flow standards to assure adequate water flows, depth, volume, and temperatures that are critical to biological quality for both resident and migratory fish populations throughout the Region's tributaries.

The entire fishery is sensitive to habitat disturbance and loss. Maintenance of the fishery must focus on preserving prime fish habitat in the lakes and streams and ensuring access to spawning and feeding habitat. Thresholds adopted for fisheries reflect the need to protect, enhance and improve fish habitat.

BASIS OF PROJECT DESCRIPTIONS

Projects, programs, and studies identified in the EIP which implement the Fisheries thresholds were initially developed during the 1996 Threshold Evaluation process with considerable input from the Fisheries and Wildlife Technical Advisory Committee (TAC). The TAC used the fish habitat assessment completed in 1996 by the U.S. Forest Service for the streams of the Region as well as the stream surveys that were conducted to establish the In-Stream Fisheries threshold standards (1982). In addition, observations and personal experience of the members of the TAC served to supplement these documents. Shoreline surveys conducted between 1993 and 1997 were used to update TRPA In-Lake Prime Fish Habitat maps. The updated and adopted map identifies areas in need of habitat restoration. This is the source of reference for the EIP In-Lake habitat projects. For specific threshold standards see Appendix C.

PRIORITY SETTING

Projects are prioritized based on projected implementation dates provided by sponsoring entities, by location (e.g., streams with an excellent fisheries potential that are currently rated as marginal), or by relative ease of implementation. Priority 2 projects need to be completed within the next ten (10) years in order to provide the improvement on the streams to aid in threshold attainment. Priority 3 projects are those projects that should occur in the ten (10) years beyond 2006. These projects would exceed the numerical targets beyond those established in the Thresholds. Projects are not added to the EIP for In-Stream habitat restoration if the stream is rated marginal and has no potential for improving as a fisheries stream.

COST ESTIMATES

Project cost estimates are based on similar projects completed to date in the Region. For In-Stream Fisheries, the cost is based on a per/mile cost for channel restoration. In-Lake Fisheries habitat improvements are based on a per/acre substrate restoration cost. It should also be noted, that because In-Stream Fisheries, Stream Environment Zone (SEZ), and Wildlife Threshold Standards are so closely interrelated and dependent on one another, there has been an effort to cross-reference. For example, the Upper Truckee River/Cove East project has an SEZ cost, a fisheries cost, and a wildlife cost. Together, these sub-total costs make up the estimated total cost for the project.

The private sector is expected to play a crucial role in the development and implementation of fisheries improvement projects. Greater than 65% of Lake Tahoe's shoreline is owned by private citizens. In many areas this ownership overlays where there are habitat improvement needs for In-Lake habitat. With the exception of a few spawning habitat projects that have identified specific areas to be improved, the In-Lake habitat improvement needs are identified by a total number of acres by county. One program identified in the EIP for Fisheries is the In-Lake Habitat Improvement Program. This program will be critical to the success of a public/private partnership approach aimed at restoring and/or improving fish habitat in Lake Tahoe.

RUBICON CREEK MOUTH - STREAM HABITAT RESTORATION — **Project Number:** 402

Program: FISHERIES — EIP Project Code: 9510 — Priority: 3

Jurisdiction: EL — Implementation Date: 2007 — Estimated Project Cost: 500,000.00

Keywords: PRIVATE/CTC/CA STATE LANDS/CA F&G/CA STATE PARKS/LAKE/STEAM

REMOVE FLUME STRUCTURE FROM MOUTH OF RUBICON CREEK AND RECONTOUR CHANNEL TO BEACH (PRIVATE PROPERTY),STABILIZE STREAM BANKS, FACILITATE THE EXCHANGE OF STREAM DIVERSION TO SOME OTHER SOURCE (10 ACRE FEET/YR), RESTORE BED SUBSTRATE

Scenic Unit: S-8 — PAS/CP: 147 — Watershed: 51
Street: — Stream: RUBICON CREEK

Needs Assessment: X — Concept: — TRPA Permit: — Completed:

EIP THRESHOLD SUBJECT

Water Quality:	+	Noise:		Wildlife:	+
Soils/SEZ:	+	Recreation:		Scenic:	+
AQ/Trans:		Fish:	+	Vegetation:	+

COMMENTS: W/ COMPLETION, 1.9 STREAM MILES WILL RATE EXCELLENT

HEAVENLY VALLEY CK PHASE I - STREAM HAB RESTORATION — **Project Number:** 404

Program: FISHERIES — EIP Project Code: 9510 — Priority: 2

Jurisdiction: EL — Implementation Date: 2004 — Estimated Project Cost: 50,000.00

Keywords: CAF&G/USFS/CTC/PRIVATE

STABILIZE THE BANKS OF HEAVENLY CREEK THROUGH REVEGETATION AT PIONEER TRAIL AND .5 MILES ABOVE AND BELOW. PHASE I OF HEAVENLY VALLEY CREEK RESTORATION

Scenic Unit: R 46 — PAS/CP: 101 — Watershed: 43
Street: PIONEER TRAIL — Stream: HEAVENLY VALLEY

Needs Assessment: X — Concept: — TRPA Permit: — Completed:

EIP THRESHOLD SUBJECT

Water Quality:	+	Noise:		Wildlife:	+
Soils/SEZ:	+	Recreation:	X	Scenic:	X
AQ/Trans:		Fish:	+	Vegetation:	+

COMMENTS: WITH THE COMPLETION OF PHASE I 4.4 MILES GO TO GOOD(SEE II)

MEEKS CREEK PHASE II - STREAM HABITAT RESTRORATION **Project Number:** 700

Program: FISHERIES EIP Project Code: 9510 Priority: 3

Jurisdiction: EL Implementation Date: 2007 Estimated Project Cost: 500,000.00

Keywords: USFS/CALTRANS/WASHOE TRIBE/STREAM HAB/ MIGRAT.

REMOVE BARRIER TO FISH MIGRATION & IMPROVE OPTIMAL FLOWS:CALTRANS TO RETROFIT BRIDGE/BOX CULVERT AT MEEKS CREEK AND HWY 89 TO ELIMINATE BARRIER TO FISH PASSAGE. USFS TO MANIPULATE STONEY RIDGE LAKE DAM FOR MORE OPTIMAL FLOWS.

Scenic Unit: R7 PAS/CP: 150 Watershed: 55
Street: HWY 89 Stream: MEEKS CREEK

Needs Assessment: X Concept: TRPA Permit: Completed:

EIP THRESHOLD SUBJECT

Water Quality:	X	Noise:		Wildlife:	X
Soils/SEZ:	X	Recreation:	X	Scenic:	X
AQ/Trans:	X	Fish:	X	Vegetation:	X

COMMENTS: PHASE II WILL BRING 6.5 STREAM MILES TO EXCELLENT SEE#147

HEAVENLY VALLEY CK PHASE II - STREAM HAB. RESTORATION **Project Number:** 710

Program: FISHERIES EIP Project Code: 9510 Priority: 3

Jurisdiction: SLT Implementation Date: 2007 Estimated Project Cost: 500,000.00

Keywords: USFS/HEAVENLY VALLEY SKI/PRIVATE/STREAM HAB

IMPROVE CHANNEL MORPHOLOGY AS NEEDED WHICH INCLUDES DEVELOPMENT OF POOLS, IMPROVE BED SUBSTRATE, REMOVE BARRIERS CREATED ROADS AND CULVERTS, FACILITATE EXCHANGE OF STREAM DIVERSION WITH OTHER WATER SOURCE.

Scenic Unit: PAS/CP: 101 Watershed: 43
Street: Stream: HEAVENLY VALLEY CK

Needs Assessment: X Concept: X TRPA Permit: Completed:

EIP THRESHOLD SUBJECT

Water Quality:	X	Noise:		Wildlife:	X
Soils/SEZ:	X	Recreation:	X	Scenic:	
AQ/Trans:		Fish:	X	Vegetation:	X

COMMENTS: PHASE II COMPLETION WILL BRING 4.4 STREAM MILES TO EXCELLENT

Water Resources

Data Category: Geographic Area:

Water Quality Samples for California

USGS 10336580 UPPER TRUCKEE R AT S UPPER TRUCKEE RD NR MEYERS CA

Available data for this site

El Dorado County, California
Hydrologic Unit Code 16050101
Latitude 38°47'47", Longitude 120°01'05" NAD27
Drainage area 14.09 square miles
Gage datum 6,490 feet above sea level NGVD29

Output formats

- Parameter Group data summary
- Inventory of available water-quality data
- Inventory of water-quality data with retrieval
- Tab-separated ASCII file, serial order
- Tab-separated ASCII file, wide order
- Reselect output format

SAMPLE DATETIME	MEDIUM CODE	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOSPHORUS TOTAL (MG/L AS P) (00665)
1989-11-01 14:20	9	.1182	.0108	.0297
1989-12-06 14:00	9	.0973		.027
1990-02-08 15:30	9	.1126		.0322
1990-03-21 11:00	9	.1341		.021
1990-04-04 14:15	9	.1545		.0254
1990-04-17 13:30	9	.1274		.0374
1990-05-01 13:35	9	.1407		.0375
1990-05-14 14:45	9	.6692		.0258
1990-05-31 13:00	9	.1087		.0132
1990-06-07 12:30	9	.1169		.0383
1990-06-18 13:00	9	.0906		.0217

1990-07-02 14:20	9	.1237		.027
1990-08-14 08:50	9	.1103		.0581
1990-10-24 13:00	9	.1297		.0378
1990-11-29 14:00	9	.1187		.0238
1991-01-23 12:10	9	.0411		.045
1991-02-20 13:30	9	.0856		.0193
1991-03-04 09:35	9	1.005		.1002
1991-03-08 14:00	9	.1586		.0285
1991-04-16 12:40	9	.1216		.0133
1991-05-01 14:05	9	.114		.0143
1991-05-08 12:00	9	.1704		.02
1991-05-15 12:20	9	.1045		.0197
1991-05-15 20:15	9	.2739		.0446
1991-05-21 13:50	9	.0984		.0182
1991-05-22 22:00	9	.249		.0383
1991-05-23 17:15	9	.878		.1472
1991-05-31 12:15	9	.1353		.0317
1991-06-04 13:00	9	.1399		.0433
1991-06-04 19:15	9	.484		.1184
1991-06-11 13:00	9	.17		.0234
1991-06-11 19:15	9	.2509		.0547
1991-06-17 17:50	9	.1195		.0214
1991-07-02 13:00	9	.0956		.0253
1991-07-22 12:00	9	.1188		.0298
1991-08-06 10:45	9	.0701		.0333
1991-08-27 11:45	9	.0523		.0434
1991-09-18 11:50	9	.0734		.0478
1991-10-16 10:00	9	.0691		.0355
1991-11-07 12:45	9	.199		.0178
1991-11-09 10:30	9	.1708		.0233
1991-12-09 14:30	9	.1501		.0174
1992-01-22 14:20	9	.0702		.0183
1992-02-18 13:00	9	.073		.0173

SAMPLE DATETIME	MEDIUM CODE	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOSPHORUS TOTAL (MG/L AS P) (00665)
1992-03-12 09:30	9	.0818		.0127
1992-03-25 11:50	9	.0961		.0127
1992-04-01 12:50	9	.1278		.0134
1992-04-06 15:50	9	.1049		.017
1992-04-12 19:20	9	.2896		.0348
1992-04-13 14:30	9	.1428		.0174
1992-04-16 22:00	9	.1087		.0186
1992-04-17 04:30	9	.4726		.065
1992-04-17 09:20	9	.4674		.0589
1992-04-21 14:30	9	.0917		.0168
1992-04-24 11:50	9	.1873		.0116
1992-04-26 20:45	9	.3384		.0238
1992-04-27 13:00	9	.2073		.0088
1992-04-27 20:15	9	.2144		.0256
1992-04-29 09:30	9	.1714		.0128
1992-04-29 14:15	9	.1526		.0107
1992-04-29 19:30	9	.4197		.0621
1992-05-04 13:20	9	.1174		.0206
1992-05-04 18:50	9	.1282		.0285
1992-05-05 16:05	9	.1343		.0234
1992-05-13 11:25	9	.1448		.0227
1992-05-18 10:40	9	.1353		.0193
1992-05-27 15:00	9	.1417		.0279
1992-05-27 17:40	9	.3099		.0497
1992-06-03 09:45	9	.1421		.0298
1992-06-15 10:30	9	.1029		.0329

1992-06-16 13:45	9	.122		.0359
1992-07-06 12:35	9	.1376		.0344
1992-07-12 11:00	9	.3617		.1167
1992-07-22 13:45	9	.1051		.0421
1992-08-18 10:10	9	.089		.0508
1992-09-09 11:10	9	.0919		.0405
1992-10-23 11:30	9	.069		.0293
1992-10-27 19:40	9	.2537		.046
1992-11-12 14:50	9	.0498		.027
1992-12-15 12:30	9	.1276		.0203
1993-01-19 10:45	9	.1071		.0172
1993-03-03 10:30	9	.0643		.0231
1993-03-11 11:30	9	.0833		.0196
1993-03-17 15:40	9	.5567		.0584
1993-03-18 10:10	9	.2739		.0209
1993-03-23 10:30	9	.14		.0094
1993-03-30 15:30	9	.0941		.0163
1993-04-13 14:30	9	.0918		.0103
1993-04-21 13:30	9	.0803		.028
1993-04-28 14:45	9	.1619		.0225
1993-05-13 14:20	9	.1607		.0371
1993-05-20 09:45	9	.133		.0353
1993-05-20 17:30	9	.225		.0537
1993-05-25 17:30	9	.1552		.0314
1993-05-31 15:20	9	.1189		.0435
1993-06-01 16:40	9	.103		.0187
1993-06-10 15:30	9	.1076		.0221
1993-06-15 12:50	9	.1048		.0291
1993-06-22 10:00	9	.1079		.0254
1993-06-23 19:00	9	.1249		.0278

		NITRO-GEN,AM-MONIA +	**NITRO-GEN,**	**PHOS-**

SAMPLE DATETIME	MEDIUM CODE	ORGANIC TOTAL (MG/L AS N) (00625)	NO2+NO3 TOTAL (MG/L AS N) (00630)	PHORUS TOTAL (MG/L AS P) (00665)
1993-06-29 13:45	9	.1772		.0287
1993-07-21 10:00	9	.0631		.0221
1993-08-02 13:10	9	.0918		.0334
1993-08-24 13:40	9	.1226		.0311
1993-09-22 11:05	9	.096		.0457
1993-10-26 13:00	9	.1177		.0388
1993-11-16 13:15	9	.043		.0256
1993-12-20 14:10	9	.07		.0213
1994-03-23 12:40	9	.145		.0183
1994-04-05 14:20	9	.1057		.014
1994-04-20 14:30	9	.1224		.0159
1994-04-20 19:30	9	.1742		.034
1994-05-02 14:50	9	.1058		.0162
1994-05-06 14:30	9	.0998		.0152
1994-05-12 17:00	9	.1094		.0303
1994-05-18 12:50	9	.0727		.026
1994-05-23 16:10	9	.1451		.0171
1994-06-02 14:20	9	.0727		.0226
1994-06-17 11:15	9	.0876		.0329
1994-07-12 14:45	9	.0712		.0456
1994-08-03 12:40	9	.07		.0495
1994-08-22 14:20	9	.0496		.0397
1994-09-19 14:40	9	.0946		.0585
1994-10-19 12:30	9	.0715		.0253
1994-11-06 15:30	9	.2928		.0315
1994-12-29 15:15	9	.1398		.0222
1995-01-30 13:45	9	.1331		.013
1995-02-27 13:50	9	.0757		.0291
1995-03-10 13:30	9	.1283		.0224

1995-03-13 18:15	9	.1728		.0169
1995-03-27 15:00	9	.1738		.0307
1995-04-26 15:45	9	.1178		.0135
1995-04-28 15:10	9	.1068		.0122
1995-04-30 16:15	9	.1619		.0165
1995-05-02 15:30	9	.1748		.0162
1995-05-09 16:10	9	.0761		.0165
1995-05-18 18:20	9	.0832		.0183
1995-05-23 15:50	9	.0307		.0187
1995-05-31 16:30	9	.1357		.0298
1995-06-01 17:00	9	.0195		.0509
1995-06-02 16:30	9	.1324		.035
1995-06-14 16:30	9	.093		.0274
1995-06-23 17:40	9	.1669		.0388
1995-06-28 15:10	9	.1196		.03
1995-07-06 14:50	9	.0897		.0281
1995-07-17 14:00	9	.1115		.0323
1995-08-02 13:50	9	.0627		.029
1995-08-29 14:30	9	.0622		.0277
1995-09-15 14:00	9	.0523		.0335
1995-10-12 14:20	9	.0611		.0336

SAMPLE DATETIME	MEDIUM CODE	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)
1995-11-21 14:05	9	.056		.0254
1995-12-14 14:10	9	.0874		.0152
1996-01-12 13:40	9	.0844		.014
1996-01-16 15:50	9	.21		.0314
1996-02-06 14:20	9	.1027		.0179

1996-03-08 12:45	9	.115		.0166
1996-03-20 13:40	9	.0781		.0171
1996-04-05 11:15	9	.1408		.0107
1996-04-17 15:15	9	.097		.0151
1996-04-25 14:30	9	.1218		.0205
1996-05-02 13:00	9	.0823		.0242
1996-05-06 19:00	9	.192		.0284
1996-05-11 16:05	9	.1888		.0224
1996-05-14 12:50	9	.0803		.0218
1996-05-15 11:15	9	.2006		.0322
1996-05-16 19:00	9	.1582		.047
1996-05-21 15:15	9	.1293		.0192
1996-05-30 15:20	9	.0164		.0195
1996-06-03 18:45	9	.0555		.0458
1996-06-06 11:40	9	.3576		.015
1996-06-06 17:45	9	.2258		.0238
1996-06-12 15:05	9	.2025		.0287
1996-06-18 14:40	9	.0431		.0266
1996-06-26 13:55	9	.0996		.025
1996-07-03 14:40	9	.0391		.0217
1996-07-19 15:20	9	.0631		.043
1996-08-16 13:05	9	.0772		.0298
1996-09-06 14:10	9	.0634		.0558
1996-10-02 17:10	9	.4156		.0317
1996-11-05 14:30	9	.1724		.0212
1996-11-18 17:00	9	.2176		.032
1996-11-19 17:05	9	.0891		.0259
1996-12-05 15:50	9	.2291		.0212
1996-12-12 16:00	9	.2772		.0156
1997-01-03 16:50	9	.0661		.0544
1997-01-08 16:00	9	.0943		.0191
1997-02-18 13:25	9	.0813		.0164
1997-03-12 13:00	9	.0821		.015

1997-03-27 13:45	9	.0842		.012
1997-04-09 13:40	9	.0764		.0166
1997-05-01 12:45	9	.0711		.0164
1997-05-08 15:40	9	.154		.0136
1997-05-15 11:45	9	.0575		.0177
1997-05-15 17:00	9	.1214		.0195
1997-05-22 16:45	9	.1036		.029
1997-05-30 14:00	9	.0669		.032
1997-06-06 14:10	9	.0636		.0207
1997-06-09 17:30	9	.1656		.0427
1997-06-12 14:50	9	.0684		.0357
1997-06-17 16:50	9	.0896		.0335

SAMPLE DATETIME	MEDIUM CODE	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)
1997-06-27 15:15	9	.0924		.025
1997-07-23 14:30	9	.0567		.0447
1997-08-18 14:20	9	.0559		.0419
1997-09-17 16:15	9	.1537		.05
1997-10-21 12:35	9	.0612		.0231
1997-11-25 13:45	9	.077		.0354
1997-12-15 16:00	9	.0643		.0219
1998-01-16 13:00	9	.1994		.03
1998-01-22 11:10	9	.0861		.0122
1998-02-25 14:00	9	.0712		.0182
1998-03-19 13:50	9	.0866		.0149
1998-03-25 15:40	9	.1337		.0297
1998-04-21 18:10	9	.0668		.0238
1998-04-30 16:30	9	.118		.0114

1998-05-05 18:10	9	.0652		.0144
1998-05-20 14:25	9	.0546		.0205
1998-05-28 13:15	9	.0518		.0177
1998-06-03 16:20	9	.0915		.036
1998-06-11 16:40	9	.0461		.0175
1998-06-17 14:35	9	.0605		.0423
1998-06-23 17:50	9	.0622		.029
1998-06-30 18:20	9	.1184		.0472
1998-07-15 12:50	9	.0539		.038
1998-07-15 19:30	9	.0904		.0257
1998-07-29 14:00	9	.055		.0347
1998-08-13 14:40	9	.1645		.0308
1998-09-29 14:00	9	.0864		.0197
1998-10-29 13:20	9	.0559		.019
1998-11-30 13:00	9	.1511		.022
1998-12-22 14:05	9	.0917		.0149
1999-01-22 13:40	9	.0778		.0166
1999-02-27 12:40	9	.0764		.0135
1999-03-24 14:10	9	.091		.0122
1999-04-16 11:40	9	.0919		.0126
1999-04-21 16:40	9	.0779		.0185
1999-05-07 12:45	9	.1825		.0144
1999-05-10 13:50	9	.0874		.0147
1999-05-13 17:35	9	.0937		.0214
1999-05-20 16:30	9	.0752		.0177
1999-05-26 14:30	9	.1124		.0248
1999-06-03 15:20	9	.0649		.0313
1999-06-09 15:10	9	.0598		.0174
1999-06-14 12:55	9	.0492		.0202
1999-06-21 14:15	9	.0488		.0192
1999-07-07 13:20	9	≤ .04		.025
1999-08-19 14:30	9	.0479		.034
1999-09-21 12:50	9	.0538		.0318

Water Quality Remark Code	Description
<	Actual value is known to be less than the value shown.

Questions about data gs-w-ca_NWISWeb_Data_Inquiries@usgs.gov
Feedback on this website gs-w-ca_NWISWeb_Maintainer@usgs.gov

USGS 10336580 UPPER TRUCKEE R AT S UPPER TRUCKEE RD NR MEYERS CA Water Quality Data
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Retrieved on 2001-08-22 15:31:55 EDT
Department of the Interior, U.S. Geological Survey
USGS Water Resources of California
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18.16 1.05

Water Quality Samples for California

USGS 103366092 UPPER TRUCKEE R AT HWY 50 ABOVE MEYERS CA

El Dorado County, California
Hydrologic Unit Code 16050101
Latitude 38°50'55", Longitude 120°01'34" NAD27
Drainage area 34.28 square miles
Gage datum 6,310 feet above sea level NGVD29

SAMPLE DATETIME	MEDIUM CODE	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	SEDI-MENT, SUS-PENDED (MG/L) (80154)
1989-08-29 13:45	9					1.4
1989-11-02 14:45	9	.1217	.0196	.0291	262.4	4.4
1989-12-06 15:00	9	.1146		.0152	197.8	2.9
1990-02-08 13:30	9	.0835		.0156	144.3	3.
1990-03-21 12:45	9	.1519		.0228	272.1	4.3
1990-04-04 16:15	9	.2514		.0197	331.	13.
1990-04-17 11:30	9	.1771		.0201	279.2	16.
1990-05-01 12:00	9	.1516		.0318	210.4	5.
1990-05-14 12:30	9	.1393		.0181	104.9	8.1
1990-05-30 16:55	9	.1126			163.6	3.5
1990-06-07 09:55	9	.157		.0307	103.	3.2
1990-06-18 10:45	9	.096		.0193	109.2	4.

1990-07-02 12:40	9	.1282		.023	86.5	4.2
1990-08-14 07:20	9	.1033		.0421	253.5	1.5
1990-10-24 09:50	9	.0975		.0225	333.3	1.
1990-11-29 11:00	9	.0646		.0116	221.4	1.
1991-01-23 10:50	9	.0555		.0361		≤ 1.
1991-02-20 11:10	9	.0902		.0102		≤ 1.
1991-03-04 10:40	9	.7694		.0777		48.
1991-03-08 11:20	9	.1531		.0194		2.
1991-04-16 10:30	9	.1355		.0151		1.
1991-05-01 11:40	9	.1495		.0161		4.
1991-05-08 10:00	9	.2114		.0342		25.
1991-05-15 10:00	9	.1173		.02		6.
1991-05-15 21:30	9	.4002		.0585		78.
1991-05-21 11:45	9	.1131		.0143		4.
1991-05-22 22:45	9	.3276		.0508		34.
1991-05-23 19:15	9	.8708		.1503		158.
1991-05-31 10:20	9	.1908		.021		5.
1991-06-04 11:00	9	.2749		.0482		23.
1991-06-04 20:15	9	.718		.0891		92.
1991-06-11 11:00	9	.1526		.017		11.
1991-06-11 20:00	9	.2033		.024		23.
1991-06-17 16:00	9	.159		.0171		5.
1991-07-02 10:45	9	.0985		.0229		7.
1991-07-22 11:00	9	.0687		.0223		1.
1991-08-06 09:00	9	.105		.0226		2.
1991-08-27 10:00	9	.0783		.0259		1.
1991-09-18 09:45	9	.0802		.0274		4.
1991-10-16 08:50	9	.1382		.0188		1.
1991-11-07 11:30	9	.129		.016		≤ 1.
1991-12-09 12:45	9	.0702		.0114		≤ 1.
1992-01-22 09:45	9	.1022		.0107		3.
1992-02-18 10:00	9	.0681		.0088		1.
1992-02-21 10:30	9	.0913		.0109		2.

1992-03-12 13:00	9	.0763		.0109		1.
1992-03-25 10:45	9	.1072		.0109		1.
1992-04-01 10:50	9	.1433		.0094		3.
1992-04-06 12:45	9	.1622		.0216		6.
1992-04-13 13:10	9	.2508		.0311		16.

SAMPLE DATETIME	MEDIUM CODE	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	SEDI-MENT, SUS-PENDED (MG/L) (80154)
1992-04-17 14:30	9	.3708		.069		67.
1992-04-21 11:10	9	.1701		.0189		4.
1992-04-24 14:40	9	.1717		.0125		3.
1992-04-27 15:30	9	.2056		.0088		3.
1992-04-27 21:30	9	.1815		.0204		7.
1992-05-04 15:50	9	.1562		.0376		4.
1992-05-05 14:50	9	.1497		.0234		2.
1992-05-13 14:15	9	.1532		.0175		4.
1992-05-18 13:25	9	.1356		.0154		4.
1992-05-28 09:55	9	.2053		.027		6.
1992-06-03 12:15	9	.145		.0219		2.
1992-06-16 15:50	9	.1251		.0253		1.
1992-07-06 09:55	9	.1457		.0183		2.
1992-07-12 12:15	9	.6063		.2481		75.
1992-07-22 14:50	9	.1175		.0329		2.
1992-08-18 13:20	9	.1449		.0205		2.
1992-09-09 13:25	9	.1148		.0155		4.
1992-10-23 10:00	9	.1117		.0173		2.
1992-11-12 13:50	9	.0857		.0151		6.
1992-12-16 10:30	9	.0762		.0085		≤ 1.
1993-01-19 13:30	9	.0694		.015		≤ 1.

1993-03-02 14:15	9	.062		.0182		2.
1993-03-11 13:30	9	.1023		.0214		2.
1993-03-17 15:30	9	.6549		.0878		85.
1993-03-18 11:15	9	.2735		.0294		20.
1993-03-23 11:40	9	.1762		.0176		5.
1993-03-30 14:15	9	.1175		.0151		3.
1993-04-13 13:30	9	.1301		.0121		1.
1993-04-21 14:45	9	.1516		.0249		6.
1993-04-28 13:30	9	.2138		.0255		9.
1993-05-13 13:00	9	.1816		.0365		23.
1993-05-20 12:45	9	.1863		.0501		36.
1993-05-25 16:00	9	.4001		.0311		23.
1993-06-01 15:00	9	.1385		.0317		32.
1993-06-10 14:30	9	.088		.0242		8.
1993-06-15 14:15	9	.1376		.0288		16.
1993-06-22 11:15	9	.0879		.0239		13.
1993-06-29 13:00	9	.2432		.0226		6.
1993-07-21 11:00	9	.0982		.0193		1.
1993-08-02 11:10	9	.2965		.0288		2.
1993-08-24 12:40	9	.1645		.0202		3.
1993-09-22 10:20	9	.0775		.0347		≤ 1.
1993-10-26 12:10	9	.0958		.0248		1.
1993-11-16 12:20	9	.0561		.0137		1.
1993-12-20 12:30	9	.0888		.0112		≤ 1.
1994-03-23 11:30	9	.1331		.0128		4.
1994-04-05 13:20	9	.1917		.0131		2.
1994-04-20 13:20	9	.1758		.0269		10.
1994-05-02 13:45	9	.1012		.0171		2.
1994-05-06 13:40	9	.1467		.0226		7.

		NITRO-GEN,AM-MONIA + ORGANIC	NITRO-GEN, NO2+NO3	PHOS-PHORUS	IRON, TOTAL RECOV-	SEDI-MENT,

SAMPLE DATETIME	MEDIUM CODE	TOTAL (MG/L AS N) (00625)	TOTAL (MG/L AS N) (00630)	TOTAL (MG/L AS P) (00665)	ERABLE (UG/L AS FE) (01045)	SUS-PENDED (MG/L) (80154)
1994-05-12 15:30	9	.1226		.0266		7.
1994-05-18 11:50	9	.0771		.0211		2.
1994-05-23 15:20	9	.09		.0156		3.
1994-06-02 13:30	9	.0867		.0192		16.
1994-06-17 10:15	9	.1144		.0244		1.
1994-07-12 13:30	9	.1024		.0288		≤ 1.
1994-08-03 11:45	9	.0741		.0266		3.
1994-08-22 13:10	9	.0976		.0195		1.
1994-09-19 13:30	9	.0687		.0331		≤ 1.
1994-10-19 11:10	9	.0626		.0129		1.
1994-11-06 14:50	9	.3411		.0405		12.
1994-12-29 14:00	9	.0621		.0143		≤ 1.
1995-01-14 15:00	9	.2011		.0263		10.
1995-01-30 12:45	9	.1259		.0093		2.
1995-02-27 13:00	9	.1092		.0254		≤ 1.
1995-03-10 12:30	9	.3122		.0461		49.
1995-03-14 12:00	9	.1471		.0138		5.
1995-03-27 13:50	9	.1003		.016		2.
1995-04-26 14:50	9	.2044		.0154		5.
1995-04-28 14:10	9	.2274		.0153		6.
1995-04-30 14:45	9	.1791		.0235		19.
1995-05-02 14:30	9	.2708		.0168		15.
1995-05-09 15:00	9	.0889		.0177		5.
1995-05-18 17:30	9	.0839		.0174		6.
1995-05-23 14:30	9	.079		.018		10.
1995-05-31 15:20	9	.1555		.0329		25.
1995-06-02 15:15	9	.2693		.0314		42.
1995-06-14 15:30	9	.1445		.0619		38.
1995-06-28 14:00	9	.0845		.0451		25.
1995-07-06 14:00	9	.124		.0191		14.

1995-07-17 13:00	9	.0897		.0332		8.
1995-08-02 12:30	9	.0755		.0226		3.
1995-08-29 13:40	9	.0712		.0243		2.
1995-09-15 12:50	9	.0661		.0149		1.
1995-10-12 12:30	9	.104		.0117		≤ 1.
1995-11-21 12:55	9	.0633		.0144		16.
1995-12-14 13:20	9	.0874		.0097		2.
1996-01-12 12:20	9	.0893		.01		≤ 1.
1996-01-16 15:10	9	.2055		.0304		18.
1996-02-06 13:30	9	.071		.0213		8.
1996-03-08 11:50	9	.0929		.0129		1.
1996-03-20 12:25	9	.0893		.0196		4.
1996-04-05 09:55	9	.1261		.0095		≤ 1.
1996-04-17 13:15	9	.3134		.0142		2.
1996-04-25 13:55	9	.4167		.0208		8.
1996-05-02 14:20	9	.0849		.0287		16.
1996-05-06 18:10	9	.2562		.0263		9.
1996-05-11 14:35	9	.3485		.0183		10.
1996-05-14 11:00	9	.1536		.0387		25.
1996-05-15 13:45	9	.2188		.0319		68.

SAMPLE DATETIME	MEDIUM CODE	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOSPHORUS TOTAL (MG/L AS P) (00665)	IRON, TOTAL RECOVERABLE (UG/L AS FE) (01045)	SEDIMENT, SUSPENDED (MG/L) (80154)
1996-05-16 17:30	9	.2541		.0442		152.
1996-05-21 14:20	9	.1431		.0229		16.
1996-05-30 14:30	9	.1245		.0214		15.
1996-06-03 17:30	9	.2986		.0312		31.
1996-06-06 14:10	9	.3844		.015		11.
1996-06-12 13:45	9	.3361		.0177		15.

1996-06-18 13:25	9	.0739		.0205		6.
1996-06-26 12:40	9	.1372		.0205		4.
1996-07-03 13:10	9	.1219		.0214		1.
1996-07-19 14:00	9	.141		.0366		1.
1996-08-16 12:30	9	.0624		.0188		1.
1996-09-06 13:00	9	.0737		.0329		1.
1996-10-01 11:23	9					2.
1996-10-02 16:30	9	.512		.0157		1.
1996-11-05 13:50	9	.1552		.0138		1.
1996-11-18 16:10	9	.1518		.0314		21.
1996-11-19 16:05	9	.0937		.0165		7.
1996-12-12 15:15	9	.0691		.0315		20.
1997-01-03 14:30	9	.0712		.0985		176.
1997-01-08 14:30	9	.1233		.0227		4.
1997-02-18 11:55	9	.0872		.0127		2.
1997-03-12 11:45	9	.0356		.012		1.
1997-03-27 12:35	9	.1885		.0141		6.
1997-04-09 14:30	9	.1344		.0132		1.
1997-05-01 12:00	9	.2771		.0133		2.
1997-05-08 14:30	9	.0857		.0121		5.
1997-05-15 13:00	9	.0846		.0311		12.
1997-05-15 18:00	9	.1277		.0296		23.
1997-05-22 15:25	9	.105		.0308		10.
1997-05-30 13:00	9	.0658		.0165		8.
1997-06-06 13:00	9	.0918		.0174		8.
1997-06-12 13:30	9	.0801		.032		3.
1997-06-17 15:50	9	.1125		.032		3.
1997-06-27 14:30	9	.0865		.0223		1.
1997-07-23 14:00	9	.2226		.0317		1.
1997-08-18 13:50	9	.0493		.0237		≤ 1.
1997-09-17 15:00	9	.0508		.0232		≤ 1.
1997-10-21 12:55	9	.0754		.0154		1.
1997-11-25 13:10	9	.0826		.0123		≤ 1.

1997-12-15 14:45	9	.0535		.0174		1.
1998-01-16 14:30	9	.164		.0206		4.
1998-01-22 13:05	9	.0865		.0085		1.
1998-02-25 13:10	9	.0567		.0152		≤ 1.
1998-03-19 14:35	9	.0543		.0149		1.
1998-03-25 14:50	9	.1947		.0199		11.
1998-04-21 16:50	9	.0756		.0185		8.
1998-04-30 15:10	9	.1266		.012		11.
1998-05-05 16:40	9	.0776		.0151		8.
1998-05-20 12:45	9	.0864		.0196		4.
1998-05-28 12:30	9	.0658		.0208		3.

SAMPLE DATETIME	MEDIUM CODE	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOSPHORUS TOTAL (MG/L AS P) (00665)	IRON, TOTAL RECOVERABLE (UG/L AS FE) (01045)	SEDIMENT, SUSPENDED (MG/L) (80154)
1998-06-03 14:55	9	.0821		.0171		14.
1998-06-11 15:55	9	.0679		.0178		44.
1998-06-17 13:20	9	.1056		.032		82.
1998-06-23 17:00	9	.0824		.0275		14.
1998-06-30 17:30	9	.0913		.051		14.
1998-07-15 11:40	9	.1106		.0235		6.
1998-07-29 12:20	9	.0564		.0319		3.
1998-08-13 13:40	9	.0802		.0367		4.
1998-09-29 12:45	9	.1439		.0141		1.
1998-10-29 12:25	9	.0866		.0107		2.
1998-11-30 11:30	9	.1223		.015		4.
1998-12-22 13:20	9	.0987		.0113		2.
1999-01-22 12:20	9	.0554		.0107		1.
1999-02-27 11:00	9	.0856		.0092		2.
1999-03-24 13:25	9	.0865		.0091		1.

1999-04-16 10:55	9	.0756		.0117		2.
1999-04-21 15:25	9	.1397		.0185		7.
1999-05-07 11:40	9	.1365		.0318		17.
1999-05-10 12:35	9	.0859		.0168		6.
1999-05-13 16:25	9	.1311		.0293		16.
1999-05-20 15:20	9	.106		.0171		12.
1999-05-26 13:15	9	.2812		.0581		62.
1999-06-03 15:10	9	.065		.0233		18.
1999-06-09 13:55	9	.0542		.0186		10.
1999-06-14 11:40	9	.0956		.0195		16.
1999-06-21 16:30	9	.0605		.0155		6.
1999-07-07 12:45	9	.0578		.0222		4.
1999-08-19 13:25	9	.0679		.0227		2.
1999-09-21 12:15	9	.0716		.0239		1.

Water Quality Remark Code	Description
<	Actual value is known to be less than the value shown.

Questions about data gs-w-ca_NWISWeb_Data_Inquiries@usgs.gov
Feedback on this website gs-w-ca_NWISWeb_Maintainer@usgs.gov

USGS 103366092 UPPER TRUCKEE R AT HWY 50 ABOVE MEYERS CA Water Quality Data
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Water Quality Samples for California

USGS 10336610 UPPER TRUCKEE RIVER AT SOUTH LAKE TAHOE CALIF

El Dorado County, California
Hydrologic Unit Code 16050101
Latitude 38°55'22", Longitude 119°59'23" NAD27
Drainage area 54.90 square miles
Gage datum 6,229.04 feet above sea level NGVD29

Output formats

Parameter Group data summary
Inventory of available water-quality data
Inventory of water-quality data with retrieval
Tab-separated ASCII file, serial order
Tab-separated ASCII file, wide order
Reselect output format

SAMPLE DATETIME	MEDIUM CODE	PH WATER WHOLE FIELD (STANDARD UNITS) (00400)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N) (00608)	NITROGEN, NITRITE DISSOLVED (MG/L AS N) (00613)	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORU[S] TOTAL (MG/L AS P) (00665)
1997-01-01 17:00	9		.0074		.3965	.0119	.230
1997-01-02 16:40	9		≤ .001		.2146	.0049	.222
1997-01-03 11:45	9		≤ .001		.1587	.0092	.098
1997-01-08 12:30	9		≤ .001		.2258	.02	.03
1997-03-13 13:10	9		≤ .001		.1827	.0185	.032
1997-03-27 11:00	9		.0019		.0973	.0397	.034
1997-04-09 12:45	9	7.3	.0041		.2941	.016	.018
1997-05-02 10:30	9		≤ .001		.2059	.0093	.018
1997-05-08 09:30	9	7.1	.0008		.2209	.0061	.017
1997-05-15 15:10	9		≤ .001		.1147	.0057	.042
1997-05-16 07:45	9		≤ .001		.1669	.0025	.049
1997-05-22 13:20	9		≤ .001		.2075	.0397	.03
1997-05-30 11:20	9		≤ .001		.0932	.0058	.027
1997-06-06 14:00	9		≤ .001		.126	.0065	.029

1997-06-13 12:15	9	7.5	≤ .001		.085	.01	.036
1997-06-20 15:50	9		.0008		.0739	.0085	.042
1997-06-27 13:15	9		.0026		.1471	.0101	.021
1997-07-23 12:40	9		.0026		.0677	.0166	.036
1997-08-19 12:40	9		≤ .001		.1482	.0117	.042
1997-08-19 13:05	9		≤ .015	≤ .01	≤ .2	≤ .09	≤ .0
1997-09-17 11:45	9	7.9	.0017		.0701	.0081	.023
1997-10-21 11:30	9		.0006		.1085	.0165	.016
1997-11-25 11:40	9		.0006		.1012	.009	.017
1997-12-15 13:10	9	7.	.0218		.1031	.0255	.038
1998-01-16 13:30	9		.0007		.4571	.0261	.111
1998-01-22 15:30	9		.0058		.2083	.0321	.020
1998-02-25 12:00	9		≤ .001		.1398	.0406	.02
1998-03-18 12:30	9		≤ .001		.1647	.0218	.026
1998-03-25 13:30	9		.0017		.4653	.0293	.063
1998-04-21 14:20	9		.0024		.1208	.0153	.027
1998-04-30 13:15	9		.0118		.1512	.0159	.024
1998-05-05 13:30	9	7.3	.0059		.1013	.0119	.018
1998-05-13 12:00	9	7.	.0016		.2009	.0196	.023
1998-05-20 12:40	9		.0007		.0912	.0148	.026
1998-05-28 14:50	9		≤ .001		.0977	.0137	.020
1998-06-03 12:55	9		.0044		.1152	.0135	.030
1998-06-07 14:15	9		≤ .001		.2109	.0138	.070
1998-06-11 14:15	9		.0015		.1566	.0095	.060
1998-06-17 11:20	9		.0008		.1158	.0074	.042
1998-06-23 15:40	9		≤ .001		.2262	.0034	.035
1998-06-30 16:10	9		≤ .001		.1447	.0104	.049
1998-07-15 15:15	9		.0009		.0847	.0092	.033
1998-07-29 10:30	9		.0021		.0813	.0118	.034
1998-08-13 12:45	9		.0034		.0488	.006	.02
1998-09-09 15:30	9		≤ .001		.1516	.0034	.029
1998-09-29 14:15	9	7.6	.0005		.1292	.0094	.018

1998-10-28 09:50	9	7.4	.0033		.1139	.0153	.015
1998-11-30 10:30	9		.001		.3196	.0223	.052
1998-12-22 11:30	9		≤ .001		.1406	.0321	.020
1999-01-22 11:10	9		.0076		.2546	.0416	.067

SAMPLE DATETIME	MEDIUM CODE	PH WATER WHOLE FIELD (STANDARD UNITS) (00400)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N) (00608)	NITROGEN, NITRITE DISSOLVED (MG/L AS N) (00613)	NITROGEN,AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORU TOTAL (MG/L AS P) (00665)
1999-02-26 16:30	9		.0096		.1799	.0404	.029
1999-03-18 16:20	9		.001		.1543	.0213	.027
1999-03-24 11:20	9		.0034		.1734	.0231	.022
1999-04-16 09:45	9		≤ .001		.1721	.0293	.023
1999-04-21 13:20	9		.003		.1916	.0279	.039
1999-04-28 14:05	9		.0025		.1027	.0307	.01
1999-05-07 09:10	9		≤ .001		.2161	.0143	.039
1999-05-10 17:00	9		.0023		.1169	.022	.026
1999-05-13 14:40	9		≤ .001		.5937	.0163	.04
1999-05-20 14:00	9		.001		.205	.0162	.026
1999-05-26 11:00	9		.0044		.241	.0165	.065
1999-06-03 12:40	9		≤ .001		.128	.0057	.032
1999-06-09 09:50	9		.0018		.0826	.013	.020
1999-06-14 08:05	9		.0019		.1042	.0039	.054
1999-06-21 11:30	9		.0045		.0836	.0075	.027
1999-07-07 11:00	9		.001		.1251	.0132	.027
1999-08-19 10:50	9		≤ .001		.0846	.0145	.025
1999-09-21 10:00	9		.0021		.062	.0189	.026

Water Quality Remark Code	Description
<	Actual value is known to be less than the value shown.

Tahoe Tribune 11-23-99

Regulations may force cattle out

By Andy Bourelle
Tribune Staff Writer

Tribune file photo

Strict regulations on cattle grazing and land usage in the Meiss Meadow have caused some to fear similar actions throughout the Sierra Nevada.

Regulations being enforced on the 11,000-acre Meiss Meadows south of Lake Tahoe may have repercussions on ranching operations throughout the Sierra Nevada.

Why?

Three reasons: Cows graze on the parcel in the summer, fecal coliform standards there are more stringent than they are in other parts of the state and, finally, if the cattle are prohibited from grazing at Meiss Meadows, in a round-about way that could lead to more development along the foothills of the western Sierra.

And if that happens to the California ranch family leasing the meadows, there is a fear that those consequences could be replicated throughout the 570-mile jurisdiction of the Lahontan Regional Water Quality Control Board.

"I think they're very concerned that what we're doing in Tahoe may be followed in the rest of the Sierra," said Bruce Warden of Lahontan. "They're worried there will be a domino effect."

Grazing's impact

Grazing has long been an issue of contention at Tahoe. Some say it has an impact on the water quality of the streams running into the lake, not only because of pathogens from manure but also because of sediment sent downstream from cattle trampling banks and stream beds.

Meiss Meadows has been used for grazing since 1868. The Upper Truckee River, Tahoe's largest tributary, starts in the meadow at an elevation of more than 8,000 feet.

The area is owned by the Forest Service, which leases it in the summer to two California families, who have ranches in the Sierra foothills.

As many as 200 cow/calf pairs — up to 400 head of cattle — are allowed to graze there.

Warden said there are several types of contamination — dissolved oxygen, floating material, settling material, taste and odor thresholds and algal-growth potential — that can show whether the cows' presence is affecting water quality. The one Lahontan has focused on is fecal coliform — a measurement of the amount of feces in the water — because it is a good indicator other violations may be present.

Lahontan earlier this year issued a notice of violation to the Forest Service for several years' worth of fecal coliform violations. Since 1991, the years when cows have grazed the area have resulted in violations; in years with no summer grazing, there were no violations.

Solutions sought

The Forest Service has been trying to come up with a long-term management plan for the grazing allotment, and the public comment period for a draft environmental assessment closed last month. In addition to Lahontan, the League to Save Lake Tahoe and California Attorney General's Office were critics of the EA.

This past summer, the Forest Service and the permitees had essentially implemented the plans called for in the EA. However, reports received recently show that violations still occurred from June to September.

Jeff Reiner, fisheries biologist for the Forest Service's Lake Tahoe Basin Management Unit, said the EA has been withdrawn. However, he said he couldn't provide further comment on what is going to happen.

"The administrative actions that the Forest Service will be taking are still under decision," he said Friday. "I can't have any further comment."

Warden said "there's an almost certainty that at a minimum" the Forest Service will have to cut back on the number of cows it allows to graze in the area, likely eliminating them from the so-called Big Meadows portion of the allotment.

However, he's unsure of whether that will be enough.

"It's kind of baby steps in the right direction," Warden said. "It's better than the status quo, but based on long-term data, I think there are always going to be violations as long as there are cows there."

EPA has weaker standards

Here's the rub, however. Lahontan's fecal coliform standards are 10 times more stringent than the U.S. Environmental Protection Agency's or any of the other eight California regional boards. Because Lahontan regulates the water quality in highly used pristine Sierra lakes, it has had those strict standards for decades at Tahoe and Sierra-wide since the early 1990s.

This is a concern to the permitees and the California Cattleman's Association because it's possible no grazing operation could meet those standards.

"If it's an unattainable standard that's starting to be enforced, then we've got a problem," said Pat Blacklock, director of administration and policy affairs for the California Cattleman's Association.

In the case of the Meiss permitees, they transport their cattle to the Sierra every summer when forage material becomes scarce in the foothills. It's a more financially prudent way to keep their business afloat when their ranch already is surrounded by development. Taking away the grazing opportunities at Meiss could force them to lose their businesses. Many California ranches do the same: transporting their cattle to the Sierra during the summer.

Selling their ranches to developers may be their only option.

Domino effect feared

Not only does the Cattleman's Association not want that to happen to the Meiss permitees, it doesn't want that to be the case elsewhere in the Sierra.

"We're all working together — working with Lahontan, working with the Forest Service," Blacklock said. "We're going to try to find a solution that works."

Warden said "drastic changes" are needed.

"We're talking to the Forest Service. They're going to have to make some really drastic changes in the way they do things, or they're going to have to take the cows away."

If violations continue, the next step for Lahontan would be to issue a cease-and-desist order, which would likely require the Forest Service to take the cattle away. After that, litigation from the California Attorney General's Office could be possible.

"They are required to live up to state standards," Warden said.

It isn't Lahontan's intention, Warden said, to create a "domino effect" elsewhere in the Sierra. However, the agency has to enforce its rules.

"We're not going to be actively trying to check them out, but if we have a complaint from an individual, we have to respond. And if there are violations, we may have to force them to take the cows away," Warden said. "I'm not saying dominoes are going to fall all over the Sierra, but if they do fall, so be it.

"Tahoe waters and eastern Sierra waters are pristine," he added. "We want to preserve that."

Dave Roberts, assistant executive director of the League to Save Lake Tahoe, said the "labor-intensive, cost-intensive procedure" under way to try to keep grazing in the meadows isn't worth the effort. And even if the Forest Service finds a way to meet the fecal coliform standards, that doesn't address other issues, such as damaging populations of Lahontan cutthroat trout in the river.

Coliform tests for Meiss Meadows

1991 — grazing — violation
1992 — no tests
1993 — grazing — violation
1994 — no grazing — no violation
1995 — no grazing — no violation
1996 — grazing — violation
1997 — grazing — violation
1998 — no tests
1999 — grazing — violation

Larger wetlands project is set for south Tahoe

By Jeff DeLong
RENO GAZETTE-JOURNAL

Move over, Snow Creek. Get ready, Cove East.

The $4.2 million restoration project nearing completion on Lake Tahoe's north shore sets the stage for a similar project — one on a much larger scale — planned for next summer on the other side of the lake.

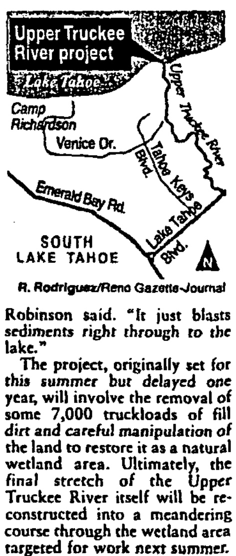
"This is sort of a small-scale Cove East," the California Tahoe Conservancy's Richard Robinson said during a recent tour of the Snow Creek wetland restoration project, the largest such effort ever undertaken on the north shore.

Similar projects have occurred around the lake at different watersheds such as Cold Creek, Angora Creek and Trout Creek. All are designed to restore important ecosystems damaged by human activity.

And all pale in comparison to what's planned next summer at Cove East near the mouth of the Upper Truckee River, Lake Tahoe's largest tributary.

At a cost of some $10.5 million, the conservancy plans to restore 23 acres of wetlands covered over during construction of the Tahoe Keys subdivision in the late 1950s. The largest wetland in the Sierra Nevada was critically damaged, strangling the Upper Truckee's natural filtering system for waterborne sediment.

"We call it a shotgun," Robinson said. "It just blasts sediments right through to the lake."



R. Rodriguez/Reno Gazette-Journal

The project, originally set for this summer but delayed one year, will involve the removal of some 7,000 truckloads of fill dirt and careful manipulation of the land to restore it as a natural wetland area. Ultimately, the final stretch of the Upper Truckee River itself will be reconstructed into a meandering course through the wetland area targeted for work next summer.

Cove East, which involves work on land abutting the shore of Lake Tahoe, could also prove trickier than similar efforts at Snow Creek and in other watersheds.

"Here we have the opportunity to make mistakes and it won't impact the lake," Robinson said. "Cove East is right on the lake."

Tahoe/Wetland work aims to help nature

From 1A

Wetlands are among nature's most productive ecosystems. They are critical habitat for hundreds of species of wildlife. They also serve as a natural filter for runoff — a characteristic particularly important at Lake Tahoe, where sediment is fueling algae growth that is robbing the lake's famed clarity at an average rate of more than a foot each year.

Wetlands are also in trouble, with more than half of the 220 million-plus acres that once existed across the country drained, filled-in and developed, mostly since the 1970s. Nevada has lost 52 percent of its wetlands and the situation is even more critical in California, where the Environmental Protection Agency estimates 91 percent are gone. In the Tahoe Basin alone, 75 percent of the marshes and 50 percent of the meadows have been covered with homes and parking lots.

Snow Creek offers a fairly typical story. Some of the meadow was graded decades ago, possibly to make way for a development that never occurred. In the early 1960s, crews working on a highway project began dumping fill dirt in the meadow, much of it contaminated with petroleum products used at the time to settle dust.

6Robinson tells of one worker who dumped dirt at the meadow from an old service station site. It was so thick with gasoline "you could light it with a match."

Mounds of fill dirt as much as 5 feet deep altered the meandering course of Snow Creek. A large pond formed and the meadow's ability to filter sediment was lost. A natural asset had become an environmental liability.

California acquired the meadow in 1987 and an initial restoration plan was stalled when hydrocarbon pollution was discovered. The new project — part of a $908 million strategy to save Lake Tahoe highlighted by President Clinton in 1997 — didn't start until last spring.

The effort has been painstaking, with workers essentially cloning a marshy meadow at the disturbed 4-acre site. Contaminated dirt was dug up and hauled away by some 2,000 trips of dump trucks.

A natural course for Snow Creek was cut, allowing for periodic flooding of the meadow during periods of high runoff. A new pond was dug in a different location so neighboring residents could continue a wintertime tradition of ice skating without interfering with the natural system.

On Friday, workers were returning vegetation to the meadow. Some of the vegetation, including willows and other wetland plants, had been removed at the start of the project, kept watered and then were replanted. Grassy sod cultivated at the Nevada Division of Forestry's seed farm at Washoe Lake was laid on parts of the meadow floor. Seed was scattered elsewhere.

"This should look really cool in the spring when it starts coming up," Kym Kelley, an erosion control subcontractor working on the project, said as sod was pressed into place Friday.

Indeed, it will be a couple of years before nature takes full control of improvements humans started this summer at Snow Creek. But Robinson is confident the project will prove to be one of Lake Tahoe's important environmental success stories.

"We can't do things as well as nature," Robinson said.

"What we try to do is point them in the right direction. Then we let nature take over."

Conservationists and land-use regulators agree wetland restoration ranks as one of the most important steps possible to save an endangered Lake Tahoe.

"We really need to restore as many of the wetlands as we can," said Juan Palma, the new director of the Tahoe Regional Planning Agency. "Wetlands play a critical role."

Loss of Tahoe's wetlands to development proved to be one of the most environmentally damaging mistakes ever made, said Rochelle Nason of the League to Save Lake Tahoe. Restoring what can be saved is thus one of the most important steps possible if the continued loss of Tahoe's clarity is to be reversed.

Jim Boyd, chief of staff for the California Resources Agency, recently toured the Snow Creek project with fellow officials. He said efforts like the one there and at Cove East will prove critical at Lake Tahoe and in many other places.

"Mother Nature spent thousands of years setting up this filtration system," Boyd said. "Man has learned the consequences of incursions into areas like this. We're in a real race with the impacts of development."

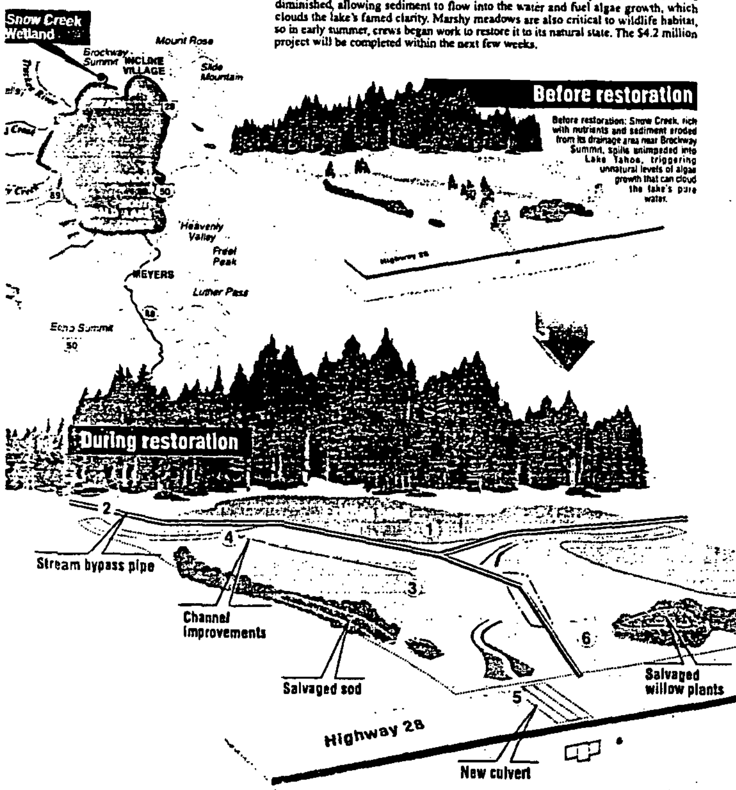
REBORN

Restoring the Snow Creek Wetland

Graphic by Jay Kurowski

Copy assistance by Jeff DeLong, Jim Sloan

More than 30 years ago, Snow Creek's natural meadow on Lake Tahoe's north shore was covered with layers of oily fill dirt. The meadow's ability to filter runoff was diminished, allowing sediment to flow into the water and fuel algae growth, which clouds the lake's famed clarity. Marshy meadows are also critical to wildlife habitat, so in early summer, crews began work to restore it to its natural state. The $4.2 million project will be completed within the next few weeks.



Reconstructing the wetlands

Here's the step-by-step process used to restore the Snow Creek Wetland to its natural state.

The existing pond, created when fill was dumped in the Snow Creek drainage more than 30 years ago, was drained to make way for $4 million restoration project

Snow Creek was diverted into pipelines so wetlands restoration could proceed in the summer of 2000

Heavy equipment removed up to 5 feet of fill dirt dumped in the meadow, much of it contaminated by oil and other petroleum products. Some 33,000 cubic yards of soil, or roughly 2,000 dump truck loads, was hauled away. Loaders then carved out the bed of a new and smaller pond in a different part of the meadow.

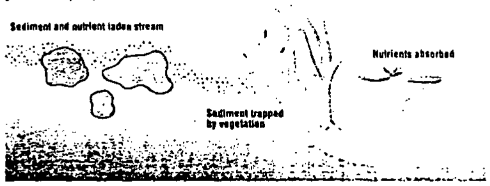
...nts of the wetland

...e common plants that inhabit the Snow ...k Wetland

- Baltic rush
- Bentgrasses
- Blue wildrye
- Bulrush
- Canada thistle
- Crested wheatgrass
- Common dandelion
- Common horsetail
- Fireweed
- Goat's beard
- Goosefoot
- Hairy willowherb
- Hoary aster
- Hooker's evening primrose
- Incense cedar
- Intermediate wheatgrass
- Kentucky bluegrass
- Knotweed
- Large-leaf avens
- Lodgepole pine
- Long-stem clover
- Lucine
- Meadow foxtail
- Mountain alder
- Monkey flower
- Orchard grass
- Owl clover
- Prickly lettuce
- Scouler's willow
- Short-awn foxtail
- Slender wheatgrass
- Smallwing sedge
- Spanish clover
- Spikerush
- Three-stamen rush
- Water buttercup
- Water sedge
- Western mountain aster
- White fir
- Woods rose

After restoration

With the restored drainage channel and re-established vegetation, the runoff from Snow Creek will be slowed down and given time to settle out. This will provide a natural filtering function and dramatically reduce the amount of sediment reaching the lake. This will reduce algae growth and help keep Tahoe's water clear.



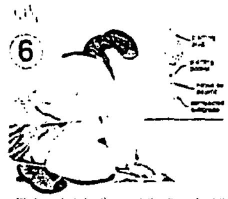
4

A new and more natural course for Snow Creek ... established with the creation of 950 feet of stre... channel. Layers of coconut fabric will protect t... streambank and its sod until vegetation fully ta... hold in several years. The stream will naturally over... its banks during heavy storms and periods of stream... flooding the wetlands and filtering sediment t... otherwise would flow into Lake Tahoe.

5

Three new box culverts were installed to carry Sn... Creek beneath Highway 28. The middle culvert ... placed lower to allow fish free passage, even du... periods of low flow. The higher two culverts ... handle 50-year flood events.

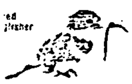
6

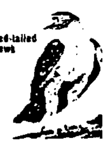


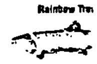
Workers planted native vegetation throughout t... meadow. Wetlands grasses and willows, careful... removed at the start of the project, were replante... along with seeds collected from the meadow over t... past three years.

...mals of the wetland

...common animals that inhabit the Snow Creek Wetland.







Bird Species
- American Coot
- American Robin
- American Widgeon
- Band-tailed Pigeon
- Barn Swallow
- Belted Kingfisher
- Black Phoebe
- Brewers Blackbird
- Brown Creeper
- *California Gull*
- Canada goose
- Cassin's Finch
- Cinnamon Teal
- Clark's Nutcracker
- Cliff Swallow
- Common Merganser
- Dark-Eyed Junco
- Evening Grosbeak
- Great Blue Heron
- Great Egret
- Harry Woodpecker
- Hermit Warbler
- *Hooded Merganser*
- Horned LarkHouse Finch
- *Killdeer*
- Mallard
- Mountain Chickadee
- Mourning Dove
- Northern Flicker
- Northern Winged Swallow
- Orange crowned Warbler
- *Red-Tailed Hawk*
- Red Breasted Nuthatch
- *Say's Phoebe*
- Solitary Vireo
- *Song Sparrow*
- Spotted Sandpiper
- Steller's Jay
- Tree Swallow
- Townsend's Jay
- Vesper Sparrow
- Violet-green Swallow
- Western Tanager
- Western Wood Pewee
- White Breasted Nuthatch
- White Crowned sparrow
- *White Headed Woodpecker*
- Wood Duck
- *Yellow Rumped Warbler*

Mammals
- Beaver
- Coyote
- Douglas Squirrel
- Raccoon
- Vole
- Western Gray Squirrel

Amphibians
- Pacific Treefrog

Reptiles
- Western Terrestrial Garter Snake

Fish (game speci...
- Brook Trout
- Rainbow Trout

Fish (native speci...
- Lahontan Redside
- *Mountain Suckers*
- Piute Sculpin
- *Speckled Dace*
- Tahoe Suckers
- Tui Chubs

Sources: California Tahoe Con... and Associates, ... and Western Botanical Services

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HISTORICAL ATMOSPHERIC DEPOSITION OF LEAD AND MERCURY RECONSTRUCTED FROM SEDIMENT CORES OF LAKE TAHOE, CALIFORNIA AND NEVADA.

Substantial trace metal enrichment of modern sediments at Lake Tahoe is attributed to atmospheric deposition, since there are no known direct industrial discharges within the watershed. Before 1850 sediment concentrations of Pb and Hg were similar to bedrock concentrations, indicating that preindustrial contributions came primarily from erosion of local soils. Above these baseline values, however, surface sediment concentrations have increased six-fold for Pb (average 83 ppm) and five-fold for Hg (average 0.191 ppm). Notably, while Pb concentrations have stabilized or decreased in recent sediments, the Hg concentrations have continued to increase. At Lake Tahoe the watershed to lake surface ratio is only 1.6. Therefore, sediment accumulation rates for Pb and Hg in excess of their baseline fluxes are interpreted directly as atmospheric deposition rates: approximately 14 mg Pb and 36 ug Hg per square meter annually. The ratios of total modern flux to preindustrial flux are 25 for Pb and 21 for Hg. While the Pb flux ratio is somewhat higher than reported from the eastern US and Canada, it is not atypical. The Hg flux ratio, however, is much higher than observed in most other natural aquatic systems without direct contamination.

Day: Friday, Feb. 5
Time: 03:45 - 04:00pm
Location: Sweeney Center

Code: CS63FR0345S

Agricultural Research Service

TEKTRAN

WET DEPOSITION OF CURRENT-USE PESTICIDES IN THE SIERRA NEVADA MOUNTAIN RANGE

Author(s):
MCCONNELL LAURA L
LENOIR JAMES
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SEIBER JAMES

Interpretive Summary:
California's Central Valley is a highly agricultural area with large amounts of pesticides used on various crops each year. Significant quantities of these chemicals are released to the atmosphere above the field through a process called volatilization. The Sierra Nevada Mountain range is located to the east of the Central Valley and air masses that travel across the valley are transported into the mountain range where precipitation can deposit pesticide residues into the ecosystem of this ecologically sensitive region. The majority of precipitation received in the Sierra Nevada mountains occurs during the winter months. Pesticide application rates in the Central Valley are significant in the winter months as well as in the summer. Snow and rain samples were collected at three locations in the Sierra Nevada Mountain range during the winter of 1995-1996. Two stations were located in Sequoia National Park, CA and the third was in the Lake Tahoe basin. Surface and deep water samples were also collected from Lake Tahoe. Chlorothalonil and chlorpyrifos were detected in almost every precipitation sample and in every water sample. Other pesticides detected were endosulfan, diazinon, malathion, and lindane. From this and other preliminary studies, it is estimated that 24-31 kg of chlorpyrifos is deposited to the Sierra Nevada range each year through different atmospheric deposition processes.

Keywords:
pesticides henry's law atmospheric transport transformation sustainable agriculture air sampling sorption volatility micrometeorology soil insecticides herbicides modeling deposition water quality analytical methods

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TEKTRAN
United States Department of Agriculture
Agricultural Research Service

Updated: 1998-12-18

USDA Sierra Nevada Mtns.

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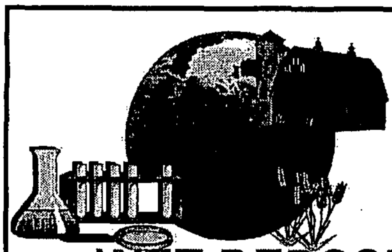


WET DEPOSITION OF CURRENT-USE PESTICIDES IN THE SIERRA NEVADA MOUNTAIN RANGE

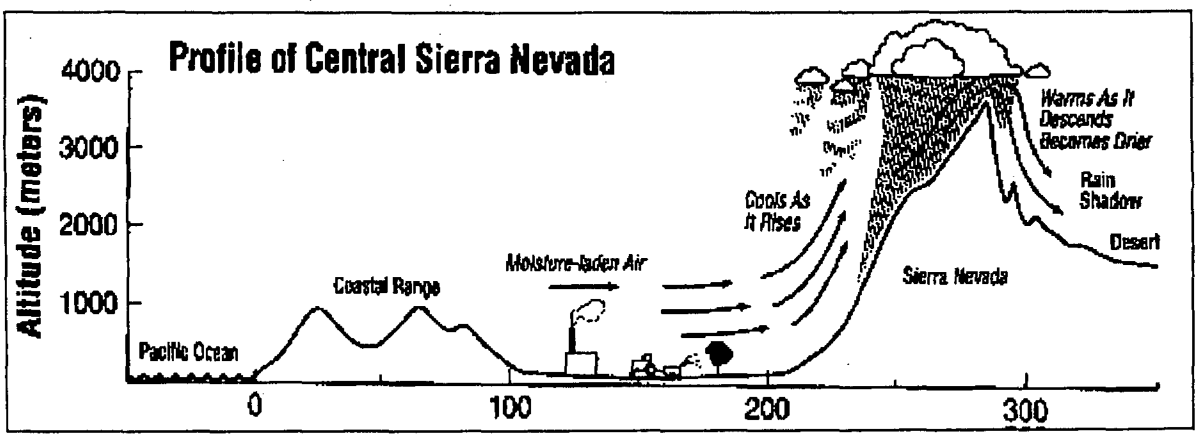
CRIS No. 1270-12220-002-00D

Laura L. McConnell, Seema Datta, Environmental Chemistry Laboratory

James S. LeNoir, James N. Seiber, University of Nevada Reno

Problem:

Deteriorating environmental quality has stimulated interest in the Sierra Nevada Mountains as a sink for airborne pollution from human activity in California's valleys and coastal metropolitan areas (Figure 1). Drost and Fellers have raised the hypothesis that a connection exists between deposited pesticide residues and the decline of populations of certain amphibians in the Sierra Nevada mountains.



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Atmo input

of pesticides transported from California's Central Valley to the Sierra Nevada mountains were investigated by collecting winter-spring precipitation (rain and snow) from Sequoia National Park (SNP) and from the Lake Tahoe basin (McConnell *et al.*, 1998). Pesticides currently used in California's Central Valley were detected in snow and rain samples from two elevations in SNP in the southern Sierras. At the lower elevation site (533m), chlorothalonil was present at the highest levels, followed by malathion, diazinon and chlorpyrifos. At 1920m elevation, chlorothalonil was also present at the highest levels followed by diazinon, chlorpyrifos, and malathion. Trifluralin and α- and β-endosulfan were also detected at both locations and at lower concentrations. In the Lake Tahoe basin, elevation 2200m, malathion was also found in snow as was diazinon, chlorpyrifos and chlorothalonil. Lake Tahoe Basin snow samples were, in general, lower in concentration than those from SNP. This difference in concentration levels reflects the closer proximity of downwind pesticide usage to SNP than the Lake Tahoe basin. An estimated annual loading of one chemical, chlorpyrifos, of 24-31 kg/yr, was made for the SNP land area.

Application of Results:

Results of this study have serious implications for wildlife in the the Sierra Nevada mountains as this area receives all water inputs through rain and snow. While levels of individual compounds were below limits that would cause toxic effects, the combined effect of these chemicals with other environmental stresses, i.e. UV radiation, may have a negative impact on sensitive species like amphibians. Further this indicates that mountainous areas adjacent to agricultural land areas may be impacted by atmospheric loadings of pesticides through volatilization from warm valleys followed by aerial transport and deposition through a cold condensation process.

McConnell, L.L., LeNoir, J.S., Datta, S., Seiber, J.N. **1998**. Wet deposition of current-use pesticides in the Sierra Nevada mountain range, California, USA. *Environ. Tox. Chem.*,17:1908-1916.

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Surface- and Ground-Water Characteristics in the Upper Truckee River and Trout Creek Watersheds, South Lake Tahoe, California and Nevada, July-December 1996

Water-Resources Investigations Report 00-4001

By Timothy G. Rowe and Kip K. Allander

Prepared in cooperation with the
TAHOE REGIONAL PLANNING AGENCY

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Lower section of Upper Truckee River, June 1999; northeast view of Barton Meadow, Truckee Marsh, and Lake Tahoe, from hot air balloon above south Lake Tahoe airport, near South Lake Tahoe, California. Photograph by Timothy G. Rowe, U.S. Geological Survey.

If you have any questions,email: scdemeo@usgs.gov

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WRIR 00-4001

Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per mile ($ft^3/s/mi$)	0.01760	cubic meter per second per kilometer
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556(°F-32).

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Abbreviated Water-Quality Units Used in this Report

µg/L (microgram per liter)
mg/L (milligram per liter)
mL (milliliter)

Next Section: Text

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WRIR 00-4001

Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

ABSTRACT

The Upper Truckee River and Trout Creek watersheds, South Lake Tahoe, California and Nevada, were studied from July to December 1996 to develop a better understanding of the relation between surface water and ground water. Base flows at 63 streamflow sites were measured in late September 1996 in the Upper Truckee River and Trout Creek watersheds. Most reaches of the main stem of the Upper Truckee River and Trout Creek had gaining or steady flows, with one losing reach in the mid-section of each stream.

Twenty-seven of the streamflow sites measured in the Upper Truckee River watershed were on 14 tributaries to the main stem of the Upper Truckee River. Sixteen of the 40 streamflow sites measured in the Upper Truckee River watershed had no measurable flow. Streamflow in Upper Truckee River watershed ranged from 0 to 11.6 cubic feet per second (ft^3/s). The discharge into Lake Tahoe from the Upper Truckee River was 11.6 ft^3/s, of which, 40 percent of the flow was from ground-water discharge into the main stem, 40 percent was from tributary inflows, and the remaining 20 percent was the beginning flow. Gains from or losses to ground water along streams ranged from a 1.4 cubic feet per second per mile ($ft^3/s/mi$) gain to a 0.5 $ft^3/s/mi$ loss along the main stem.

Fourteen of the streamflow sites measured in the Trout Creek watershed were on eight tributaries to the main stem of Trout Creek. Of the 23 streamflow sites measured in the Trout Creek watershed, only one site had no flow. Flows in the Trout Creek watershed ranged from zero to 23.0 ft^3/s. Discharge into Lake Tahoe from Trout Creek was 23.0 ft^3/s, of which, about 5 percent of the flow was from ground-water discharge into the main stem, 75 percent was from tributary inflows, and the remaining 20 percent was the beginning flow. Ground-water seepage rates ranged from a 1.4 $ft^3/s/mi$ gain to a 0.9 $ft^3/s/mi$ loss along the main stem.

Specific conductances measured during the seepage run in September 1996 increased in a downstream direction in the main stem of the Upper Truckee River and remained relatively constant in the main stem of Trout Creek. Water temperatures measured during the seepage run also increased in a downstream direction in both watersheds.

Depths to ground water measured at 62 wells in the study area were used with the results of the seepage run to produce a water-level map in the Upper Truckee River and Trout Creek watersheds. Ground-water levels ranged from 1.3 to 69.8 feet below land surface. In the upper sections of the watersheds ground-water flow is generally toward the main stems of Upper Truckee River and Trout Creek, whereas in the lower sections, ground-water flow generally parallels the two streams and flows toward Lake Tahoe. The altitude of ground water between Lake Tahoe and Highway 50 was nearly the same as the lake-surface altitude from July to November 1996. This suggests ground-water discharge beneath the Upper Truckee River and Trout Creek drainages directly to Lake Tahoe was minimal and that much of the ground-water discharge was to the channels of the Upper Truckee River and Trout Creek upstream from Highway 50. Hydraulic gradients ranged from near zero to 1,400 feet per mile.

Samples were collected at six surface-water-quality and eight ground-water-quality sites from July through mid-December 1996. Specific conductance of the ground-water-quality sites was higher than that of the surface-water-quality sites. Water temperature and pH median values were similar between ground-water-quality and surface-water-quality sites but ground water had greater variation in pH and surface water had greater variation in water temperature. Ground-water nutrient concentrations were generally higher than those in streams except for bioreactive iron.

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WRIR 00-4001
Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

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INTRODUCTION

Lake Tahoe is an outstanding natural resource and is known for its deep, clear water (fig. 1). Protection of this renowned clarity has become important in the past half century, as clarity has been decreasing by about 1 ft each year (Goldman and others, 1986), mainly due to human activities.

Increased nutrient concentrations within Lake Tahoe are considered the leading cause of algal growth and loss of clarity in the lake. Within the Lake Tahoe Basin, both surface- and ground-water discharge are suspected of being significant mechanisms for nutrient transport to Lake Tahoe (Thodal, 1994, p. 2).

Background

The Tahoe Regional Planning Agency (TRPA) is a bi-state resource management agency that has primary responsibility for the environmental protection of Lake Tahoe. TRPA's principal mission is to reduce the loss of clarity in Lake Tahoe. TRPA oversees the monitoring of existing environmental conditions in the basin through a number of programs. The U.S. Geological Survey (USGS) began a tributary discharge and water-quality monitoring study in 1988 in cooperation with TRPA. TRPA and USGS also instituted a cooperative ground-water monitoring study during 1990-92. A revised ground-water study was reinstated in 1995. Both of these ongoing water-quality data-collection efforts include the involvement of the University of California-Davis, Tahoe Research Group (TRG) and are included in the Lake Tahoe Interagency Monitoring Program (LTIMP). LTIMP was formed in 1978 with 12 State and Federal agencies and TRG (Goldman and others, 1986). Agencies currently participating in LTIMP include TRG; USGS; TRPA; U.S. Forest Service (USFS); U.S. Natural Resources Conservation Service (NRCS); U.S. Environmental Protection Agency (USEPA); Lahontan Regional Water Quality Control Board; California Department of Parks and Recreation; California Department of Fish and Game; California Tahoe Conservancy; Nevada Department of Environmental Protection; University of Nevada, Reno; Douglas County, Nev.; El Dorado County, Calif.; Washoe County, Nev.; and the City of South Lake Tahoe, Calif.

The current USGS-TRPA networks include 32 surface-water sites where suspended sediment, water-quality, and streamflow data are collected, and 32 ground-water sites, where water-quality and water-level data are collected. These surface- and ground-water sites are located throughout the Lake Tahoe Basin. Both of these networks are described in more detail by Boughton and others (1997) and are shown on a map by Rowe and Stone (1997). From these two networks, six surface-water sites and eight ground-water sites were used from within the study area.

In 1996, TRPA developed the Lake Tahoe Federal Legislative Agenda, a public-private partnership of agencies in the Tahoe region (Tahoe Regional Planning Agency, 1996). The plan designated four Lake Tahoe watersheds as high priority for possible watershed restoration projects. TRPA included Third and Incline Creek watersheds in the north, Edgewood Creek watershed in the southeast, and the Upper Truckee River watershed in the south.

In 1996, the Upper Truckee River watershed was chosen for a focused effort to improve water quality within one watershed of the Lake Tahoe Basin. An advisory group, the Upper Truckee River Watershed Focused Group, was formed as a subgroup of LTIMP.

The Upper Truckee River watershed is the largest of the 63 watersheds in the Lake Tahoe Basin. The Upper Truckee River also delivers the largest volume of surface water and may be providing some of the largest nutrient and sediment loads to the lake. Also, the Upper Truckee River watershed has the greatest human population of any watershed in the Lake Tahoe Basin, thus increasing the chances of negative human effects on water quality. The watershed also has several land-uses representative of many water-quality influences that occur throughout the Lake Tahoe Basin. Trout Creek is included in the study area because the watersheds are adjacent to each other and together comprise most of the South Lake Tahoe area.

Purpose and Scope

This report presents a compilation of ground-water and surface-water data collected in the Upper Truckee River and Trout Creek watersheds during baseflow conditions from July to December 1996. The data are used to (1) determine ground-water levels and direction of ground-water flow in the watersheds, (2) determine the interaction between ground water and streamflow, and (3) compare the water quality of the ground- and surface-water systems during baseflow conditions.

USGS, in cooperation with TRPA, began a study in July 1996 to improve the understanding of the surface-water and ground-water systems and their interactions within the Upper Truckee River and Trout Creek watersheds. Principle efforts included (1) making streamflow measurements during baseflow conditions on the Upper Truckee River and Trout Creek and their tributaries; (2) inventorying existing wells on the basis of well drillers' reports and canvassing local residents; (3) determining depth to water in located wells; (4) developing a map showing the altitude of the water table using depth-to-water measurements in wells and results of seepage estimates; and (5) collecting additional water-quality data.

Previous Studies

The USGS has been involved with surface-water studies in the Upper Truckee River and Trout Creek watersheds since 1960, when operation of streamflow-gaging stations and surface-water-quality sampling sites first began. Periods of record of daily streamflow, water-quality, and suspended-sediment data are listed in table 1 for eight current and historical sites. Data from these eight sites have been published previously in USGS annual data reports by California and Nevada. Previous USGS surface-water studies in the Upper Truckee River and Trout Creek watersheds have included sediment discharge (Kroll, 1976); flood and related debris-flow hazards map for the South Lake Tahoe area (Katzer and Glancy, 1978); and suspended-sediment factors for the Lake Tahoe Basin (Hill and Nolan, 1988). Jeton (1999) has constructed a precipitation/runoff model for the Lake Tahoe Basin that includes Upper Truckee River and Trout Creek.

TRG has been involved with several studies and has collected physical and chemical data on Upper Truckee River and Trout Creek since the early 1970's. These data are included in LTIMP annual reports. The most recent LTIMP report is by Byron and others (1989).

TRPA also has published annual water-quality reports since 1990 for the Lake Tahoe Basin. These reports have included USGS and TRG data on Upper Truckee River and Trout Creek. The most recent report is by Hill (1996).

USFS also has been involved with several studies collecting physical and chemical data on Upper Truckee

River and Trout Creek. USFS has published a water-quality report on the Santa Fe erosion control project by Hoffman (1991); a water-quality report summarizing five baseline stations by Lowry and Meeker (1993); a monitoring report on Hell Hole Road water-quality improvement project by Norman (1996); a water-quality-monitoring report on spring runoff in the Grass Lake research natural area by Norman and Parsons (1997); and a monitoring report on Pope Marsh burn by Norman (1997).

U.S. Army Corps of Engineers (USCOE) published a report on flood-plain information for the Upper Truckee River, South Lake Tahoe, Calif. (U.S. Army Corps of Engineers, 1969). El Dorado County Department of Transportation has been involved in several studies and data collection efforts on the Upper Truckee River and Trout Creek. A recently published report on the Apache Erosion Control project was done by Robinson (1996).

Within the study area, ground water is the primary source for domestic and public water supplies. Historical wastewater disposal practices and current large municipal withdrawals of ground water within the Upper Truckee River and Trout Creek watersheds are the basis for several studies that focused on water quality and quantity. For example, the California Department of Water Resources has been monitoring water levels since 1958 for selected wells to identify long-term trends, if any, within the Lake Tahoe Basin. Two of these wells are within the study area. Thodal (1997) used data from 32 wells to characterize ground-water quality within the Lake Tahoe Basin. Six of these wells are within the study area. Scott and others (1978), Blum (1979), and Woodling (1987) report the results of hydrogeologic investigations in the study area. Results of investigations of ground-water nutrient flux of the Upper Truckee River and Trout Creek watersheds are included in reports by Loeb and Goldman (1979), Loeb (1987), and Thodal (1997).

Acknowledgments

This work was done in cooperation with the Tahoe Regional Planning Agency. Appreciation is extended to residents in the area who gave permission to access their wells. Many government and private agencies also are acknowledged for providing data and access to their wells: Agra Earth and Environmental; California Department of State Parks and Recreation; California Department of Water Resources; California Tahoe Conservancy; El Dorado County Department of Transportation; Lahontan Water Quality Control Board; South Tahoe Public Utility District; and U.S. Forest Service--Lake Tahoe Basin Management Unit.

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DESCRIPTION OF STUDY AREA

The study area is in the southern part of the Lake Tahoe Basin Hydrographic Area[1] and includes the entire Upper Truckee River and Trout Creek watersheds (figs. 1 and 2) in California. Additionally, samples were taken from wells and a spring adjacent to the study area in California and Nevada.

Historically, Trout Creek was tributary to Upper Truckee River in the Truckee Marsh area near the lake (fig. 2). But with development of the Tahoe Keys, the Upper Truckee River was channeled to the lake and currently the streamflow of the two tributaries combine only during high runoff. Because of this historical combination of the Upper Truckee River and Trout Creek on the surface, speculation is that their ground-water systems also may combine at some point. This is one reason that both watersheds are included in this study.

Geology

The main geologic units identified within the study area are granitic rocks and glacial deposits. Other units that are much less extensive are pluvial and alluvial deposits, volcanic rock, and metamorphic rock (Tahoe Regional Planning Agency and U.S. Forest Service, 1971, plate).

The geology of the study area can be characterized by lake and glacial deposits at the lower altitudes, flatlands, and low-lying hills; and by granitic rocks that make up the steep and high mountain slopes and peaks. The only volcanic rocks within the study area are in the extreme headwaters of the Upper Truckee River watershed, and the only metamorphic rocks are two small areas above Echo Lake and two small areas in the low-lying hill between the City of South Lake Tahoe and Fallen Leaf Lake. Lake deposits are evident in a few high-mountain meadows and along the lower stream channels in the Upper Truckee River and Trout Creek watersheds (Tahoe Regional Planning Agency and U.S. Forest Service, 1971, plate).

Landforms of the study area were principally shaped from tectonic and glacial processes. A combination of basin-and-range style fault-bounded blocks and glacial erosional and depositional action resulted in the formation of the present-day landforms. Four periods of major glaciation shaped these landforms (Tahoe Regional Planning Agency and U.S. Forest Service, 1971). The major landforms attributed to glaciation are deep basin-fill deposits, steep mountain slopes adjacent to the upper reaches of the Upper Truckee River and Trout Creek, and large lateral moraines that divide the Trout Creek watershed from the Upper Truckee River watershed and the Upper Truckee River watershed from Fallen Leaf Lake (Tahoe Regional Planning Agency and U.S. Forest Service, 1971).

The basin-fill deposits within the study area are comprised entirely of lake, stream, and glacial deposits. Also, the underlying basement rock is assumed to be entirely granitic. Thicknesses of the basin-fill deposits in the South Lake Tahoe area near Lake Tahoe may be as great as 1,600 - 1,900 ft (Blum, 1979). For the purposes of this report, the areas with basin-fill deposits will be referred to as unconsolidated areas and the areas that have exposed bedrock will be referred to as consolidated areas.

Vegetation

Vegetation in the Upper Truckee River and Trout Creek watersheds is primarily coniferous forest with lodgepole pine, ponderosa pine, Jeffrey pine, white fir, red fir, western white pine, mountain hemlock, and sugar pine. Alders, aspen, and willows are common along the stream zones (Cartier and others, 1993).

Climate

In the Upper Truckee River watershed, precipitation (mostly in the form of snow) ranges from nearly 25 in. to greater than 60 in., with a general decrease from west to east (Twiss and others, 1971). In the Trout Creek watershed, precipitation ranges from nearly 20 in. to about 40 in. with a general decrease from southwest to northeast. The National Weather Service reported above average annual precipitation during 1996 at the long-term weather stations in Tahoe City and Glenbrook. The daily precipitation record for a nearby National Resource Conservation Service (NRCS) Snow Telemetry (SNOTEL) site near Lake Tahoe just north of Fallen Leaf Lake is shown in figure 7. Most of the precipitation for 1996 (approximately 94 percent) occurred between late November 1995 and mid-May 1996. Minor rainfall amounts were recorded at the end of June, mid-July, and mid-August of 1996. Summer thunderstorms, typical of the study area, were almost absent in 1996.

History

Historically, the land use of the Lake Tahoe Basin by humans first began with the Washoe Indian Tribe. Major changes in land use occurred with the discovery of the Comstock Lode in nearby Virginia City, Nev. Many trees in the Lake Tahoe Basin, including those within the study area, were harvested to provide shoring timbers for the Comstock mines (Crippen and Pavelka, 1972). When the Comstock era began to decline during the late 1800's, the Lake Tahoe Basin began to emerge as a seasonal vacation area. By the end of World War II, the Lake Tahoe Basin had become an established year-round destination.

Upper Truckee River Watershed

The Upper Truckee River watershed is almost entirely within El Dorado County, Calif. (fig. 2). About 3 mi^2 of the southern tip is in Alpine County, Calif. This watershed is the largest in the Lake Tahoe Basin and occupies 56.5 mi^2, which is 18 percent of the total land area tributary to Lake Tahoe (314 mi^2). Upper Truckee River has a drainage perimeter of 53.9 mi (Cartier and others, 1995). The Upper Truckee River main channel length is 21.4 mi. The land-surface altitudes range from lake level to 10,063 ft above sea level at Red Lake Peak (fig. 2).

The lowest land-surface altitude within the study area that is above water is determined by the surface of Lake Tahoe, which can fluctuate from a little below its natural rim of 6,221.9 ft (6,223.0 ft Bureau of Reclamation (BOR) datum) to slightly greater than its legal maximum altitude of 6,228.0 ft (6,229.1 ft BOR datum). For the period of this study, July through December, Lake Tahoe had a maximum lake-surface altitude in July of 6,227.9 ft, a minimum in November of 6,226.1 ft, and a mean of 6,227.0 ft (Bonner and others, 1998).

Percent slope, which describes the steepness of the topography within the watershed, ranges from approximately zero near Lake Tahoe and along the valley bottoms, to as much as 50 in the upper altitudes of the watershed (Cartier and others, 1993). Dominant aspect, which is the compass direction of a slope face, is generally east, west, southwest, and northwest facing slopes.

The main tributary drainages to the Upper Truckee River (pl. 1) include Grass Lake Creek (drainage area of 6.4 mi^2; table 2), Angora Creek (5.7 mi^2), Echo Creek (5.4 mi^2), and Big Meadow Creek (5.1 mi^2). Major wetlands include Grass Lake, Osgood Swamp, Truckee Marsh, Benwood Meadow, and Big Meadow (pl. 1). Major lakes include Upper and Lower Echo Lakes and smaller lakes include Dardanelles, Round, Showers, Elbert, Tamarack, Ralston, and Angora Lakes (fig. 2). The only diversion from this watershed is to the American River Basin from Echo Lake, which has a storage capacity of 1,890 acre-ft (Bostic and others, 1997, p. 260).

Trout Creek Watershed

The Trout Creek watershed is within El Dorado County, Calif., east of the Upper Truckee River watershed (fig. 2). The watershed is the second largest in the Lake Tahoe Basin and occupies 41.2 mi^2, which is 13 percent of the total land area tributary to Lake Tahoe. Trout Creek has a drainage perimeter of 34.8 mi. Trout Creek has a main channel length of 12.1 mi. The land-surface altitudes range from lake level to 10,881 ft at Freel Peak (fig. 2).

Percent slope ranges from approximately zero in the lower reach near Lake Tahoe, to 50 at higher altitudes (Cartier and others, 1993). Aspect is a mixture of generally west, east, north, northwest, and southwest facing slopes.

The main tributaries to Trout Creek include Cold Creek (drainage area of 12.8 mi^2), Saxon Creek (8.2 mi^2), Heavenly Valley Creek (3.0 mi^2), and Hidden Valley Creek (1.7 mi^2; table 2, pl. 1). Major wetland areas include Truckee Marsh, High Meadows, and Hell Hole (pl. 1, fig. 2). The only lake in the Trout Creek watershed is Star Lake (fig. 2). The major basin diversion is ground-water withdrawal for municipal use.

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[1] Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960's (Rush, 1968; Cardinalli and others, 1968) for scientific and administrative purposes. The official hydrographic-area names, numbers, and geographic boundaries continue to be used in Geological Survey scientific reports and Division of Water Resources administrative activities.

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INVENTORY AND MEASUREMENT METHODS

Streamflow and Seepage

Seepage estimates were determined for selected reaches in the Upper Truckee River and Trout Creek watersheds by measuring streamflow entering and leaving the reach and by measuring all tributary flows entering the reach during base-flow conditions. If streamflow leaving the reach exceeded all streamflow entering the reach by at least 5 percent, the difference was assumed to be ground-water seepage to the stream and the reach is referred to as a gaining reach. If flow leaving the reach was less than all inflow to the reach by at least 5 percent, then the streamflow was assumed lost to ground water and the reach is referred to as a losing reach. If flow leaving the reach was within 5 percent of all the inflow to the reach, then the difference was within standard measurement error and the reach is referred to as a steady reach with no losses or gains. This method for estimating seepage along the stream channels assumes no overland runoff, negligible evaporation directly from the stream, negligible evapotranspiration from riparian vegetation along the stream, and no storage changes along the stream channel.

Unit-runoff values were derived by dividing streamflow values by contributing drainage area. Unit-runoff values are defined as the average number of cubic feet per second flowing from each square mile of area drained by a stream, assuming that the runoff is distributed uniformly in time and space. Delineation of drainage areas used in this study are from Cartier and others (1995).

Seventy streamflow measurement sites were established in the study area--45 in the Upper Truckee River watershed and 25 in the Trout Creek watershed. Streamflow was determined at 63 of the streamflow measurement sites--40 in the Upper Truckee River watershed and 23 in the Trout Creek watershed. These sites were selected to estimate seepage and unit-runoff values along selected reaches in the main stems and tributaries (tables 3 and 4, pl. 1, fig. 3). Of the 40 sites in the Upper Truckee River watershed with streamflow measurements, 13 are main-stem sites and 27 are tributary sites. The main stem of the Upper Truckee River was divided into 10 reach segments. Of the 23 sites in the Trout Creek watershed with streamflow measurements, 9 are main-stem sites and 14 are tributary sites. The main stem of Trout Creek was divided into six reach segments. Existing streamgage locations and water-quality sampling sites were selected along with sites at the confluence of all inflowing tributaries with the main-stem streams. Additional sites along the major tributaries were selected in each watershed. The selection of these sites was made on the basis of accessibility. Measurements of streamflow were made on the same day within each watershed. Streamflow measurements in the Upper Truckee River watershed were made on September 23, 1996, and streamflow measurements in the Trout Creek watershed were made on September 26, 1996.

Streamflows were measured following USGS guidelines (Buchanan and Somers, 1969). Water and air temperatures were measured using calibrated field thermometers.

River miles (distance from mouth of river to seepage measurement sites) along the main stems were calculated from the mouth of each watershed using a geographical information system (table 2, fig. 3). River miles on the tributaries were calculated by taking the river mile of the main channel at the tributary mouth and then adding the distance of the tributary channel going upstream. River miles were used in computing relative ground-water seepage rates along selected reaches of the Upper Truckee River and Trout Creek.

Wells and Ground-Water Levels

Well drillers' logs in the study area were obtained from the California Department of Water Resources. These logs are used to locate existing domestic and public supply wells and to provide well-construction information such as well depth, screen interval, well diameter, and lithology. A field reconnaissance of existing wells was made from early August 1996 through November 1996. Some wells were found after interviewing local residents in areas of known domestic withdrawals. When a well was found, its location was plotted on a 7.5-minute topographic map and its latitude and longitude coordinates were determined using a Precision Lightweight Global Positioning System Receiver (PLGR). The accuracy of these locations is ±100 ft, or approximately 1 second of latitude or longitude.

Field information collected for each well included casing diameter, well depth, well-owner information, measuring-point height, land-surface altitude, well and water-use status, and water level (table 5). All land-surface altitudes were taken from USGS 7.5-minute topographic quadrangle maps except for those wells that already had land-surface altitudes determined by conventional surveying techniques. The accuracy of land-surface altitudes estimated from the maps is typically within 20 ft and often within 10 ft, depending on the topographic-contour interval (plus or minus one-half of the topographic-contour interval). For land-surface altitudes determined by surveying techniques, accuracies are within 0.1 ft. All water-level measurements were made using either a steel or electric tape. Because water levels were determined by subtracting depth to water from land-surface altitudes, they carry the same uncertainties as the land-surface altitudes. Domestic wells were frequently used for yard irrigation during the late summer and early fall when data were collected. Water levels from these pumping wells are not representative of static conditions (table 5). Data for wells presented in this report are stored in the USGS National Water Information System (NWIS) data base.

Between July 16 and November 8, 1996, USGS staff inventoried 94 wells and 1 spring. Of the 94 wells, 79 are within the study-area boundaries. The other 15 wells and 1 spring are adjacent to the study area. Most of the sites adjacent to the study area were included in this study to help interpret water-level contours and hydraulic gradients at the study area boundaries. The remainder of these sites were included because the information from them is previously unpublished. Of the 79 wells within the study area, water levels were measured at 62 wells. Seventeen wells were not measured because they were either flowing, inaccessible, or pumping almost continuously. Thirteen of the wells measured had been pumped recently (identified with an R on table 5), and may not represent a static water level. Two of the wells measured were pumping; these water levels are not representative of static levels but do give a lower boundary for the water surface (water level in parentheses in table 5). The water-use distribution for the 79 wells within the study area is as follows: 11 wells are used for public supply; 45 wells are used for domestic purposes; and 23 wells are used for monitoring purposes (fig. 4).

Well locations and associated water-level altitudes were used along with seepage estimates to develop a water-level map of the study area (pl. 1). Directions of ground-water flow in the study area were determined from the water levels on plate 1.

Hydraulic gradients in the study area were determined also from water levels shown on plate 1. Because of the uncertainties in water-level altitudes, an inherent uncertainty is associated with the hydraulic gradients.

These uncertainties are generally greatest in the middle part of the study area (Tahoe Paradise area) and the least in the steeply sloping area above Christmas Valley along Luther Pass.

The 94 wells inventoried for this study are a sample of the entire population of wells in and adjacent to the study area. How many wells make up the entire well population is unknown due to inconsistent reporting of well drilling in the past as well as undocumented destruction of wells. The sample distribution of wells is assumed to be representative of the total well distribution. This results in clusters of wells in areas of current domestic withdrawals and areas of environmental ground-water monitoring. Three major clusters are apparent on plate 1. The largest cluster is in the south end of Christmas Valley, where the residential population is still on domestic-well systems. Another cluster is on the south side of Twin Peaks, where the residential population still uses wells for domestic supply and where environmental monitoring of ground water is done in a nearby meadow. The third cluster is in the Trout Creek watershed at the old landfill near Meyers, Calif. This cluster of observation wells was established to monitor environmental effects of the landfill on the local ground water.

Water Quality

Samples were collected to determine specific conductance at each streamflow site at the time of measurement (table 3). Specific conductance is the ability of a substance to conduct an electric current at a specific temperature. In water, specific conductance is a good indicator of the concentration of dissolved solids. The greater the specific conductance, the greater the concentration of dissolved solids (Hem, 1985). Samples for specific-conductance measurements were collected by hand dipping a field-rinsed 250-mL polyethylene bottle in the center of flow at each site. Readings were then made within 24 hours of collection for each sample at the USGS Nevada District Laboratory using a calibrated specific conductance field meter adjusted to conductance at 25°C.

Six surface-water-quality sites (fig. 3; three on the Upper Truckee River and three on Trout Creek) were sampled periodically from July through December 1996 (table 6). These sites were sampled for total kjeldahl (ammonia plus organic nitrogen), total phosphorous, dissolved orthophosphorus, dissolved ammonia, dissolved nitrite plus nitrate, and total bioreactive iron. Field measurements of specific conductance, pH, water temperature, and dissolved oxygen were collected also. Historical USGS water-quality data, dating back to 1992, are available for all these sites. Standard USGS methods were used for sample collection. The method used for this study to collect water-quality samples was the equal-width increment (EWI) method, which is a depth- and width-integration method. This method involves collecting depth-integrated samples from equal-width segments of the cross section of a stream. The sample was then composited and mixed in a churn. The samples for measurements of total constituents were collected directly from the churn and the dissolved samples were filtered from the churn. These water-quality samples were then preserved (nutrients were chilled to 4°C and stored in the dark, and iron samples were acidified with concentrated nitric acid to a pH below 2) and shipped overnight to the UC Davis-TRG laboratories in Davis and Tahoe City, Calif. The samples were analyzed for iron and nutrients within 8 days according to procedures described by Hunter and others (1993). Specific-conductance and pH measurements were made from water taken from the churn after thoroughly mixing. The water temperature and dissolved oxygen were measured directly in the stream at the time of sampling. Specific conductance, pH, and dissolved oxygen were measured with field meters that were calibrated before each sample.

Summary statistics were computed for the combined samples of all six surface-water-quality sites on the Upper Truckee River and Trout Creek for July through December 1996 (figs. 5 and 6). For all 6 sites, only samples collected the same day or within 1 day were used in the analysis to compare with the summary statistics for the ground-water-quality sites.

Seven wells in the study area (five in the Upper Truckee River watershed and two in the Trout Creek watershed) and one well adjacent to the study area were sampled in July 1996 (table 7). These wells were sampled for dissolved nitrite plus nitrate, dissolved ammonia, dissolved kjeldahl (ammonia plus organic nitrogen), dissolved phosphorous, dissolved orthophosphorus, and dissolved bioreactive iron. Historical USGS water-quality data dating back to 1990 is available for these wells. These eight wells and well 143 (table 7) were sampled in November and December 1996. Seven of these are public supply wells and two are observation wells. The public-supply wells were sampled from the delivery system using existing pumps. For these wells, water was collected as close to the wellhead as possible to ensure that the sample was not affected by any treatment or storage of the water. Because these samples were collected from public-supply wells that are heavily used, it is assumed that the water is representative of the aquifer water. The two observation wells were sampled using a submersible pump. Because these wells are not pumped regularly, more than three casing volumes of water were pumped prior to sampling and specific conductance and water temperature were checked until stabilized, to assure that the water was representative of the aquifer water. These water-quality samples were filtered (through 0.45-μm filter) in the field and then preserved (nutrients were chilled to 4°C and stored in the dark and iron samples were acidified with concentrated nitric acid to a pH below 2) and shipped to the UC Davis-TRG laboratories in Davis and Tahoe City, Calif. The samples were analyzed for iron and for nutrients within 8 days according to the procedures described by Hunter and others (1993). Specific conductance, water temperature, water level, and pH were measured in the field during sampling. Specific conductance and pH measurements were made from water taken with field meters that were calibrated before each sample.

Ground-water-quality data are presented in table 7. The ground-water data are reported also in the 1996 annual data report for Nevada (Bostic and others, 1997, p. 532-536).

Summary statistics were computed for the combined samples of the seven ground-water-quality sites within the Upper Truckee and Trout Creek watersheds that were sampled in July 1996 and in November-December 1996 (figs. 5 and 6). Well 143 was not used in the analysis because only one sample was collected during the study period. Also, this well is suspected of being affected by the landfill near Meyers, which is directly upgradient, and therefore probably is not a good representation of the overall ground-water quality in that area.

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SURFACE- AND GROUND-WATER CONDITIONS

Streamflow and Seepage Estimates

The measured streamflows in the Upper Truckee River watershed ranged from zero to 11.6 ft^3/s (table 3). Streamflow measured along the main stem of the Upper Truckee River increased from 2.6 ft^3/s at site 45 to 11.6 ft^3/s at site 3 in a downstream direction (fig. 3, pl. 1). At site 1, flow was not measured because the river was too deep to wade and velocities too slow for an accurate measurement due to backwater effects caused by the high level of Lake Tahoe on September 23, 1996. Three of the 13 remaining main-stem sites had no streamflow because these sites were on dry, divergent branches of the main stem. Of the 31 streamflow measurement sites that are tributary to the Upper Truckee River or are along the tributaries, 13 had no measurable streamflow. Major tributary inflows to the Upper Truckee River on September 23, 1996, included 2.0 ft^3/s at sites 27 and 28 (sum of divergent flows in tributary), 0.9 ft^3/s at site 37, and 0.8 ft^3/s at site 12.

The measured streamflows in the Trout Creek watershed ranged from 0 to 23.0 ft^3/s. Streamflow measured along the main stem of Trout Creek increased from 4.7 ft^3/s at site 70 to 23.0 ft^3/s for combined sites 46-48 (fig. 3, pl. 1). All the main stem sites had streamflow. Of the 14 streamflow measurement sites that are tributary to Trout Creek or are along the tributaries, only 1 (site 55) had no measurable streamflow. Major tributary inflows to Trout Creek on September 26, 1996, included 11.2 ft^3/s at site 53, 2.4 ft^3/s at site 61, 1.4 ft^3/s at site 67, and 0.8 ft^3/s at site 66.

The streamflows measured in September 1996, for both watersheds, were representative of base-flow conditions from August through December. The smallest daily streamflow for the 1996 water year at the most downstream gage on the Upper Truckee River (site 6) was 7.7 ft^3/s in late October 1995 (Bostic and others, 1997, p. 268). The lowest monthly mean streamflow, 10.2 ft^3/s, occurred during November 1995. The lowest daily streamflow for the 1996 water year at the most downstream gage on Trout Creek (site 52) was 14.0 ft^3/s in late December 1995. The lowest monthly mean streamflow occurred during November 1995, and was 22.0 ft^3/s (Bostic and others, 1997, p. 333). Hydrographs for these two streamgages are shown in figure 7, along with the daily precipitation record for a nearby NRCS SNOTEL site.

All streamflow data were entered into the USGS National Water Information System (NWIS) databases. Streamflow measurement data for September 1996 also appear in the annual data report for Nevada (Bostic and others, 1997).

Results of the streamflow measurements, seepage estimates, seepage rates per unit length, and unit runoffs are listed in table 4. In addition, the location of gaining, losing, and steady reaches are shown on plate 1 and figure 3.

Seepage estimates for reaches along the Upper Truckee River indicate that, of the 11.6 ft^3/s streamflow near the mouth at site 3, 4.4 ft^3/s (38 percent) was gained from ground-water seepage to the main stem, 4.5 ft^3/s (39 percent) was gained from tributary inflows, and 2.6 ft^3/s (23 percent) was the beginning streamflow at site 45. The average rate of gain per unit length along the main stem over the distance from site 45 to site 3 (13.3 mi) was 0.33 ft^3/s per mile. Of the 10 reach segments along the main stem of the Upper Truckee River, 5 were gaining from ground-water seepage, 1 was losing due to ground-water seepage, 3 had no measurable influence due to ground water, and 1 was undetermined because a streamflow measurement was not possible (fig. 8).

Seepage estimates for reaches along Trout Creek indicate that, of the 23.0 ft^3/s streamflow near the mouth at sites 46-48, 0.7 ft^3/s (3 percent) was gained from ground-water seepage to the main stem, 17.4 ft^3/s (76 percent) was gained from tributary inflows, and 4.7 ft^3/s (21 percent) is the beginning streamflow at site 70. The average rate of gain per unit length along the main stem over the distance from site 70 (8.9 mi) to sites 46-48 was about 0.08 ft^3/s per mile. Of the six reach segments along the main stem of Trout Creek, three were gaining from ground-water seepage, two were losing, and one had no measurable loss or gain (fig. 8).

The Upper Truckee River and Trout Creek have similar characteristics in the location of ground-water seepage contributions to their streamflows. Both streams are gaining in their upper reaches, both are steady or losing through their middle reaches, and both gain streamflow over a mile reach starting at about 2.5 mi upstream from Lake Tahoe (fig. 8).

The value obtained when discharge is divided by contributing drainage area, termed unit runoff, is often useful in comparing the magnitude of flow between two basins or the discharge at two or more locations in one basin. Unit runoff along the main stem of the Upper Truckee River ranged only slightly from 0.21 to 0.23 $ft^3/s/mi^2$ while its tributaries had greater variation, from zero at many of the tributaries to 0.31 $ft^3/s/mi^2$ at site 28 (table 3). Unit runoff along the main stem of Trout Creek ranged from 0.56 $ft^3/s/mi^2$ in the lower reaches to 0.84 $ft^3/s/mi^2$ in the upper reaches while its tributaries ranged from 0.07 $ft^3/s/mi^2$ at site 50 to 1.00 $ft^3/s/mi^2$ at site 67. The unit runoff in Trout Creek is larger than that of the Upper Truckee River. This is because most of the streamflow into Trout Creek is from the Cold Creek tributary whose unit runoff is 0.88 $ft^3/s/mi^2$. The high unit runoff of the Cold Creek tributary is assumed to be from delayed snowpack melt because the drainage has a significant percentage of north-facing aspect (Peltz and others, 1994) or because the capacity of ground-water storage within the Cold Creek watershed is large.

Ground-Water Levels and Direction of Flow

The distribution of inventoried wells, their water use, and geology (consolidated rock or unconsolidated basin fill) of the study area are shown in figure 4. Because of the lack of drillers' reports for many wells, the distribution of wells completed in unconsolidated basin-fill deposits or consolidated rock is unknown. For wells with drillers' reports, most are completed in basin-fill deposits (unconsolidated) with a few wells completed in fractured granite (consolidated).

The median depth to water on the basis of measurements from 60 non-pumping wells was 12.7 ft below land surface and ranged from 1.33 ft below land surface at well 94 to 69.85 ft below land surface at well 137. Depths to water were generally shallow in observation wells in meadows and particularly along the meadow near the mouth of Angora Creek where it is tributary to the Upper Truckee River. Depths to water were the greatest in observation wells in the old landfill near Meyers.

Well locations, results of seepage estimates, water-level contours, generalized directions of ground-water flow, and consolidated and unconsolidated geology are shown on plate 1. Water-level contours derived from measured water levels and results of seepage estimates are represented on plate 1 by solid lines; contours determined by using a median depth to water of about 13 ft are represented on plate 1 by dashed lines. The interpretation of the water-level contours in areas with wells that have land-surface altitudes determined from topographic maps has an inherent uncertainty due to uncertainties associated with the water-level altitudes. In steeply sloping terrain, the horizontal uncertainty of the water-level contours is small. In the more gently sloping terrain, where the topographic-contour interval is 40 ft, this horizontal uncertainty can be greater. Where the topographic-contour interval is 20 ft or less, the horizontal uncertainty is less. Water-level contours exist only in the unconsolidated sediments of the study area and do not cross consolidated rock. The water-level contour interval on plate 1 is variable and in general increases to the south, from about 10 ft in South Lake Tahoe to 200 ft along Highway 89 near Luther Pass.

Ground-water altitudes (pl. 1) in the Upper Truckee River watershed range from about 6,220 ft at well 76 in the northern part of the study area near Lake Tahoe to 7,250 ft at well 130 in the southern part of the study area. Ground-water altitudes in the Trout Creek watershed range from 6,190 ft at well 137 in the northern part of the study area to 6,380 ft at well 148 in the old Meyers landfill. Ground-water altitudes in the study area generally mimic the topography, with higher altitudes in the upland areas and lower altitudes near Lake Tahoe.

Ground-water levels in two wells in the study area (wells 73 and 131) have been monitored by California Department of Water Resources since June 1962. These two wells have responded to climatic variations such as drought and wet years (fig. 9).

In general, ground water in the study area is flowing northward toward Lake Tahoe (pl. 1) and parallels surface-water flow. Ground water generally discharges to the Upper Truckee River and Trout Creek along the upper reaches, whereas in the middle reaches ground water is flowing parallel to both streams. In the middle reach, the Upper Truckee River is losing streamflow for about 1.9 mi and Trout Creek has a net loss over its middle reaches. Ground water discharges to both streams between river miles 1.5 and 2.8 as both streams have a net gain in streamflow that is not accounted for by tributary flows. Both streams show little gain in flow further downstream suggesting that little ground water discharges to the two streams close to Lake Tahoe (table 4, pl. 1).

From July to November 1996, altitude of ground water in wells in the area between Lake Tahoe and Highway 50 (about river mile 1.5 on both stems) was nearly the same as the lake-surface altitude (table 5, pl. 1). This suggests that the ground-water flow beneath the Upper Truckee River and Trout Creek drainages between Highway 50 and Lake Tahoe was minimal during the study. Much of the ground-water discharge in these drainages was to the channels of the Upper Truckee River and Trout Creek upstream from Highway 50 (pl. 1).

Hydraulic gradients in the study area upstream from Highway 50 ranged from 10 to 1,400 ft/mi. Hydraulic gradients in the Upper Truckee River watershed are greatest in the upland areas. For example, the gradient near Luther Pass is 700 to 1,400 ft/mi. Hydraulic gradients tend to decrease rapidly in the lower areas, such as Christmas Valley, where gradients ranged from 30 to 60 ft/mi. In the Tahoe Paradise area, the hydraulic gradients ranged from about 20 to 40 ft/mi. In the northern part of the study area, the hydraulic gradients ranged from 10 ft/mi along the Upper Truckee River near the airport to as much as 50 ft/mi in the South Lake Tahoe area near the intersection of Highway 50 and Highway 89 in the Upper Truckee River watershed. The hydraulic gradients in the Trout Creek watershed ranged from about 420 ft/mi for areas along Saxon Creek to about 20 ft/mi along the lower reaches of Trout Creek upstream from the confluence of Heavenly Valley Creek. In the South Lake Tahoe area of the Trout Creek watershed, just south of

Highway 50, the hydraulic gradient is about 30 ft/mi except in the area of well 137, where a cone of depression is caused by municipal pumping (Woodling, 1987, p. 21) and the hydraulic gradient is as high as 300 ft/mi. Hydraulic gradients vary on either side of the large lateral glacial moraine that divides the Trout Creek watershed from the Upper Truckee River watershed. Hydraulic gradients ranged from 170 to 1,300 ft/mi on the west side of the moraine and from 60 to 730 ft/mi on the east side.

Water Quality

Specific conductance of surface-water samples from sites in the Upper Truckee River watershed on September 23, 1996, ranged from 31 µS/cm at site 16 to 148 µS/cm at site 19 (table 3). Specific conductance in the main channel of the Upper Truckee River increased in a downstream direction from 50 µS/cm at site 45 to 99 µS/cm at site 15 and then remained relatively constant from site 15 to site 1 with a range of only 96 to 99 µS/cm (fig. 10). The relatively large increase in specific conductance with downstream direction for the upper half of the Upper Truckee River was probably caused by the relatively large component of higher conductance ground water contributing to the rivers streamflow for this segment (fig. 3, tables 3 and 4). The lower half of the Upper Truckee River has relatively constant specific conductance probably because streamflow has almost no gain from ground-water seepage for this segment (fig. 3, tables 3 and 4). The specific conductance values found along the main stem of the Upper Truckee River during base-flow conditions are similar to the highest values found during the 1996 water year. For the 1996 water year, specific conductance ranged from 22 to 96 µS/cm at site 6 near the mouth to 14 to 51 µS/cm at site 43 (Bostic and others, 1997, p. 263-269). Specific conductances are usually greatest during the low streamflow of late summer through fall and immediately following some storms prior to snowmelt. Specific conductances are lowest during snowmelt runoff, which generally peaks in late spring through early summer.

Specific conductance of surface-water samples from sites in the Trout Creek watershed on September 26, 1996, ranged from 43 µS/cm at site 53 to 92 µS/cm at site 58 (table 3). The specific conductance measured in the main channel of Trout Creek ranged from 49 to 54 µS/cm (fig. 10). The lack of increase in specific conductance with downstream direction in Trout Creek as compared with the Upper Truckee River might be due to the minimal contribution of ground-water seepage to streamflow. The specific conductance values found along the main stem of Trout Creek during base-flow conditions are similar to the highest values found during the 1996 water year. For the 1996 water year, specific conductance ranged from 25 to 54 µS/cm at site 49 near the mouth and from 19 to 53 µS/cm at site 68 (Bostic and others, 1997, p. 329 and 334). Specific conductances also are the greatest during the low-flow periods of late summer through fall and the smallest during snow melt runoff in late spring to early summer.

Specific conductance of surface-water samples for the three Upper Truckee River water-quality sites from early July through mid-December 1996, ranged from 17 µS/cm at site 43 to 101 µS/cm at site 17 (table 6). Specific conductances for the three Trout Creek water-quality network sites for the same period ranged from 31 µS/cm at site 68 to 55 µS/cm at site 57.

Specific conductance of ground-water samples for wells in the Upper Truckee River and Trout Creek watersheds from mid-July through mid-December 1996, ranged from 94 µS/cm at well 137 to 542 µS/cm at well 143 (table 7). As stated earlier, the water-quality results from well 143 may not represent the overall ground-water conditions due to the proximity of the old Meyers landfill. The next highest value of specific conductance is 305 µS/cm at well 135. Specific conductances varied in only two wells between summer and fall samples (fig. 11). Specific conductance did not appear to have any trend with respect to distance from Lake Tahoe (fig. 11).

Water temperatures measured at streamflow sites in the Upper Truckee River watershed on September 23, 1996, ranged from 4.5°C at site 14 to 13.5°C in the lower reaches of the main channel at site 6 (table 3). The main channel water temperatures generally increased in a downstream direction. Water temperatures ranged from 6.0 to 9.5°C at the upper sites and ranged from 11.5 to 13.5°C at the lower sites. Water temperatures can be affected by air temperatures, which ranged from 3.5°C in the morning to 25.0°C in the afternoon. Water temperature measured at streamflow sites in the Trout Creek watershed on September 26, 1996, ranged from 5.0°C at site 68 to 11.5°C near the mouth at sites 46 and 48. Water temperatures also increased in a downstream direction with a range of 5.0 to 6.5°C in the upper reaches to 7.0 to 11.5°C in the lower reaches. The air temperatures ranged from 9.5°C in the morning to 30.0°C in the afternoon. Weather was clear and warm on both days of the seepage run.

Water temperatures for the six surface-water-quality sites in the Upper Truckee River and Trout Creek watersheds ranged from 0.5°C at site 49 in early December to 16.0°C at site 6 in mid-July. Water temperatures of ground water for the seven wells in both watersheds ranged from 8.0°C at wells 71 and 77 in late November and mid-December to 14.5°C at well 97 in mid-July. Ground-water temperatures varied seasonally by more than a half degree Celsius at only three wells (fig. 10).

Values of pH in surface water for the six sites for the Upper Truckee River and Trout Creek had a narrow range from 6.6 at site 57 to 7.8 at sites 6, 17, and 43 (table 6). Values of pH in ground water for the seven wells in both watersheds had a greater range from 5.5 at well 71 to 9.0 at well 80 (table 7). About 53 percent of ground-water quality sites had pH values from 6 to 8. Determination of the cause of this variability is beyond the scope of this study. The variation of values between summer and fall samples were small except for well 71, which varied by 1 pH unit (fig. 11). Values of pH did not appear to have any trends with respect to distance from Lake Tahoe (fig. 11).

Nutrient data collected from the six surface-water-quality sites for July through December 1996 are listed in table 6. Nitrite plus nitrate (NO_2+NO_3) concentrations ranged from 0.002 to 0.036 mg/L. The NO_2+NO_3 concentrations are well below the USEPA drinking water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996). Ammonia nitrogen (NH_4) concentrations ranged from less than the detection limit of 0.001 to 0.013 mg/L. Kjeldahl (NH_4 plus organic nitrogen) concentrations ranged from 0.04 to 0.51 mg/L. Phosphorous (P) concentrations ranged from 0.014 to 0.241 mg/L. Orthophosphorus concentrations ranged from 0.003 to 0.032 mg/L. Bioreactive iron (Fe) concentrations ranged from 45 to 2,650 µg/L. Some of these extreme values were from samples collected during storms and are not representative of normal flow conditions. Samples collected during storms were not used in the summary statistic comparisons between surface- and ground-water quality in figure 6 because they were not randomly collected.

Nutrient data collected from nine ground-water-quality sites in July through December 1996 are listed in table 7. NO_2+NO_3 concentrations ranged from 0.002 to 3.24 mg/L. Three samples, all from the Trout Creek watershed, were greater than 1.8 mg/L, whereas, 75 percent of concentrations were below 0.76 mg/L. These NO_2+NO_3 concentrations are below the USEPA drinking water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996). Ammonia (NH_4) concentrations ranged from 0.001 to 0.523 mg/L, with 75 percent below 0.2 mg/L. Kjeldahl (ammonia plus organic nitrogen) concentrations ranged from less than 0.01 to 1.7 mg/L, with two samples greater than 1.2 mg/L and 75 percent below 0.18 mg/L. Phosphorus (P) concentrations ranged from 0.018 to 0.101 mg/L, with 75 percent below 0.06 mg/L. Phosphorus concentrations were lower in samples collected in the fall than in the summer at all wells. Orthophosphorus concentrations ranged from 0.010 to 0.067 mg/L, with 75 percent below 0.032 mg/L. Bioreactive iron (Fe) concentrations ranged from 4.3 to 8,800 µg/L, with 75 percent of samples having concentrations below 32 µg/L. The highest values of the ammonia species of nitrogen nutrients occurred in one shallow observation well near the Truckee Marsh (well 71). Ground water from this well also had high concentrations of ammonia in the 1995 and 1996 water years (Bauer and others, 1996; Bostic and others, 1997). These high values probably are due to decomposition of organic material from the wetland.

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USGS

WRIR 00-4001
Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

SUMMARY AND CONCLUSIONS

Lake Tahoe is an outstanding natural resource and known for its deep, clear waters. Increased nutrient concentrations within Lake Tahoe are considered the leading cause of algal growth and loss of clarity in the lake. Surface- and ground-water discharge throughout the Lake Tahoe Basin are assumed to be significant mechanisms for nutrient transport to Lake Tahoe. The Tahoe Regional Planning Agency has primary responsibility for the environmental protection of Lake Tahoe with an emphasis on reducing the loss of lake clarity in Lake Tahoe.

The Upper Truckee River and Trout Creek watersheds are the two largest watersheds and have the greatest areas of urban land use within the Lake Tahoe Basin. In 1996, the USGS, in cooperation with TRPA, began a study to improve the understanding of the surface-water and ground-water systems and their interactions within the Upper Truckee River and Trout Creek watersheds.

The contribution of ground water to surface-water streamflow, the unit runoff, the general direction of ground-water flow, and the comparisons of water quality from the surface-water system to the ground-water system during a period of minimal snowmelt runoff for the Upper Truckee River and Trout Creek watersheds were evaluated. Streamflow and water-quality data were collected at existing and supplemental surface-water streamflow and water-quality sites and water-level and water-quality data were collected at existing and supplemental ground-water sites.

Seepage estimates were determined for the Upper Truckee River and Trout Creek by measuring streamflow at designated sites used to define reach segments. Seepage gains and losses were determined for the selected reaches by subtracting the sum of the flow at the upstream end of the reach plus any tributary inflows from the flow at the downstream end of the reach. Unit-runoff values were determined by normalizing streamflow to contributing drainage-area size. Specific conductance and water temperature were determined at the time of streamflow measurements to provide synoptic field water-quality conditions for both watersheds.

Water levels were determined for wells within the study area and were used to produce a water-level altitude map, to determine directions of ground-water flow, and to determine hydraulic gradients.

Samples from six surface-water-quality and eight ground-water-quality sites were collected for nutrient species and iron as well as the basic field measurements of specific conductance, pH, and water temperature. Summary statistics for the chemical and field data were computed for surface- and ground-water-quality sites.

Streamflows measured during the seepage run were during a base flow period for both the Upper Truckee River and Trout Creek. All but 3 of the 13 streamflow measurement sites on the main stem of the Upper Truckee River had measurable streamflow. The three dry sites were divergent branches of the main stem. Forty-eight percent of the streamflow measurement sites that are tributary to the Upper Truckee River or along the tributaries were dry. All the streamflow measurement sites on the main stem of Trout Creek had measurable flow. Only one of the streamflow sites measured in the Trout Creek watershed was dry. This indicates that streamflows in the Trout Creek watershed are more perennial than those in the Upper Truckee River.

The largest tributary inflow into the Upper Truckee River was from Grass Lake Creek, which accounted for 17 percent of the total flow near the mouth of the Upper Truckee River. The largest tributary inflow into Trout Creek was Cold Creek, which accounted for 49 percent of the total flow near the mouth of Trout Creek.

The Upper Truckee River has greater ground-water seepage contributing to its overall streamflow than Trout Creek, while Trout Creek has greater tributary inflows contributing to its overall streamflow. Both streams had a similar proportion of streamflow at their uppermost main stem sites (when computed as a percentage of the most downstream sites). The total streamflow of the Upper Truckee River near its mouth was 38 percent ground-water seepage to the main stem, 39 percent tributary inflows, and 23 percent was the streamflow at the uppermost main stem site. The total streamflow of Trout Creek near its mouth was 4 percent ground-water seepage to the main stem, 76 percent tributary inflows, and 20 percent streamflow from the upper most main stem site.

Both the Upper Truckee River and Trout Creek had streamflow that was gaining from ground-water seepage in their upper reaches, both were steady or losing to ground-water seepage in their middle reaches, and both were again gaining flow from ground-water seepage in their lower reaches.

Unit runoff values for the Upper Truckee River watershed were less than those of the Trout Creek watershed. This was mainly due to the large contribution of flow from the Cold Creek tributary to Trout Creek. The large unit runoff of the Cold Creek tributary is assumed to be due to protracted snowmelt resulting from the high percentage of north-facing aspect or due to the delayed release of ground water from storage.

The median depth to water in the study area during this period was 12.7 ft below land surface with a range of 1.33 to 69.85 ft below land surface. Depths to water were generally least in meadows and greatest in the old Meyers landfill. Ground-water altitudes in the study area ranged from 6,190 to 7,250 ft and generally mimicked the land-surface topography.

Ground-water in the study area generally flows parallel to surface water. In the upper reaches of both watersheds, ground water flows towards the stream channels and in the middle reaches it flows parallel to the main channels. In the lower reaches near Lake Tahoe, ground-water levels and the water level at Lake Tahoe are nearly equal resulting in a very small hydraulic gradient. This suggests that ground-water discharge directly to Lake Tahoe is minimal.

Hydraulic gradients in the study area varied greatly, ranging from nearly zero to 1,400 ft/mi upstream from Highway 50. Hydraulic gradients were the greatest in upland areas and least near Lake Tahoe and along the middle reaches of the main stems of both streams.

The specific conductance of surface water measured during the seepage study had a greater range in the Upper Truckee River watershed than in the Trout Creek watershed and was generally greater in value also. In the Upper Truckee River watershed, specific conductance ranged from 31 to 148 μS/cm and in the Trout Creek watershed it ranged from 43 to 92 μS/cm. The specific conductance of water in the upper half of the main stem of the Upper Truckee River increased in the downstream direction and was consistent for the lower half. The specific conductance for Trout Creek was consistent throughout the length of its main stem. This is likely attributed to the larger ground-water seepage component of total streamflow in the upper half of the Upper Truckee River than in Trout Creek.

Specific conductance for surface water was much less than that of ground water and had a much smaller range. Specific conductance for the six surface-water-quality sites for the period of study ranged from 17 to 101 µS/cm. Specific conductance for the ground-water-quality sites for the same period ranged from 94 to 305 µS/cm for wells that were considered representative of general ground-water conditions.

Temperature of surface water measured during the seepage study was generally lowest at upstream sites and highest at downstream sites in both the Upper Truckee River and Trout Creek. The overall range was 4.5 to 13.5°C. Air temperatures ranged from 3.5 to 30.0°C during the seepage study.

Median values of water temperature for both surface water and ground water were similar. Surface-water temperatures (0.5 to 16.0°C) had a significantly greater range than those measured in ground water (8.0 to 14.5°C).

Median values of pH for surface and ground water were similar; however, pH ranges for ground water (5.5 to 9.0) were significantly greater than those measured for surface water (6.6 to 7.8).

Concentrations of nitrite plus nitrate, ammonia, and orthophosphorus were greater for the ground-water samples than for the surface-water samples collected. Concentrations of bioreactive iron were generally greater for ground-water samples than for surface-water samples. Both surface- and ground-water samples had similar concentrations of phosphorous and kjeldahl (ammonia plus organic nitrogen). Ground water typically had greater variation in nitrite plus nitrate, ammonia, kjeldahl, and bioreactive iron concentrations than surface water. Surface- and ground-water samples had similar variations in phosphorous and orthophosphorus.

The most important results of this study are that, even though the Upper Truckee River and Trout Creek share many similarities in geology, vegetation, land use, and location, they had significantly different characteristics with respect to their interactions with the ground-water system. In particular, 38 percent of the streamflow of the Upper Truckee River near its mouth originated from ground-water seepage to its main channel while that of Trout Creek was only 4 percent. Ground-water contribution to streamflow also can be seen in the field measurement of specific conductance because ground water generally has greater conductivity. At the upper sites of both streams, specific conductance values are similar. However, the specific conductance increased in the downstream direction along the upper half of the Upper Truckee River but remained relatively constant along the lower half of the main stem. Specific conductance remained fairly constant for the entire length of Trout Creek.

Another important result is that during July to November 1996, the altitude of ground-water between Lake Tahoe and Highway 50 was nearly the same as the lake-surface altitude. This suggests ground-water discharge beneath the Upper Truckee River and Trout Creek drainages directly to Lake Tahoe was minimal and that much of the ground-water discharge was to the channels of the Upper Truckee River and Trout Creek upstream from Highway 50.

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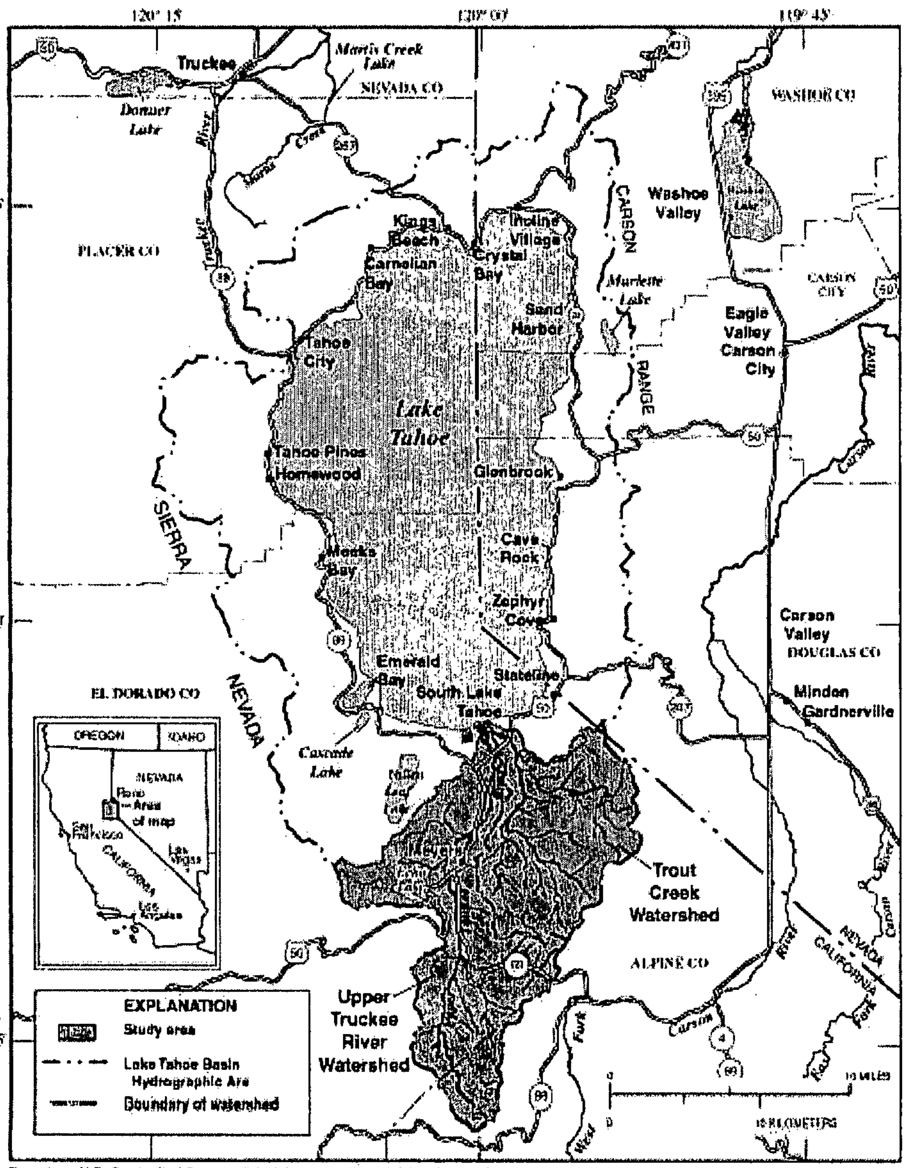
Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000, 1969-83
Universal Transverse Mercator projection, Zone 11

Figure 1. Location of Lake Tahoe Basin and Upper Truckee River and Trout Creek watersheds, California and Nevada.

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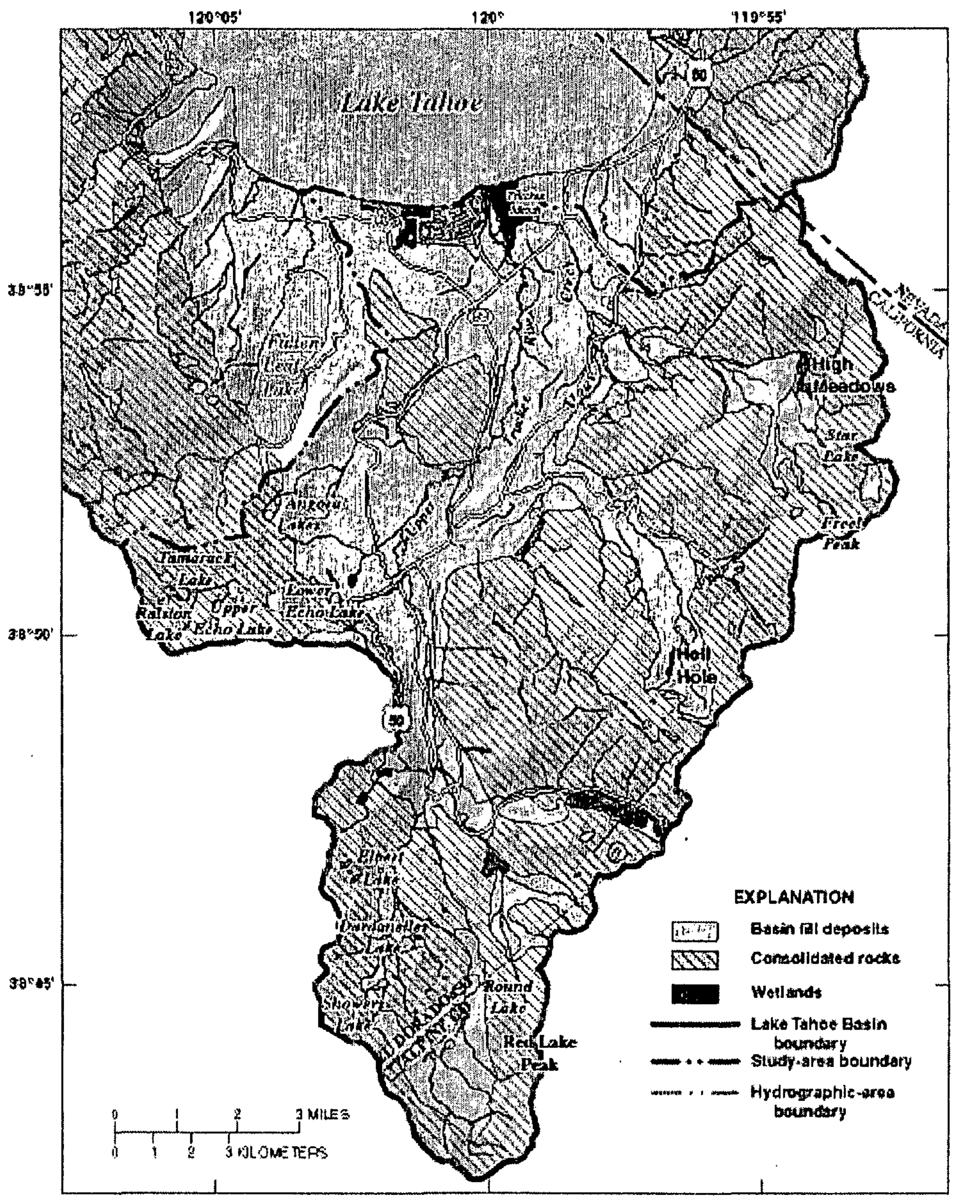

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Shaded-relief base from 1:24,000 Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Geology from Burnett (1971)

Figure 2. Locations of roads, streams, and general surficial geology, Upper Truckee River and Trout Creek watersheds, California.

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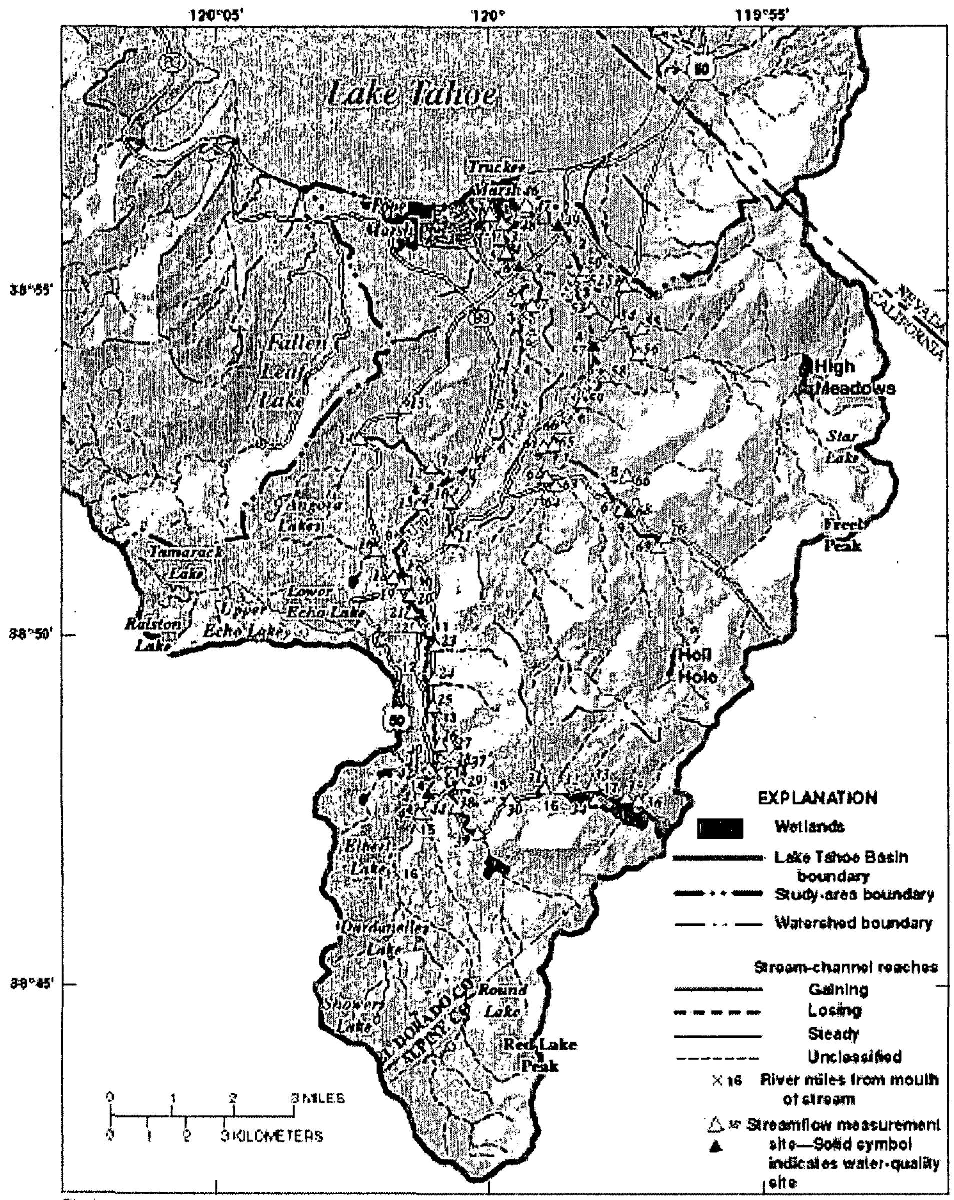

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Universal Transverse Mercator Projection, Zone 11.
Shaded-relief base from 1:24,000 Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Figure 3. Streamflow measurement sites, Upper Truckee River and Trout Creek watersheds, California, September 1996.

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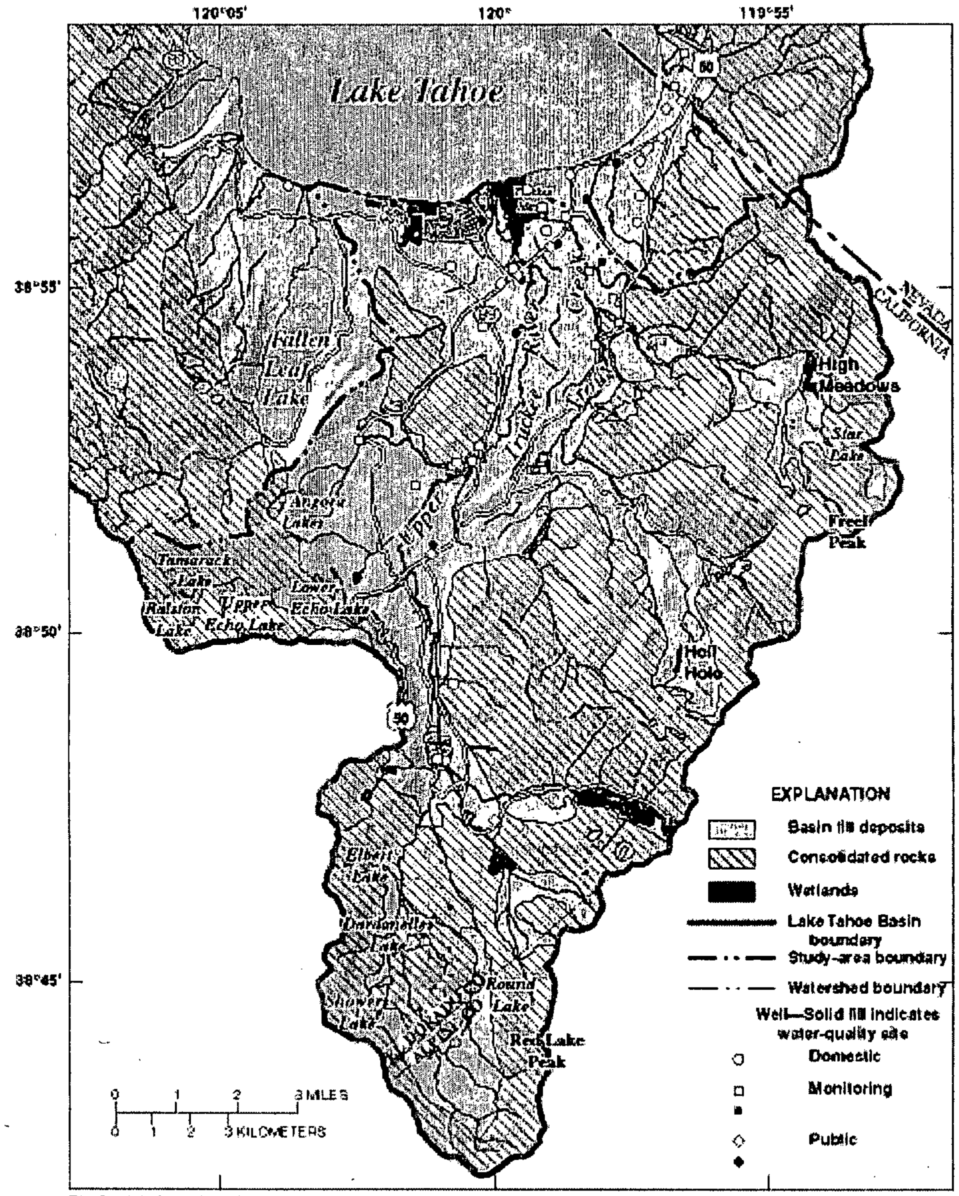

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Shaded-relief base from 1:24,000 Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Geology from Burnett (1971)

Figure 4. Locations of well sites and general surficial geology, Upper Truckee River and Trout Creek watersheds, California, September 1996.

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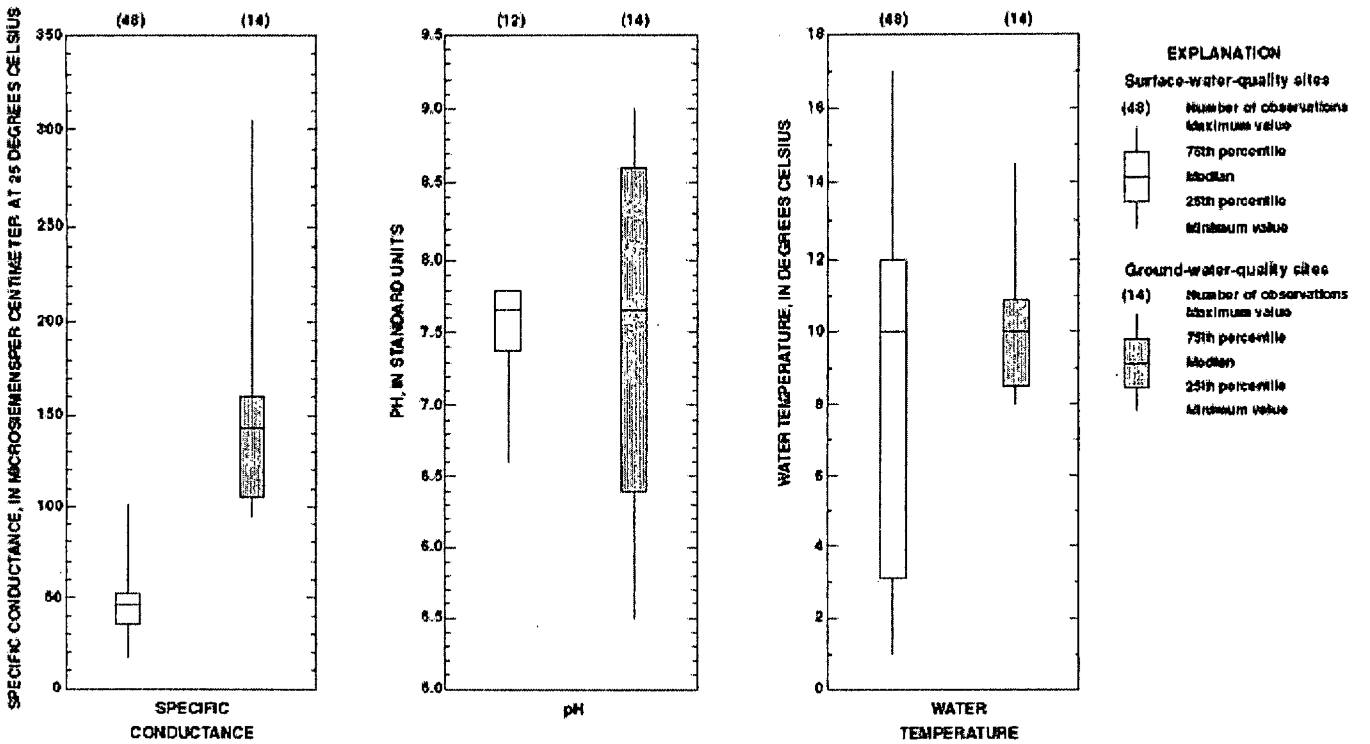

Figure 5. Water-quality field measurements for surface- and ground-water sites, Upper Truckee River and Trout Creek watersheds, California, July-December 1996.

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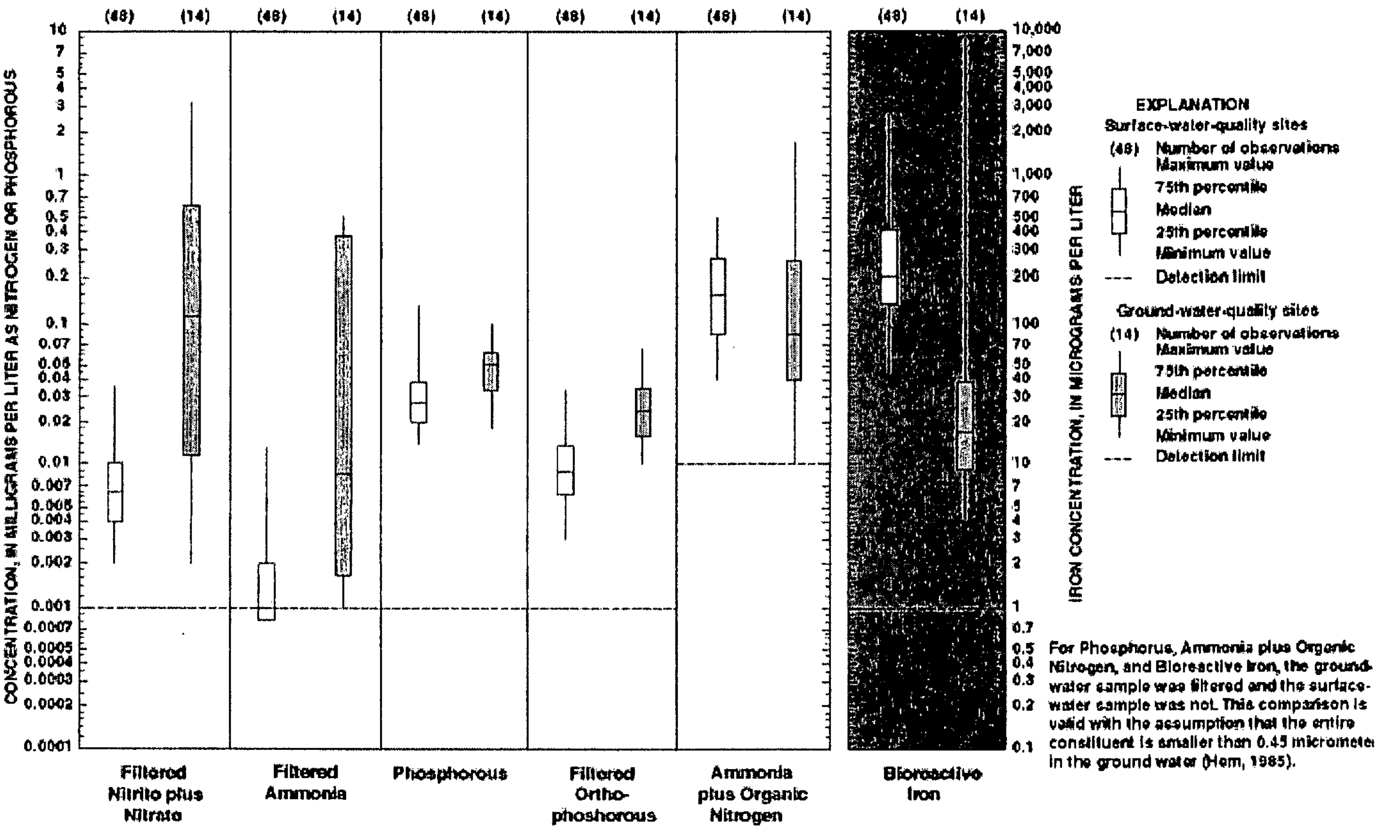

Figure 6. Nutrient concentrations for surface- and ground-water sites, Upper Truckee River and Trout Creek watersheds, California, July-December 1996.

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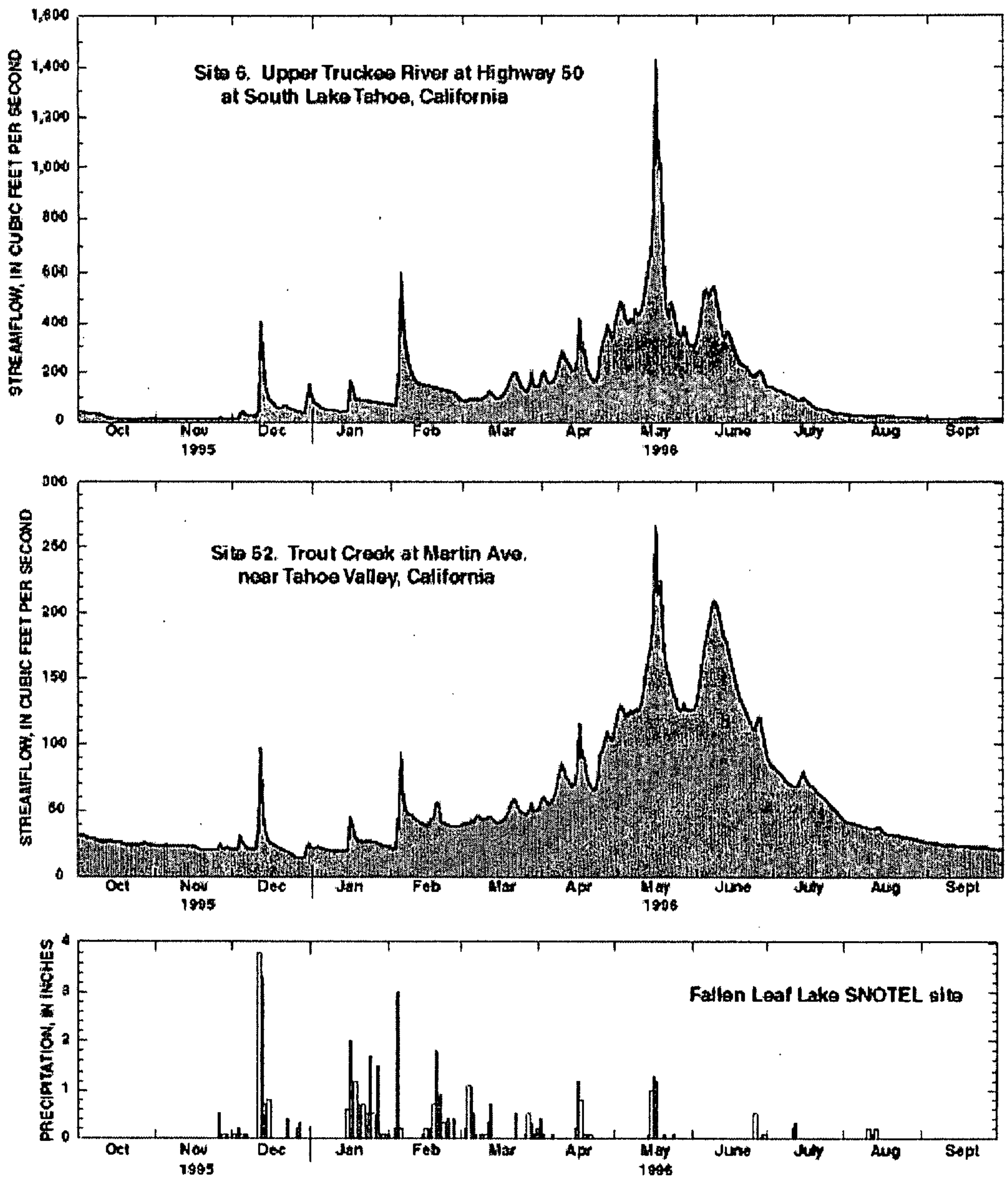

Figure 7. Streamflow for the Upper Truckee River at South Lake Tahoe, California, and for Trout Creek near Tahoe Valley, California, and daily precipitation below Fallen Leaf Lake, California, 1996 water year. (Precipitation data courtesy of National Resource Conservation Service.)

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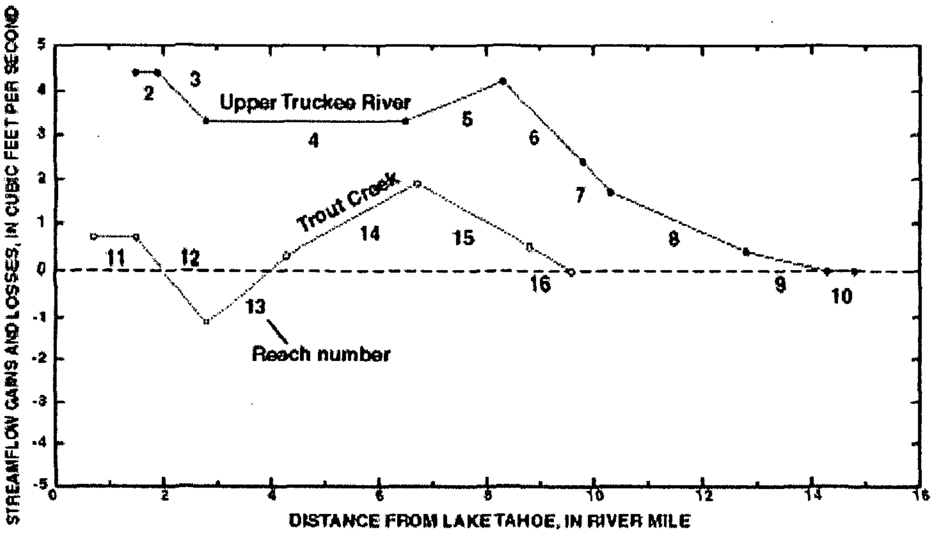

Figure 8. Cumulative streamflow gains and losses for Upper Truckee River and Trout Creek, California, September 1996.

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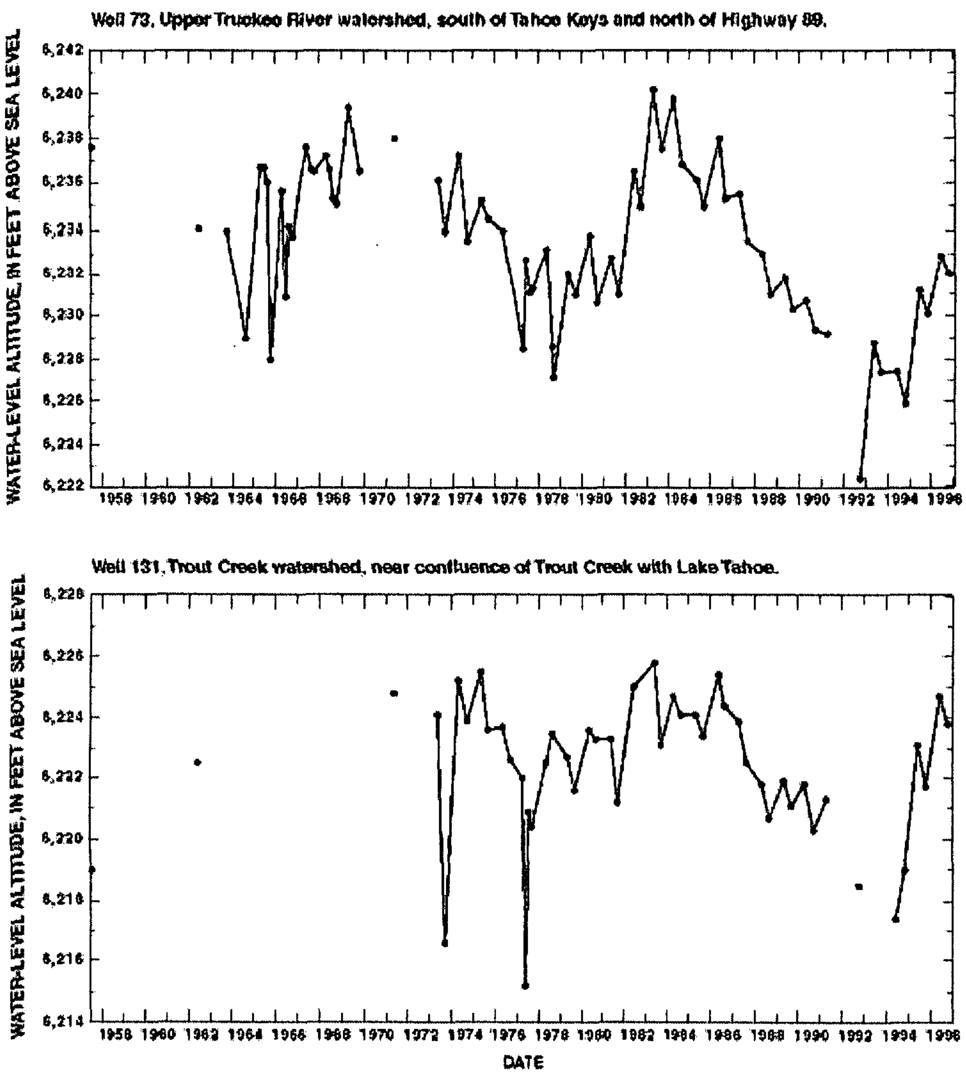

Figure 9. Water-level changes in wells 73 and 131 in Upper Truckee River and Trout Creek watersheds, California. (Data courtesy of California Department of Water Resources.) Locations of wells is shown on plate 1.

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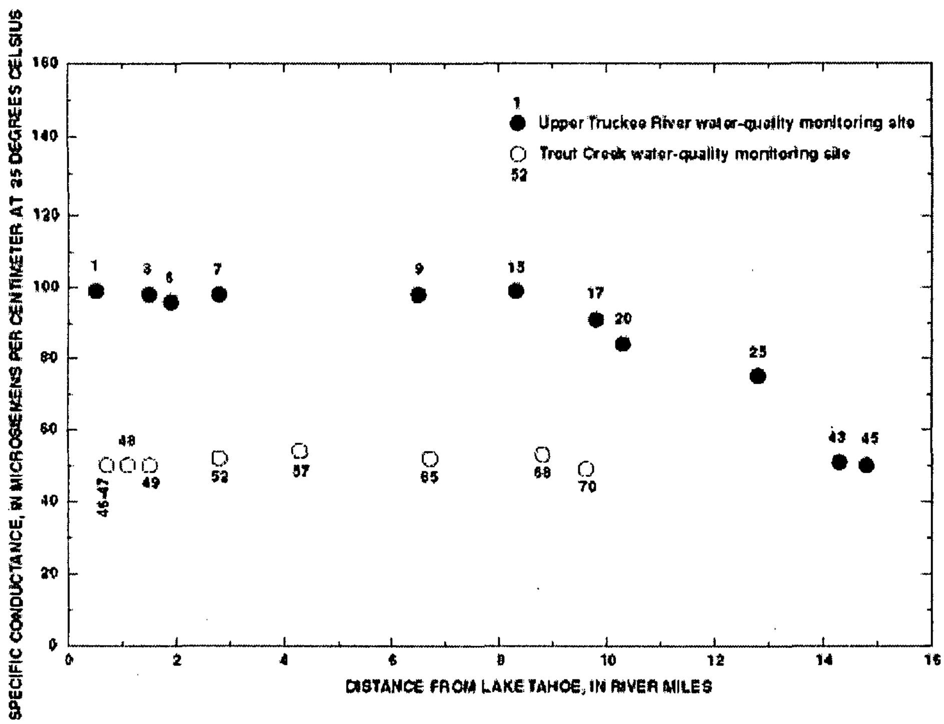

Figure 10. Relation between distance from Lake Tahoe and specific conductance for surface-water-quality monitoring sites on Upper Truckee River and Trout Creek, California, September 1996, as listed in table 4..

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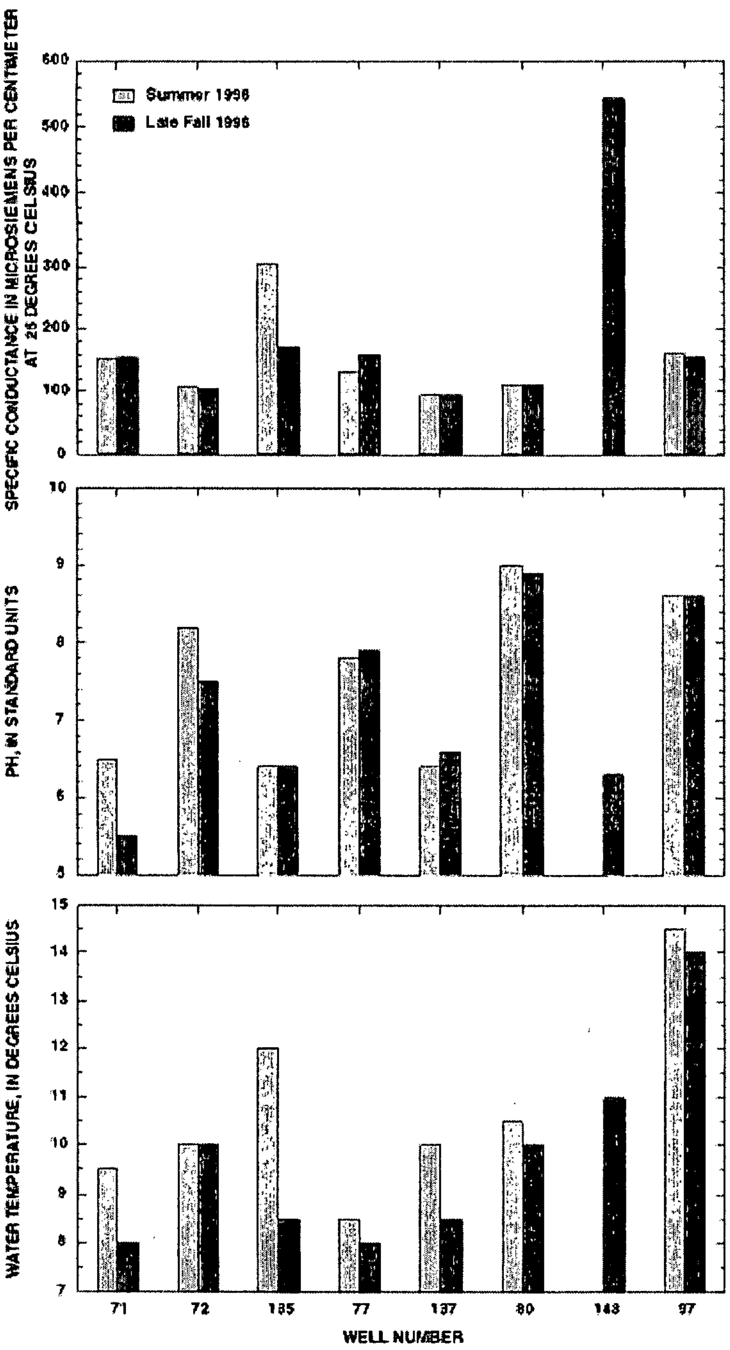

Figure 11. Field ground-water-quality measurements, Upper Truckee River and Trout Creek watersheds, California, July-December 1996. Sites are listed with increasing distance from Lake Tahoe from left to right.

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Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

Table 1. Periods of record for daily streamflow, water-quality, and suspended-sediment data at c Geological Survey gaging stations and sampling sites for Upper Truckee River and Trout Creek \

Water quality: NUT, instantaneous nutrient samples; SC, daily specific conductance; WT, daily water temperature.
Suspended sediment: DAILY, daily suspended sediment; INST, instantaneous suspended sediment discharge.
[Abbreviation: USFS, U.S. Forest Service]

Site no. (pl. 1)	Site name	Station number	Daily streamflow	Water quality
	Upper Truckee River watershed			
6	Upper Truckee River at Hwy 50 at South Lake Tahoe (gage)	10336610	1972-74,77, 78,80-current	WT:1972-74,78,80-: SC:1981-83 NUT:1993-current
17	Upper Truckee River at Hwy 50 above Meyers (gage)	103366092	1990-current	NUT:1990-current
20	Upper Truckee River nr Meyers (inactive gage)	10336600	1961-86	
43	Upper Truckee River at S. Upper Truckee Rd (gage)	10336580	1990-current	NUT:1990-current
	Trout Creek watershed			
49	Trout Creek at Hwy 50 at South Lake Tahoe	10336790		WT:1972-74,89-92 NUT:1993-current
52	Trout Creek at Martin Ave nr Tahoe Valley (gage)	10336780	1961-current	WT:1972-74,78, 80-85,88 SC:1981-83
57	Trout Creek at Pioneer Trail nr South Lake Tahoe (gage)	10336775	1990-current	NUT:1990-current
68	Trout Creek at USFS Rd 12N01 nr Meyers (gage)	10336770	1990-current	NUT:1990-current

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Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

Table 2. Streamflow measurement sites used for seepage estimates in the Upper Truckee River and Trout Creek watersheds, California, September 1996

Site no. (pl. 1)	Site name	Station number	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Drainage area (square miles)	Altitude (feet)	River mile, from mouth (miles)
Upper Truckee River watershed							
1	Upper Truckee R. at mouth - W. channel-off Venice Dr	10336612	385604	1195957	56.5	6,228	0.5
2	Upper Truckee R. at mouth - E. channel	103366117	385557	1195944		6,228	.9
3	Upper Truckee R. abv marsh - W. channel-off Michael	103366113	385532	1195939		6,228	1.5
4	Upper Truckee R. abv marsh - E. channel-off Michael	10336611	385531	1195937		6,228	1.5
5	D St Drainage at Sky Meadows	103366107	385531	1195939		6,240	1.5
6	Upper Truckee R. at Hwy 50 at S. Lake Tahoe (gage)	10336610	385522	1195925	54.0	6,229	1.9
7	Upper Truckee R. blw SLT Airport - E. channel	1033660987	385447	1195911		6,240	2.8
8	Upper Truckee R. blw SLT Airport - W. channel	1033660985	385453	1195926		6,240	3.1
9	Upper Truckee R. at Hwy 50 blw Meyers	103366098	385231	1200016	50.1	6,280	6.5
10	Sante Fe Trib at Country Club Rd nr Arapahoe St	103366095	385157	1200041	1.0	6,320	7.5
11	Sante Fe Trib blw Hwy 50 off Sante Fe Rd	1033660947	385125	1200041		6,350	8.2
12	Angora Ck. nr Sawmill Rd at Ranch Rd	103366096	385228	1200102	5.7	6,290	7.3
13	Sawmill Pond Outlet at Sawmill Rd	1033660957	385319	1200132		6,340	8.7
14	Angora Ck. at Lake Tahoe Blvd	1033660953	385252	1200221		6,360	8.9

15	Upper Truckee R. abv Golfcourse off Country Club Dr	1033660943	385155	1200114		6,290	8.3
16	Osgood Ck. at N. Upper Truckee Rd	103366094	385114	1200203	1.6	6,380	9.4
17	Upper Truckee R. at Hwy 50 abv Meyers (gage)	103366092	385055	1200134	39.2	6,310	9.8
18	Upper Truckee R. Trib at N. Upper Truckee Rd nr Hwy 50	103366091	385051	1200143		6,360	9.9
19	Echo Ck. at S. Upper Truckee Rd nr Meyers	10336609	385045	1200135	5.4	6,350	10.0
20	Upper Truckee R. nr Meyers (old gage)	10336600	385035	1200125	33.2	6,322	10.3
21	Upper Truckee R. Trib nr Kekin St at S. Upper Truckee Rd	10336599	385020	1200124		6,380	10.6
22	Upper Truckee R. Trib at Celio Ranch at S. Upper Truckee Rd	10336598	385008	1200119		6,380	11.1
23	Upper Truckee R. Trib at Hwy 89 N. of Santa Claus Dr	10336597	384951	1200058		6,400	11.5
24	Upper Truckee R. Trib at Hwy 89 S. of Santa Claus Dr	10336596	384923	1200059		6,410	12.3
25	Upper Truckee R. blw Grass Lake Ck. (blw Portal Rd)	10336594	384858	1200101		6,410	12.8
26	Upper Truckee R. N. Trib at Grass Lk Rd	1033659356	384826	1200052		6,480	13.6
27	Upper Truckee R. S. Trib at Grass Lk. Rd (Grass Lk. Ck. Div)	1033659354	384813	1200052		6,480	13.7
28	Grass Lake Ck. nr Meyers (off Grass Lake Rd)	10336593	384807	1200054	6.4	6,480	13.9
29	Grass Lake Ck. at Hwy 89 (lower)	103365925	384753	1200030		6,880	14.3
30	Grass Lake Ck. abv Big Meadow Ck. at Hwy 89	10336592	384740	1195935		7,440	15.3
31	Grass Lake Ck. Trib W. abv Hwy 89	103365915	384750	1195847		7,640	15.9
32	Grass Lake Ck. Trib MidWest abv Hwy 89	10336591	384751	1195840		7,650	16.2
33	Grass Lake Ck. Trib MidEast abv Hwy 89	103365905	384752	1195805		7,720	16.8
34	Grass Lake Ck. blw Grass Lake	10336590	384740	1195802		7,720	16.8
35	Grass Lake Ck. Trib E. abv Hwy 89	10336588	384741	1195729		7,720	17.5

36	Grass Lake Ck. Trib abv Hwy 89 nr Luther Pass	10336587	384738	1195715		7,720	17.8
37	Big Meadow Ck. at mouth off Grass Lake Rd	1033659352	384803	1200050	5.1	6,480	14.0
38	Big Meadow Ck. at Hwy 89 (lower)	103365935	384732	1200035		7,010	14.7
39	Big Meadow Ck. abv Hwy 89	103365932	384711	1200011		7,160	15.4
40	Benwood Meadows Trib N. at S. Upper Truckee Rd	10336584	384806	1200105	1.4	6,480	14.0
41	Benwood Meadows Trib Middle at S. Upper Truckee Rd	10336583	384804	1200105		6,480	14.0
42	Benwood Meadows Trib S. at S. Upper Truckee Rd	10336582	384803	1200103		6,480	14.0
43	Upper Truckee R. at S. Upper Truckee Rd (gage)	10336580	384745	1200106	14.2	6,490	14.3
44	Upper Truckee R. Trib abv Hawley Grade Rd	10336579	384727	1200110		6,600	14.7
45	Upper Truckee R. abv Trib abv Hawley Grade Rd	10336578	384727	1200115		6,600	14.8
Trout Creek watershed							
46	Trout Ck. nr mouth - E. channel-off Bellevue/El Dorado Ave	10336795	385611	1195917	41.0	6,230	.7
47	Trout Ck. nr mouth - middle channel-off Bellevue/El Dorado Ave	10336794	385607	1195920		6,230	.7
48	Trout Ck. nr mouth - W. channel-off Bellevue/El Dorado	10336793	385605	1195922		6,230	1.1
49	Trout Ck. at Hwy 50 at S. Lake Tahoe	10336790	385556	1195842	40.4	6,240	1.5
50	Heavenly Valley Ck. at Black Bart nr Tahoe Valley	10336785	385517	1195813	3.0	6,260	2.8
51	Heavenly Valley Ck. at Pioneer Trail	10336783	385504	1195730		6,300	3.8
52	Trout Ck. at Martin Ave nr Tahoe Valley (gage)	10336780	385512	1195817	36.7	6,241	2.8
53	Cold Ck. at mouth (off Plateau Dr)	10336779	385444	1195806	12.8	6,260	3.6
54	Cold Ck. at Pioneer Trail	10336778	385432	1195739		6,300	4.1
55	Cold Ck. Trib at Del Norte Dr	10336777	385427	1195712		6,440	4.7
56	Cold Ck. off Del Norte Dr	10336776	385406	1195715		6,440	4.8
57	Trout Ck. at Pioneer Trail nr S. Lake Tahoe (gage)	10336775	385413	1195804	23.0	6,270	4.3

58	Trout Ck. Trib off Columbine nr USFS Rd 12N08	103367745	385346	1195751		6,280	5.1
59	Trout Ck. Trib off Pioneer Trail at old RR grade	10336774	385324	1195816		6,280	5.7
60	Trout Ck. blw Saxon Ck. off Powerline Rd	10336773	385302	1195836		6,280	6.3
61	Saxon Ck. blw Landfill at Powerline Rd	103367726	385245	1195858	8.2	6,300	6.8
62	Saxon Ck. at USFS Rd 12N01	10336772	385219	1195855		6,320	7.4
63	Saxon Ck. Trib abv USFS Rd 12N01	103367718	385212	1195845		6,360	7.6
64	Saxon Ck. abv Trib abv old RR grade	103367716	385206	1195853		6,360	7.7
65	Trout Ck. abv Saxon Ck. at Powerline Rd	103367708	385247	1195847		6,300	6.7
66	Hidden Valley Ck. at Trail Crossing	103367706	385220	1195727	1.7	7,000	8.4
67	Trout Ck. Trib blw gage at USFS Rd 12N01	103367702	385151	1195733	1.4	6,940	8.8
68	Trout Ck. at USFS Rd 12N01 nr Meyers (gage)	10336770	385148	1195726	7.4	6,850	8.8
69	Hell Hole Meadow Trib nr mouth	10336768	385117	1195654	2.8	7,520	9.6
70	Trout Ck. abv Hell Hole Trib at Horsetrail Crossing	10336769	385126	1195646		7,500	9.6

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Table 3. Streamflow and water-quality data for streamflow sites in the Upper Truckee River and Trout Creek watersheds, California, September 1996

[Abbreviations and symbol: ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $ft^3/s/mi^2$, cubic feet per second per square mile; --, not measured]

Site no. (pl. 1)	Flow (ft^3/s)	Specific conductance (µS/cm)	Air temperature (degrees Celsius)	Water temperature (degrees Celsius)	Unit runoff ($ft^3/s/mi^2$)
Upper Truckee River watershed					
1	--	99	--	--	--
2	0	--	--	--	--
3	11.6	98	16.0	12.0	0.21
4	0	--	--	--	--
5	0	--	--	--	0
6	11.2	96	--	13.5	.21
7	10.1	98	14.0	12.0	--
8	0	--	--	--	--
9	10.3	98	18.5	11.5	.21
10	0	--	--	--	0
11	0	--	--	--	0
12	.8	72	14.5	6.5	.14
13	0	--	--	--	0
14	.2	39	3.5	4.5	--
15	10.4	99	18.5	12.0	--
16	.1	31	5.0	5.5	.06
17	8.5	91	14.5	9.5	.22
18	0	--	--	--	0
19	.1	148	15.5	9.0	.02

20	7.7	84	14.0	10.5	.23
21	0	--	--	--	0
22	0	--	--	--	0
23	0	--	--	--	0
24	0	--	--	--	0
25	6.4	75	20.0	11.0	--
26	0	--	--	--	0
27	.9	73	19.5	8.5	--
28	1.1	73	16.5	7.5	.31
29	--	--	--	--	--
30	2.6	65	18.5	8.5	--
31	.1	36	17.0	9.5	--
32	.3	43	17.5	7.5	--
33	.2	--	--	--	--
34	1.0	43	18.0	11.5	--
35	--	--	--	--	--
36	--	--	--	--	--
37	0.9	69	10.0	7.5	0.18
38	--	--	--	--	--
39	.5	50	18.5	8.0	--
40	0	--	--	--	0
41	0	--	--	--	--
42	0	--	--	--	--
43	3.1	51	10.0	6.0	.22
44	.6	50	14.5	7.0	--
45	2.6	50	25.0	9.0	--
Trout Creek watershed					
46	11.8	50	17.0	11.5	.56
47	8.4	50	15.5	10.5	--
48	2.8	50	15.5	11.5	--
49	22.6	50	14.0	7.0	.56
50	.2	52	20.5	7.0	.07

51	.4	50	11.0	7.0	--
52	20.6	52	--	10.5	.56
53	11.2	43	27.0	8.0	.88
54	11.3	44	30.0	7.0	--
55	0	--	--	--	0
56	--	--	--	--	--
57	10.8	54	14.5	10.5	.47
58	.1	92	17.0	9.0	--
59	.1	75	16.0	9.0	--
60	--	--	--	--	--
61	2.4	55	15.5	6.5	.29
62	2.5	46	19.0	7.5	--
63	.2	54	19.5	7.5	--
64	2.0	45	18.0	7.5	--
65	9.8	52	18.5	6.0	--
66	.8	51	18.0	7.0	.47
67	1.4	44	17.0	6.0	1.00
68	6.2	53	9.5	5.0	.84
69	1.0	54	11.5	6.0	.36
70	4.7	49	12.0	7.0	--

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Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

Table 4. Streamflow measurement data and seepage estimates for designated main-stem reach in the Upper Truckee River and Trout Creek, California, September 1996

[Abbreviations and symbol: ft^3/s, cubic feet per second; ft^3/s/mi, cubic feet per second per mile; nd, streamflow not determined; · not applicable]

Reach number (pl. 1)	Reach segment (between site numbers)	Flow at beginning of reach (ft^3/s)	Tributary flows (ft^3/s)	Flow out of reach (ft^3/s)	Percent change in flow[1]	Estimated ground-water seepage (ft^3/s)[2]	Reach designation[3]	Estimated gain (· or loss (-) per unit length (ft^3/s/mi)[4]
Upper Truckee River								
1	1 to 3	11.6	0	nd	--	--	--	--
2	3 to 6	11.2	0	11.6	+3.6	--	Steady	--
3	6 to 7	10.1	0	11.2	+11	+1.1	Gaining	+1.2
4	7 to 9	10.3	0	10.1	-1.9	--	Steady	--
5	9 to 15	10.4	.8	10.3	-8.0	-0.9	Losing	-0.50
6	15 to 17	8.5	.1	10.4	+21	+1.8	Gaining	+1.2
7	17 to 20	7.7	.1	8.5	+9.0	+0.7	Gaining	+1.4
8	20 to 25	6.4	0	7.7	+20	+1.3	Gaining	+0.52
9	25 to 43	3.1	2.9	6.4	+6.7	+0.4	Gaining	+0.27
10	43 to 45	2.6	.6	3.1	-3.1	--	Steady	--
Trout Creek								
11	46 to 49	22.6	0	23.0	+1.8	--	Steady	--
12	49 to 52	20.6	.2	22.6	+8.7	+1.8	Gaining	+1.4
13	52 to 57	10.8	11.2	20.6	-6.4	-1.4	Losing	-0.93
14	57 to 65	9.8	2.6	10.8	-13	-1.6	Losing	-0.67
15	65 to 68	6.2	2.2	9.8	+17	+1.4	Gaining	+0.67
16	68 to 70	4.7	1.0	6.2	+8.8	+0.5	Gaining	+0.62

[1] Percent change in flow determined as difference between flow out of reach and sum of flow at beginning of reach and all tributary flows.

[2] Ground-water seepage is difference between flow out of reach and sum of flow at beginning of reach and all tributary flows.

[3] If percent change in flow is greater than 5 percent, then reach is designated as gaining (gaining flow from ground-water seepage into reach). If percent change in flow is less than -5 percent, then reach is designated as losing (losing flow to ground-water seepage out of reach). If percent change in flow is greater than -5 percent and less than 5 percent, then reach is designated as steady (no change in flow due to ground-water seepage).

[4] Gain (+) or loss (-) is estimated ground-water seepage divided by length of reach (see table 2 for river mile designations).

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Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

Table 5. Selected characteristics of ground-water monitoring sites in Upper Truckee River and Tı

Land-surface altitude uncertainties:
this region is 40 feet for altitudes greater than 6,280 feet with a supplementary contour interval of 20 feet for altitudes less than 6
Site status: D, dry well; F, flowing well, but head was not measured; P, well being pumped; R, well pumped recently; S, site is a level measurement represents static level. Water level may represent local conditions only.
Method: S, steel tape; T, electric tape; O, observed in field.
[Symbols: --, unknown; <, less than; >, greater than]

Well no. (pl. 1)	U.S. Geological Survey site identification number[1]	Local identification number[2]	Station name	(f s
			Upper Truckee R	
71	385613120014801	90 N13 E18 06ABBC1	USGS TM-2A [3]	
72	385559120001301	90 N12 E18 05AADD1	KEYS 1 [3]	
73	385519120004601	90 N12 E18 05CAAD1	LOPEZ	6
74	385518119593801	90 N12 E18 04CAAD1	LITTLE TRUCKEE MOBILE PARK	
75	385517119593901	90 N12 E18 04CAAD2	SWEATT	
76	385511119593301	90 N12 E18 04DBCB1	EDS AUTO BODY	
77	385507119593002	90 N12 E18 04DBCA2	HELEN 2 [3]	
78	385504119595201	90 N12 E18 04CACC1	MATTERHORN MOTEL	
79	385428120001101	90 N12 E18 08AAAD1	HURLEY	
80	385423119593601	90 N12 E18 09ABC 1	AIRPORT 2 [3]	
81	385318120000301	90 N12 E18 16BCCA1	MCGEE	
82	385251120022601	90 N12 E18 18CCCB1	ANGORA CR SED BASIN 1	
83	385251120022401	90 N12 E18 18CCCB2	ANGORA CR SED BASIN 2	
84	385245120001601	90 N12 E18 20AAAB1	BROWN ABANDONED HOUSE	
85	385234120002401	90 N12 E18 20ADBB2	LOEFLER	
86	385232120002401	90 N12 E18 20ADBB1	GUARNERO	
87	385232120002301	90 N12 E18 20ADBD2	YANT1	

88	385231120004001	90 N12 E18 20ACBD1	SKALBERG
89	385231120001901	90 N12 E18 20ADBD1	FRAZIER
90	385227120004601	90 N12 E18 20BDDA1	ANGORA CREEK 10
91	385227120003701	90 N12 E18 20ACCA2	ANGORA CREEK 18
92	385226120003701	90 N12 E18 20ACCA1	ANGORA CREEK 15
93	385225120004801	90 N12 E18 20BDDB1	ANGORA CREEK 2
94	385223120004601	90 N12 E18 20BDDD1	ANGORA CREEK 4
95	385210120012502	90 N12 E18 19DADC2	WASHOE MEADOW STATE PARK 2
96	385210120012501	90 N12 E18 19DADC1	WASHOE MEADOW STATE PARK 1
97	385118120010601	90 N12 E18 29CBD 1	ARROWHEAD 2 [3]
98	385110120010701	90 N12 E18 29CCAD1	CHRIS CAFE
99	384917120004401	90 N11 E18 08BAAA1	SHIELDS
100	384837120010501	90 N11 E18 08CCAB1	MYERS
101	384832120011001	90 N11 E18 08CCBD1	CHARSHAFIAN
102	384832120010501	90 N11 E18 08CCAC1	PAULING
103	384831120011001	90 N11 E18 08CCCA1	AMUNDSON
104	384828120010501	90 N11 E18 08CCDB1	WILKIE
105	384828120005301	90 N11 E18 08CDCA1	BAGINSKI
106	384826120010801	90 N11 E18 08CCCD1	PAULSON
107	384825120005201	90 N11 E18 08CDCD1	CAPELLA
108	384824120010901	90 N11 E18 17BBBA1	RENNISON
109	384823120005301	90 N11 E18 17BABA1	MOSBACHER 1
110	384822120005201	90 N11 E18 17BABA2	FEVES
111	384821120010801	90 N11 E18 17BBAB1	RECORD
112	384821120010602	90 N11 E18 17BBAB3	HOSMAN 2
113	384821120010601	90 N11 E18 17BBAB2	HOSMAN 1
114	384821120010001	90 N11 E18 17BBAA1	ULRICH
115	384820120005002	90 N11 E18 17BAAC2	ZAIGER 2
116	384820120005001	90 N11 E18 17BAAC1	ZAIGER 1
117	384818120010201	90 N11 E18 17BBAD1	YURE
118	384817120010501	90 N11 E18 17BBDB1	WILLIAMS
119	384817120005201	90 N11 E18 17BACA1	MOSBACHER 2

120	384814120005301	90 N11 E18 17BACD1	ROMAN	
121	384813120010701	90 N11 E18 17BBDC1	GINOTTI	
122	384813120010601	90 N11 E18 17BBDC1	ALI	
123	384813120010301	90 N11 E18 17BBDD2	RADEKAN 1	
124	384813120010101	90 N11 E18 17BBDD3	RADEKAN 2	
125	384812120005301	90 N11 E18 17BACD2	JETT-PEARCE	
126	384811120010201	90 N11 E18 17BBDD1	SHEA	
127	384811120005501	90 N11 E18 17BDBA1	CHILCOTES	
128	384810120010301	90 N11 E18 17BCAA1	ROBERSON	
129	384807120005801	90 N11 E18 17BDBC1	AGEE	
130	384721119595901	90 N11 E18 21BDBB1	USFS BIG MEADOW TRAILHEAD	
Trout Creek watersl				
131	385624119592401	90 N13 E18 32CCCC1	SCHWABL	
132	385609119590701	90 N12 E18 04AAAD1	HARCOTUNIAN	
133	385602119584201	90 N12 E18 03BACD1	EPPLER	
134	385549119590301	90 N12 E18 03BCBB1	GERKEN	
135	385538119585001	90 N12 E18 03BCC 1	SKY LAKE LODGE [4]	
136	385535119585801	90 N12 E18 03ACCA1	SILVER DOLLAR MOTEL	
137	385522119580204	90 N12 E18 03DAAB4	USGS TCF-4 [3]	
138	385514119581601	90 N12 E18 03DBAD1	BLACK BART	
139	385432119574201	90 N12 E18 11BBAA1	LAKE CHRISTOPHER WELL	
140	385413119580801	90 N12 E18 10ADCA1	GOLDEN BEAR	
141	385235119590701	90 N12 E18 21AADC1	MEYERS LANDFILL 10	6
142	385231119590901	90 N12 E18 21ADAB1	MEYERS LANDFILL 4	6
143	385231119590301	90 N12 E18 22BCBB1	MEYERS LANDFILL 9 [3]	6
144	385229119591102	90 N12 E18 21ADAC2	MEYERS LANDFILL M-5	6
145	385229119591101	90 N12 E18 21ADAC1	MEYERS LANDFILL M-3	6
146	385226119591201	90 N12 E18 21ADCA1	MEYERS LANDFILL 2	6
147	385225119591601	90 N12 E18 21ADCB1	MEYERS LANDFILL 1	6
148	385224119591901	90 N12 E18 21ADCC1	MEYERS LANDFILL M-7	6
149	385224119590701	90 N12 E18 21ADDC1	MEYERS LANDFILL 8	6
Adjacent to study a				

150	385627120034401	90 N13 E17 26DDBA1	USFS BALDWIN BEACH 1	
151	385824119550401	90 N13 E18 23CBB 1	FOLSOM SPRING	
152	385816119563001	90 N13 E18 22DCA 1	EDGEWOOD4	
153	385742119565701	90 N13 E18 27BDA 1	EDGEWOOD1	
154	385736119563401	90 N13 E18 27DBBC1	TAHOE TROPICANA LODGE	(
155	385729119565101	90 N13 E18 27CACC1	STATION HOUSE INN	
156	385708119564901	90 N13 E18 34BACA1	MIDWAY MOTEL ANNEX	
157	385705119565601	90 N13 E18 34BBDA1	MI TIERRA	
158	385658119571001	90 N13 E18 34BCBC1	OSGOOD 4	
159	385654119571401	90 N13 E18 33ADDA1	COPPER LANTERN MOTEL	
160	385646119571901	90 N13 E18 33DAAB1	ALDER INN MOTEL	
161	385644119574601	90 N13 E18 33CAD 1	BEVERLY LODGE [4]	
162	385636119583701	90 N13 E18 32DCAA1	TIMBERLAKE INN	
163	385618119572001	90 N12 E18 02ABBB1	ROEDER	
164	385651119581701	90 N12 E18 03ABA 1	AL TAHOE SCHOOL [4]	
165	385557119572301	90 N12 E18 02BDDD1	EPPS	(

[1] Sites are identified by standard U.S. Geological Survey identification number, which is a unique number based on grid system of latitude and longitude of the site. Number consists of 15 digits: First six denote degrees, minutes, and seconds of latitude; next seven denote degrees, minutes, and seconds of longitude; and last two digits (assigned sequentially) identify sites within 1-second grid. For example, site 385816119563001 refers to 38° 58' 16" latitude and 119° 56' 30" longitude, and is first site recorded in that 1-second grid. If more precise latitude and longitude subsequently are determined, initial site-identification number is retained.

[2] Locations are assigned using a grid system referenced to Mount Diablo base line and meridian for official rectangular subdivision of public lands. Location consists of four units: First unit is the hydrographic area number (Rush, 1968), Second unit is township, preceded by N or S to indicate location north or south of base line. Third unit is range, preceded by E to indicate location east of meridian. Fourth unit consists of section number and letters designating quarter section, quarter-quarter section, and so on (A, B, C, and D indicate northeast, northwest, southwest, and southeast quarters, respectively), followed by number indicating sequence in which site was recorded. For example, well 90 N11 E18 21BDBB1 is in the Lake Tahoe Basin (hydrographic area 90). It is the first site recorded in the northwest quarter (B) of the northwest quarter (B) of the southeast quarter (D) of the northwest quarter (B) of section 21, Township 11 North, Range 18 East, Mount Diablo base line and meridian.

[3] Ground-water-quality sites used in this study.

[4] Water levels in parenthesis are pumping levels and probably do not represent static water level. Pumping levels were used as a lower boundary for static water level on plate 1.

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Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

Table 6. Water-quality data for selected streamflow sites in Upper Truckee River and Trout Creek watersheds, California, July - December 1996

[Abbreviations: ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; USFS, U.S. Forest Se
Symbol: --, not determined]

Ba
ug/L
as Fe

Date	Time	Discharge, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH field (standard units)	Air temperature (°C)	Water temperature (°C)	Oxygen, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Phosphorus total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Ir b rea to (µ as
Upper Truckee River watershed													
Site No. 6 - Upper Truckee River at South Lake Tahoe													
07-03-96	1110	130	35	--	23.5	13.5	--	0.008	0.001	0.11	0.028	0.006	318
07-19-96	1320	57	51	7.8	20.0	16.0	8.4	.003	<.001	.07	.038	.006	228
08-16-96	1030	24	77	--	23.0	17.0	--	.003	<.001	.05	.019	.004	53
09-06-96	1115	11	96	7.8	14.0	12.0	9.4	.008	<.001	.13	.028	.003	352
09-23-96	1147	11	96	--	--	13.5	--	--	--	--	--	--	-
10-01-96	1030	10	100	7.7	14.0	11.5	8.8	.011	.004	.15	.023	.003	215
11-05-96	1240	12	90	--	5.0	3.0	--	.009	.001	.33	.017	.006	372
11-18-96	1530	627	27	--	7.5	4.5	--	.020	.005	.27	.105	.015	1,630
11-19-96	1335	200	25	--	2.5	4.5	--	.018	.002	.28	.067	.006	1,030
12-05-96	1315	770	39	--	1.5	1.0	--	.011	.010	.08	.144	.032	919

Date	Time	Disch(cfs)	EC	pH	Air temp C	Water Temp C	DO	NO2+NO3	Diss. Ammonia	TKN	Tot P	Ortho P	Bac
12-09-96	1430	70	57	--	3.0	3.0	--	.017	.002	.19	.020	.007	227
12-12-96	1400	700	43	--	4.5	2.5	--	.010	.013	.20	.074	.016	737
12-13-96	1300	200	40	--	6.5	3.5	--	.006	.008	.17	.047	.009	767
12-31-96	1545	200	40	--	7.0	1.5	--	.012	.003	.34	.078	.010	231
Site No. 17 - Upper Truckee River at Hwy 50 abv Meyers													
07-03-96	1310	118	34	--	24.0	13.0	--	.008	.001	.12	.021	.006	186
07-19-96	1400	45	47	7.6	23.0	14.0	8.3	.007	<.001	.14	.037	.007	198
07-31-96	0915	29	43	--	19.0	13.0	--	--	--	--	--	--	-
08-16-96	1230	19	71	--	24.0	15.0	--	.010	<.001	.06	.019	.007	45
09-06-96	1300	9.7	87	7.8	22.5	12.5	9.4	.002	<.001	.07	.033	.016	182
09-23-96	1030	8.5	91	--	14.5	9.5	--	--	--	--	--	--	-
10-02-96	1630	7.1	101	--	16.0	12.5	--	.010	.003	.51	.016	.004	430
11-05-96	1350	8.8	82	--	5.0	3.5	--	.012	.001	.16	.014	.005	206
11-18-96	1610	445	22	--	6.0	4.5	--	.016	.001	.15	.031	.005	484
11-19-96	1605	277	21	--	3.0	4.0	--	.012	<.001	.09	.016	.003	859
12-12-96	1515	290	41	--	2.0	2.0	--	.007	.005	.07	.032	.008	1,180
Site No. 43 - Upper Truckee River at S. Upper Truckee Rd													
07-03-96	1440	73	23	--	23.0	12.0	--	0.004	0.002	0.04	0.022	0.009	175
07-19-96	1520	30	31	7.6	22.5	12.0	8.6	.006	.003	.06	.043	.014	167
07-31-96	1200	13	37	--	24.0	13.0	--	--	--	--	--	--	-
08-16-96	1305	12	41	--	26.0	13.0	--	.015	.007	.08	.030	.018	139
09-06-96	1410	3.7	49	7.8	23.0	10.0	9.5	.021	<.001	.06	.056	.034	180
09-23-96	0930	3.1	51	--	10.0	6.0	--	--	--	--	--	--	-
10-02-96	1710	3.0	52	--	14.0	9.5	--	.036	.013	.42	.032	.026	438
11-05-96	1430	2.7	49	--	4.5	1.5	--	.002	.001	.17	.021	.021	187
11-18-96	1700	102	18	--	3.5	2.0	--	.012	.002	.22	.032	.007	170

								NO2+NO3		TKN	Total P	Ortho P	Bact
11-19-96	1705	67	24	--	4.0	3.0	--	.008	<.001	.09	.026	.008	221
12-05-96	1550	103	18	--	.5	1.0	--	.003	<.001	.23	.021	.007	246
12-12-96	1600	109	17	--	1.0	1.0	--	.003	.002	.28	.016	.006	135
Trout Creek watershed													
Site No. 49 - Trout Creek at South Lake Tahoe													
07-02-96	1040	87	33	--	20.5	10.0	--	.006	.002	.17	.038	.009	657
07-19-96	1235	66	35	7.3	18.0	10.0	--	.007	.001	.25	.062	.009	689
08-16-96	0950	34	44	--	19.0	12.0	--	.010	<.001	.12	.030	.009	397
09-06-96	1030	25	46	7.6	13.0	7.0	9.8	.003	<.001	.26	.030	.012	137
09-26-96	1010	23	50	--	14.0	7.0	--	--	--	--	--	--	-
10-02-96	1840	20	50	--	14.0	10.5	--	.004	.002	.24	.023	.009	273
11-05-96	1200	22	52	--	5.0	3.0	--	.007	.002	.22	.019	.009	283
11-18-96	1410	70	41	--	8.0	4.5	--	.017	.003	.37	.133	.018	2,650
12-05-96	1120	150	40	--	3.0	0.5	--	.014	<.001	.24	.241	.020	1,680
12-09-96	1340	40	50	--	2.5	2.0	--	.006	.002	.17	.027	.012	600
12-12-96	1210	40	46	--	4.5	2.5	--	.011	.002	.31	.109	.016	357
12-31-96	1415	100	48	--	6.5	2.0	--	.010	<.001	.28	.067	.011	440
Site No. 57 - Trout Creek at Pioneer Trail													
07-02-96	1205	41	34	--	23.0	10.5	--	0.004	0.002	0.10	0.032	0.009	362
07-19-96	1555	20	40	6.6	21.5	13.0	8.3	.004	.001	.15	.040	.009	442
07-29-96	0935	24	54	--	19.0	11.0	--	--	--	--	--	--	-
08-16-96	1500	18	49	--	23.0	14.5	--	.005	<.001	.12	.028	.010	146
09-06-96	1615	14	51	7.7	20.0	11.5	8.7	.005	.001	.40	.026	.011	202
09-26-96	1547	11	54	--	14.5	10.5	--	--	--	--	--	--	-
10-02-96	1420	11	55	--	20.0	10.0	--	.004	.003	.31	.020	.007	313

								NO2+NO3		TKN	Total P	Otho P	
11-05-96	1510	12	53	--	3.0	2.0	--	.004	.001	.19	.016	.006	197
11-18-96	1640	36	43	--	5.5	4.0	--	.015	.002	.25	.074	.014	1,020
12-05-96	1520	72	38	--	1.0	1.0	--	.010	.001	.18	.087	.016	758
12-12-96	1530	79	41	--	2.0	2.5	--	.009	.001	.32	.071	.018	629
Site No. 68 - Trout Creek at USFS Rd 12N01													
07-02-96	1300	22	31	--	25.0	10.0	--	.003	.001	.16	.025	.009	130
07-19-96	1440	14	37	7.1	18.5	10.0	8.7	.004	.001	.06	.039	.009	144
07-29-96	1300	12	46	--	23.0	11.0	--	--	--	--	--	--	-
08-16-96	1430	10	47	--	23.0	10.5	--	.003	.001	.07	.021	.009	65
09-06-96	1530	8.4	49	7.7	18.5	7.5	9.3	.006	<.001	.35	.027	.011	125
09-26-96	1014	6.1	53	--	9.5	5.0	--	--	--	--	--	--	-
10-02-96	1455	5.5	52	--	16.5	7.0	--	.004	.003	.25	.018	.009	137
11-04-96	1145	7.2	50	--	4.5	2.0	--	.002	.002	.13	.016	.009	127
11-21-96	1455	10	46	--	6.5	4.5	--	.003	<.001	.27	.018	.009	79
12-13-96	1040	8.0	46	--	3.0	2.5	--	.003	.001	.07	.022	.010	194

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USGS

WRIR 00-4001

Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds

Table 7. Water-quality data for ground-water monitoring sites in Upper Truckee River and Trout Creek watersheds, California, July-December 1996

[Abbreviations: ft[3]/s, cubic feet per second; mg/L, milligrams per liter; µs/cm, microsiemens per centimeter at 25 degrees Celsius; ° C, degrees Celsius]

Site no. (pl. 1)	Date	Time	Specific conductance (µS/cm)	pH field (standard units)	Air temperature (°C)	Water temperature (°C)	Nitrogen NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia+ organic dissolved (mg/L as N)	Phosphorus dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Iron, bio-reactive dissolved (µg/L as Fe)
Upper Truckee River watershed												
71	07-15-96	1145	154	6.5	22.5	9.5	0.059	0.523	1.2	0.074	0.041	8,800
71	11-21-96	1255	155	5.5	10.0	8.0	.073	.429	1.7	.047	.032	1,800
72	07-15-96	1420	106	8.2	24.5	10.0	.454	.001	.10	.051	.019	4.3
72	11-22-96	1325	105	7.5	5.5	10.0	.393	.003	<.01	.031	.018	16
77	07-16-96	0755	131	7.8	14.0	8.5	.531	.018	.05	.059	.033	9.0
77	12-13-96	0750	160	7.9	3.5	8.0	.999	.002	.04	.034	.025	9.0
80	07-16-96	0955	110	9.0	18.5	10.5	.010	.009	.10	.101	.067	25
80	12-13-96	0830	110	8.9	4.0	10.0	.012	.008	.05	.056	.056	18
97	07-16-96	0940	161	8.6	20.0	14.5	.095	.001	.07	.051	.016	9.5
97	12-13-96	0900	156	8.6	4.0	14.0	.135	.010	.22	.038	.015	31
Trout Creek watershed												
135	07-15-96	1320	305	6.4	25.0	12.0	2.02	.006	.12	.055	.010	24
135	11-21-96	1130	173	6.4	12.0	8.5	3.24	.001	.03	.018	.012	13
137	07-18-96	1350	94	6.4	22.5	10.0	.002	.409	.36	.069	.026	9.2
137	11-26-96	1255	94	6.6	4.0	8.5	.002	.375	.04	.034	.023	68

143	11-26-96	1400	542	6.3	5.0	11.0	1.89	.002	.13	.039	.029	1,800
Adjacent to study area												
164	07-15-96	0950	101	6.5	19.5	9.0	.449	.001	.01	.055	.014	8.5
164	11-22-96	1240	98	7.0	5.0	8.0	.430	.001	.01	.020	.014	29

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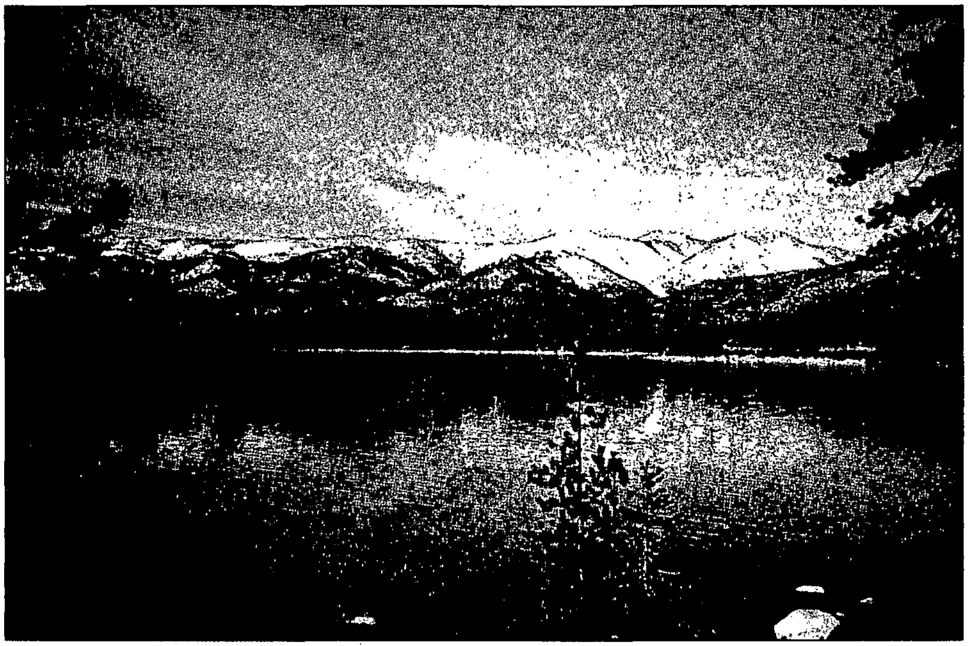
Stream and Ground-Water Monitoring Program, Lake Tahoe Basin, Nevada and California

USGS science for a changing world

TAHOE REGIONAL PLANNING AGENCY

U.S. Department of the Interior—U.S. Geological Survey

Lake Tahoe has long been admired for its alpine setting and the clarity of its water. During the last half-century, however, human activity in the lake basin has increased while the lake has been losing water clarity at a rate of about 1 foot (ft) per year. The Tahoe Regional Planning Agency (TRPA), the U.S. Geological Survey (USGS), and the Tahoe Research Group of the University of California, Davis (TRG) are monitoring loads of sediment and important nutrients flowing into the lake from the streams and ground-water aquifers in the basin. This fact sheet provides an overview of that monitoring program and summarizes some of the results regarding loads of sediment and nutrients to the lake.



Lake Tahoe, March 1995; northward view of Incline Village area, from near Sand Harbor, Nevada. Photograph by Timothy G. Rowe, U.S. Geological Survey.

Basin Geography

The basin is surrounded by mountain peaks of the Sierra Nevada to the west and the Carson Range to the east (fig. 1). The lake is renowned for its deep, clear water which, on sunny days, appears to be cobalt-blue. The Lake Tahoe Basin was formed by downward block faulting during the uplift of the Sierra Nevada 2-3 million years ago, which resulted in dramatic topographic relief. Mountain peaks, snow capped nearly year-round, rise to altitudes above 10,000 ft above sea level. Lake Tahoe, 1,646 ft deep, is the second deepest lake in the United States and tenth deepest in the world. It has an average lake-surface altitude of about 6,225 ft.

The Lake Tahoe Basin is 506 square miles (mi^2). The surface area of the Lake is 192 mi^2, and the watershed area is 314 mi^2. Most of the land in the basin is mountainous, limiting development mainly to relatively flat-lying areas along tributary streams, such as the southern part of the basin within the Upper Truckee River and Trout Creek Basins. About 78 percent of the basin is at altitudes from about 6,500 ft to greater than 10,000 ft. This altitude range, combined with other factors such as prevailing storm systems from the Pacific Ocean, causes an unequal distribution of precipitation throughout the basin. More than 80 inches per year (in/yr) of precipitation, mostly as snow, falls on the western side of the basin, whereas about 30 in/yr falls on the eastern side.

Since 1874, the outflow of Lake Tahoe into the Truckee River has been regulated by a dam at Tahoe City, Calif. The current dam was built by the Bureau of Reclamation in 1913 to provide irrigation water for the Newlands Project in the Fallon, Nev., area. The upper 6 ft of the lake forms the largest storage reservoir in the Truckee River Basin, with an effective capacity of 745,000 acre-feet (acre-ft), about 0.6 percent of the estimated 122 million acre-ft in the lake. The dam is operated by the U.S. District Court Water Master under a complex set of legal agreements and operating rules to maintain levels between a maximum altitude of 6,229.1 ft and the altitude of the natural rim (6,223 ft). During droughts the lake level can fall below the rim, and during wet years the lake level can rise higher than the legal maximum. Since 1987, the lake levels have fluctuated from 6,220.26 ft (about 3 ft below the rim), during a prolonged drought in 1992, to 6,229.39 ft (about 0.2 ft above the legal maximum), during the flood of January 1997.

The Lake Tahoe Basin is divided by the Nevada-California State line, with about one-third of the basin in Nevada and two-thirds in California. The location of the basin, about 150 miles (mi) from the San Francisco Bay area and 90 mi from the Sacramento Valley, makes a wide variety of recreational opportunities available to a population of about 8 million. Major recreational activities within the basin include casino gaming in Nevada, alpine and cross-country skiing, golfing, water sports, hiking, fishing, camping, and bicycling.

History of Environmental Regulation

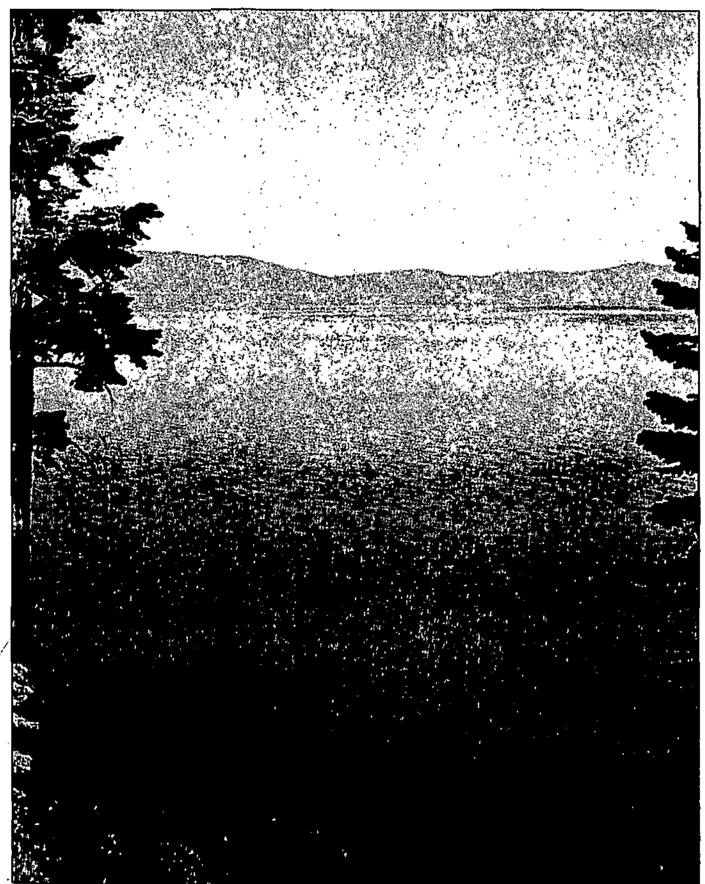
Until its "discovery" in 1844 by General John C. Fremont, the basin was occupied by the Washoe Tribe who had hunted and fished there for centuries. Upon discovery of gold in the South Fork of the American River in 1848, thousands of west-bound gold seekers passed near the basin on their way to the gold fields. "White-man's" civilization first made its mark in the Lake Tahoe Basin with the 1858 discovery of the Comstock Lode, just 15 mi to the east in Virginia City, Nev. From 1858 until about 30 years later, logging in the basin supplied large timbers to shore up the underground workings of the Comstock mines. The logging was so extensive that almost all of the native forest was cut. In 1864, Tahoe City was founded as a resort community for Virginia City, the first recognition of the basin's potential as a destination resort area.

Public appreciation of the Tahoe Basin grew, and during the 1912, 1913, and 1918 congressional sessions, unsuccessful efforts were made to designate the basin as a national park. During the first half of this century, development around the lake consisted of a few vacation homes. The post-World War II population and building boom, followed by construction of gambling casinos in the Nevada part of the basin during the mid-1950's, and completion of the interstate highway links for the 1960 Squaw Valley Olympics, resulted in a dramatic increase in development within the basin. From 1960 to 1980, the permanent resident population increased from about 10,000 to greater than 50,000, and the summer population grew from about 10,000 to about 90,000.

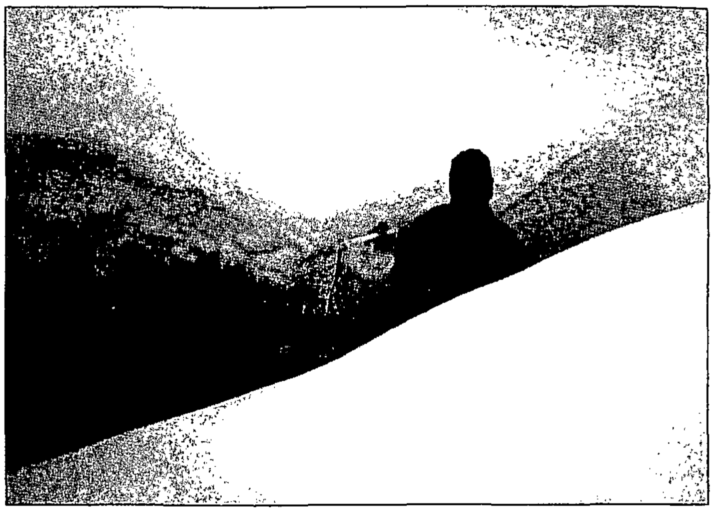
Increased development included urbanization of wetland areas that had formerly served as zones for retention of sediments and nutrients (nitrogen, phosphorus, and iron); development on steep mountain sides with consequent sediment erosion; discharge of septic and sewage systems within the basin; and increased airborne nutrients from automobile emissions and wood-burning stoves.

By the 1950's, evidence was mounting that the clarity of the lake was decreasing. Concerns about the effects of sewage effluent and septic-system leakage on stream and lake quality led to formation of the Lake Tahoe Area Council (LTAC) which, in a historic decision, acted to develop a basin-wide sewage-collection system by which the effluent would be exported from the basin, primarily to other areas in Douglas County, Nev., and in Alpine County, Calif. During this time, researchers of TRG documented increases in algal growth and decreases in lake clarity. It was suspected that development was increasing transport of nutrients to the lake, thus stimulating growth of algae.

In 1969, at the joint request of the States of California and Nevada, TRPA was chartered by Federal law under an Interstate Compact. TRPA was formed as a bi-state agency to better manage and regulate land use and development to protect the lake and the natural resources of the basin. The first two decades of TRPA's management focused on development and application of land-use regulations. In the early 1990's, the agency shifted focus from regulation to science-based environmental management and decision making.



Lake Tahoe, September 1996; eastward view from Rubicon Point, California. Photograph by Timothy G. Rowe, U.S. Geological Survey.



Sampling water quality at Incline Creek, January 1993. Photograph by Rita Whitney, U.S. Geological Survey.

LTIMP Cooperative Monitoring Program

In 1978, the Lake Tahoe Interagency Monitoring Program (LTIMP) was formed. This group included collaborative monitoring and research efforts among TRPA, USGS, TRG, U.S. Forest Service, California State Water Resources Control Board (CSWRCB), Lahontan Regional Water Quality Control Board, California Department of Water Resources (DWR), California Department of Transportation, California Air Resources Board, California Department of Fish and Game, Nevada Department of Environmental Protection, and U.S. Environmental Protection Agency (EPA). The combined resources of LTIMP have contributed significantly to the body of literature and hydrological and limnological data available for the Lake Tahoe Basin.

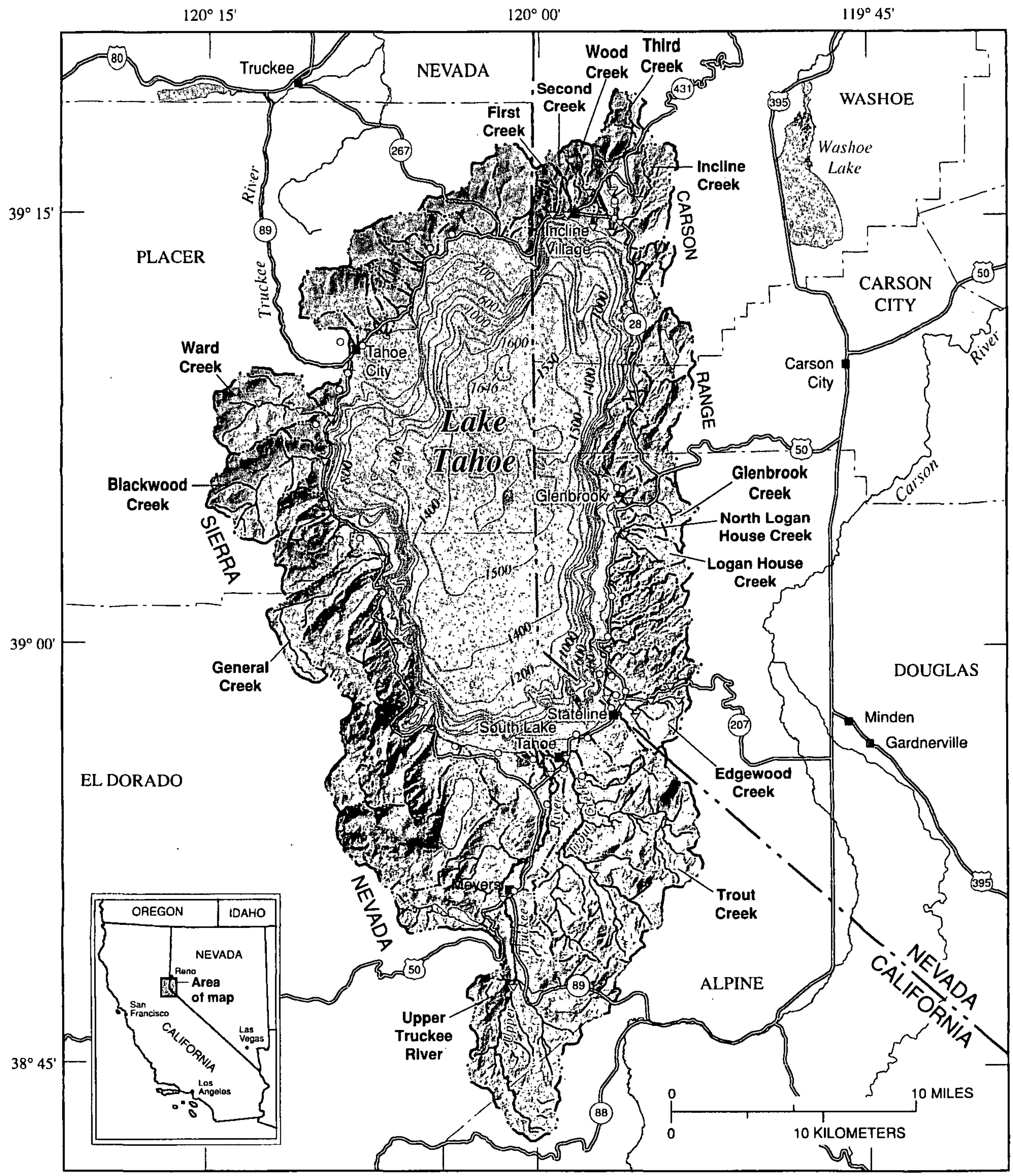
Although early concerns focused on suspended-sediment and nutrient transport to the lake by streams, potential nutrient contribution by ground water became recognized in the late 1980's. Suspected sources included abandoned septic systems, golf courses, organic-rich stream deposits, and contaminated surface-water infiltration into ground water.

In 1982, TRPA adopted Resolution No. 82-11, which includes environmental thresholds for the Lake Tahoe Basin. Among those thresholds is "Water Quality 4," which establishes standards for total nitrogen, soluble inorganic nitrogen, total phosphorus, soluble phosphorus, total iron, and suspended sediment in tributary streams.

TRPA also adopted "Water Quality 6," a threshold that establishes standards for total nitrogen, total phosphorus, total iron, turbidity, and grease and oil in surface discharge to ground water.

These thresholds provide the basis for the current program for stream and ground-water monitoring operated cooperatively by TRPA, USGS, and TRG. Since 1988, funding for this program has been shared equally by TRPA and USGS, with additional support and services provided by TRG.

The California part of Lake Tahoe is designated by EPA as an Outstanding Natural Resource Water, which provides that no further degradation of Lake Tahoe can be allowed. All reasonable, cost-effective, best-management practices for nonpoint source control are required. Under



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000, 1969-85. Universal Transverse Mercator projection, Zone 11

Bathymetric contours from Rush, 1973. Compiled from soundings made by the U.S. Coast and Geodetic Survey (1923)

EXPLANATION

- **Selected hydrologic basin used in this study**
- **Boundary of Lake Tahoe Basin**
- **Boundary of subbasin**
- *1200* **Bathymetric contour, in feet below highest legal lake-surface altitude (6,229.1 feet above U.S. Bureau of Reclamation datum of 1929)**
- ▽ **Surface-water site**
- ○ **Ground-water site**

Figure 1. Geographic setting, hydrologic basins, bathymetry, and surface-water and ground-water monitoring sites in the Lake Tahoe Basin.

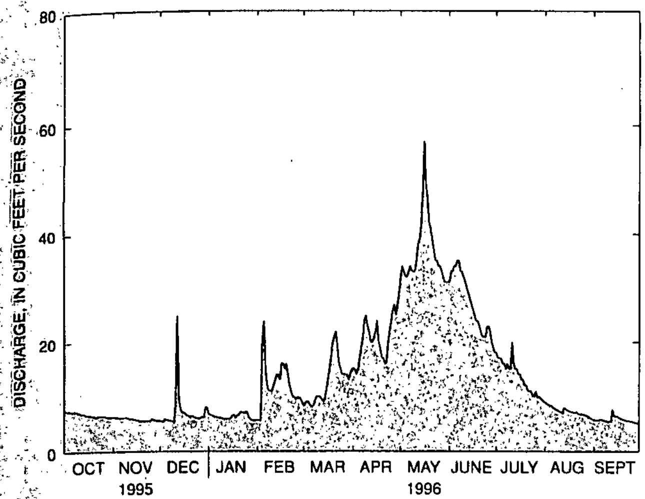


Figure 2. Daily mean discharge for Incline Creek during 1996 water year, representative of streams in the Lake Tahoe Basin.

Nevada Pollution Control Regulations, the Nevada part of Lake Tahoe has a designated beneficial use as a water of extraordinary ecological and/or aesthetic value, which is also a nondegradation standard (Adelle Basham, Nevada Department of Environmental Protection, oral commun., 1997). Although no specific monitoring program has been implemented within the basin to meet all the requirements of these policies, regulatory agencies rely upon LTIMP data in implementation of their programs.

Stream Monitoring Network

In 1979, the LTIMP stream-sampling network began as a cooperative effort of the CSWRCB, DWR, USGS, and TRG. The objectives of this network are to acquire and disseminate the water-quality information necessary to support science-based environmental planning and decision making in the basin. Seven major tributary streams were monitored for streamflow and suspended-sediment and nutrient contribution to Lake Tahoe. By 1987, decreases in funding had reduced the network to four streams in California: General, Blackwood, and Ward Creeks, and Upper Truckee River.

In 1987, TRPA and USGS provided funding to expand the program by adding four Nevada tributaries. By 1993, the LTIMP network had expanded to 32 sites in 14 basins (fig. 1). Of the 32 sites, 20 have recording streamflow gages. The 14 basins total 157 mi^2, or about half of the entire basin tributary to Lake Tahoe. The largest basin monitored is the Upper Truckee River Basin (56.5 mi^2, 18 percent of the total drainage to the lake); the smallest is the First Creek Basin (1.08 mi^2).

Routine and storm-based monitoring is done to provide data for comparisons between spring runoff, storm-generated runoff, and base-flow, and for estimating suspended-sediment and nutrient transport. Comparisons can be made among the 14 monitored basins. Monitoring stations at the mouths of the basins measure loads to the lake and provide a basis for comparisons of the effects of the differing geology, soils, and land uses on those loads. Eight of the basins also have internal sampling stations to allow for comparisons of the effects of upstream and down-stream land uses.

The greatest transport of sediment and some associated nutrients occurs during high flows caused by storms and snowmelt. To quantify transport during such events, individual samples must be collected as the stream-flows rise, peak, and recede. A timely and steady field presence in the basin during storms is required to accomplish this. During runoff monitoring, USGS field crews frequently collect hydrologic data late into the night and on weekends and holidays to meet the program objectives.

Tributary monitoring includes field measurement of streamflows, temperature, pH, dissolved oxygen, and specific conductance; and laboratory measurement of major nutrients (dissolved nitrate and nitrite, dissolved ammonia, total ammonia and organic nitrogen, dissolved orthophosphorus, total phosphorus, and total iron) and suspended sediment. These measurements are necessary to determine whether the environmental thresholds for the basin are being exceeded and to provide long-term data that can be used to determine suspended-sediment and nutrient loads to the lake.

Depth-integrating and equal-width-increment sampling techniques are used for suspended-sediment and nutrient sampling. Suspended-sediment analyses are made by the USGS California sediment laboratory in Salinas, Calif. Nutrient analyses are done at TRG laboratories in Tahoe City and Davis, Calif. The streamflow gages are operated by USGS personnel from the Carson City, Nev., and Carnelian Bay, Calif., field offices. LTIMP data are entered in national USGS data bases and published every year in USGS California and Nevada Water Data Reports.

Ground-Water Monitoring Network

In 1990, USGS and TRPA established a ground-water monitoring network with 32 sampling sites (fig. 1) to provide a long-term data base on ground water. Previous ground-water studies found concentrations of nitrogen, phosphorus, and iron to be greater in ground water than in the lake. These studies indicated the need to better describe ground-water quality and rates of ground-water flow into the lake.

Field measurements of water from wells include temperature, pH, dissolved oxygen, specific conductance, and water level. Laboratory measurements of dissolved nutrients, including iron, are made. Ground-water samples are obtained by pumping long enough to remove stagnant well water before sampling.

Monitoring Results

The monitoring provides scientific data on stream discharge and quality and ground-water levels, quality, and flow paths. Selected results are described below.

The hydrograph of daily mean discharge for Incline Creek (fig. 2) for 1996 shows a seasonal pattern that is typical of streams in the Lake Tahoe Basin. Most runoff is during the April through June snowmelt period. Sharp peaks represent fall rains, rain-on-snow storms, and summer thunder

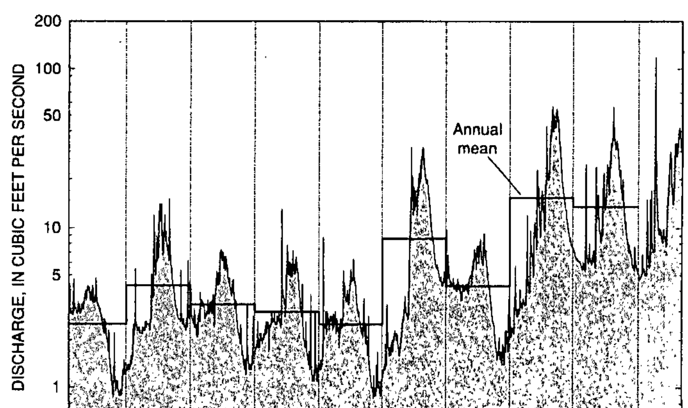
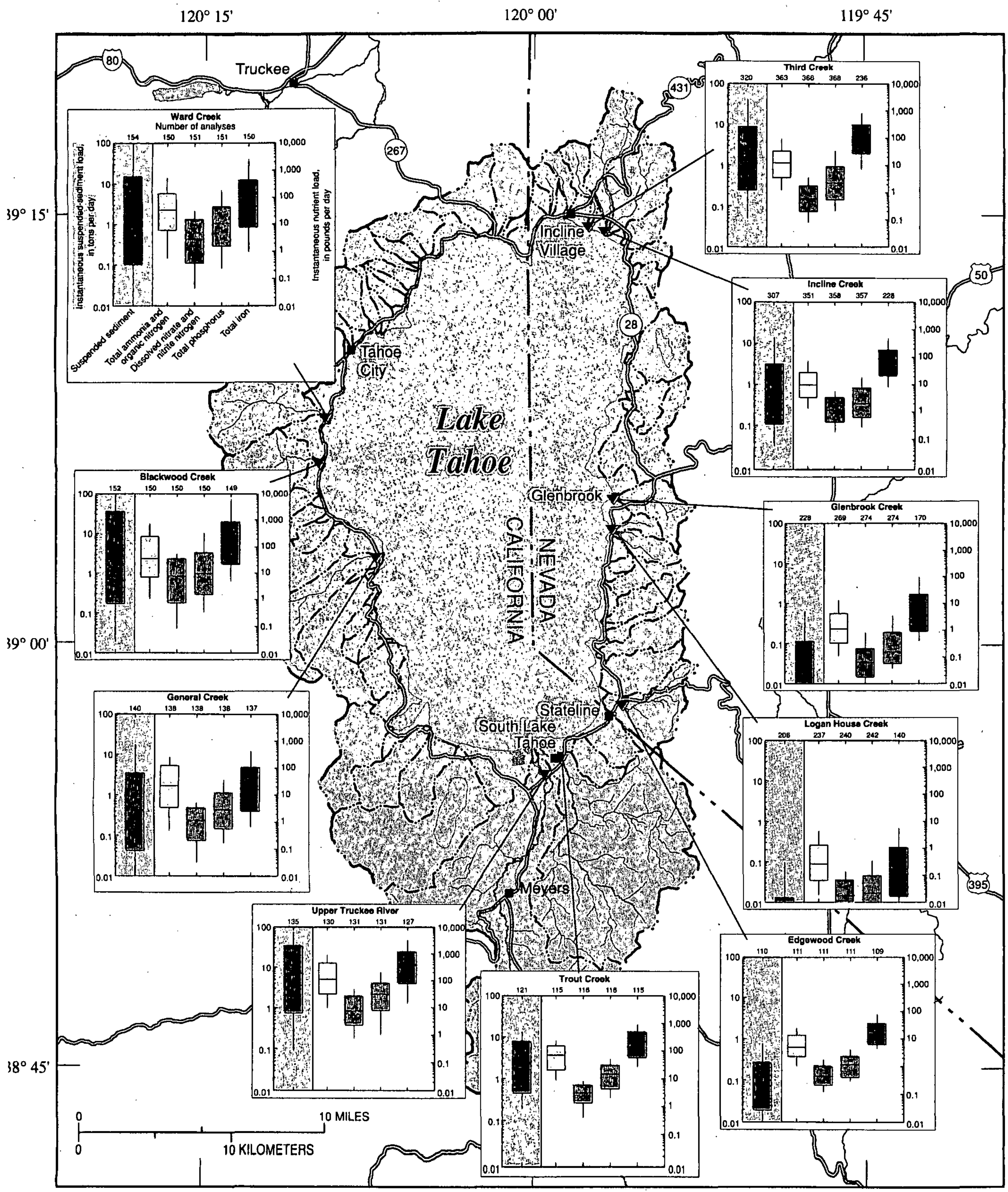


Figure 3. Mean daily discharge for Incline Creek, 1988-97 water years, representing years of drought and above-normal runoff.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000, 1969-85
Universal Transverse Mercator projection, Zone 11

EXPLANATION

Boundary of Lake Tahoe Basin

Boundary of hydrologic basin—Selected streams shown for study basins

90th Percentile
75th Percentile
Median
25th Percentile
10th Percentile

Figure 4. Instantaneous suspended-sediment and nutrient loads depicted by box plots for selected surface-water monitoring sites in the Lake Tahoe Basin.

Measuring streamflow at Third Creek, May 1993.
Photograph by Timothy G. Rowe, U.S. Geological Survey.

The longer term hydrograph (fig. 3) for Incline Creek for the 9-year period of record clearly shows the effects of drought (water years 1988-92 and 1994) as compared to years in which runoff was above normal (1993, 1995, and 1996). The mean daily discharge for the 9 years is 6.38 ft^3/s. The highest mean daily discharge (15.4 ft^3/s) was in 1995 and the lowest (2.51 ft^3/s) in 1992. The average annual runoff for the period of record is 5,160 acre-ft. Among the 14 basins monitored, the Upper Truckee River has the highest average runoff (101,500 acre-ft) and Logan House Creek (330 acre-ft) the lowest. Instantaneous suspended-sediment and nutrient concentrations are highest during summer thunderstorms and rain-on-snow storms, but overall loads are greater during spring runoff.

Calculations for measured loads of suspended sediment and nutrients are shown for 10 tributary watersheds in figure 4. As many as 368 analyses for a given variable are included. For each basin, "boxplots" are shown summarizing sampled loads for five selected constituents. For each constituent, the box shows the range in load for 25-75 percent of the samples. The median value (half the samples were less than this value and half were more) is indicated by the horizontal line through the box. The vertical lines above and below the box extend from the 10th percentile (only 10 percent of the samples were lower) to the 90th percentile (only 10 percent had higher values). For example, of the 307 suspended-sediment samples from the Incline Creek site, half (154) had loads between 0.11 ton per day (ton/d), the 25th percentile, and 3.1 ton/d, the 75th percentile. The range from 0.032 to 14 ton/d represented 80 percent of all samples (10th to 90th percentile). The median value was 0.61 ton/d.

The Upper Truckee River had the largest load of suspended sediment and all nutrients. This is because the Upper Truckee River Basin is the largest basin and contributes the most flow. The Logan House Creek Basin contributes the smallest sediment and nutrient loads. Watersheds on the western side of the basin (California) of the lake have higher loads of sediment and nutrients than the sites on the eastern side (Nevada) due to smaller drainage areas and less precipitation on the eastern side.

Summary and Conclusions

Lake Tahoe has long been admired for the clarity of its water and majestic mountain setting. Human activity in the basin has accelerated the decline in clarity and quality of this pristine lake. Resource-management agencies, such as TRPA, need long-term water-quality data to assess the effectiveness of both current and new projects and regulations. Since 1987, the LTIMP has been monitoring the water quality of surface-water and ground-water flow tributary to Lake Tahoe. Additional data are necessary to provide the basis for reliable quantification of nutrient loads to the lake from ground water. Additional scientific data and interpretation are essential for water managers to prioritize their efforts for the most effective protection of Lake Tahoe.

—Carol J. Boughton, Timothy G. Rowe, Kip K. Allander, and Armando R. Robledo

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TRPA seeks nearly $1M for pollution study at lake

Aquatic life: Research looks at combustion byproduct.

By Jeff DeLong
RENO GAZETTE-JOURNAL

Determining the threat posed to Lake Tahoe's aquatic animals from a combustion byproduct that reacts with sunlight is a million-dollar question.

That's nearly how much money the Tahoe Regional Planning Agency and scientists are seeking to study polycyclic aromatic hydrocarbons, or PAHs — the biggest unknown when it comes to assessing dangers posed by gasoline pollution at Tahoe and other bodies of water.

TRPA is seeking $975,000 to study the problem over the next few years, most of it from the $1.9 billion water bond approved by California voters last March. Studies funded by the money would help address the many questions concerning PAHs, which are believed to be dangerously toxic to aquatic animals at concentrations as incredibly low as parts per trillion.

"This is the time and the place to do it," said Glenn Miller, a researcher from University of Nevada, Reno who spent much of last summer studying the issue. With all the attention focused on motorized watercraft and resulting pollution at Tahoe, Miller said expanded studies into PAHs at the landmark Sierra lake could produce nationwide benefit.

PAHs consist of more than 100 different organic compounds that are created from incomplete combustion, including emissions from watercraft. Some PAHs react with sunlight to harm aquatic animals with what amounts to a dangerous case of sunburn.

TRPA's 1999 ban on dirty two-stroke engines used by older models of Jet Skis and many outboard motorboats has dramatically reduced the amount of many gasoline pollutants found in Lake Tahoe, including toluene and the fuel additive MTBE, a suspected carcinogen.

See **LAKE** on **6C**

See Next Page

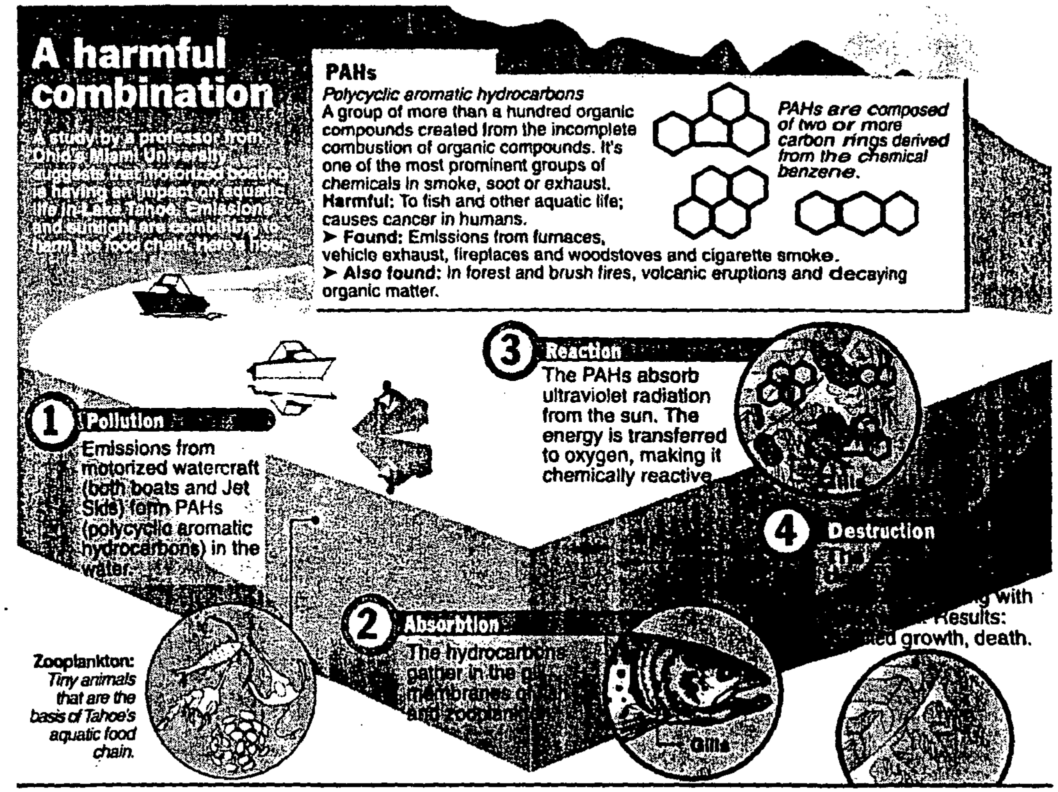
Lake/Water's clarity may make it more vulnerable to pollutants

From 1C

But Miller and others suspect that cleaner engines won't decrease the amount of PAHs discharged into the lake. Early studies into the matter conducted at Lake Tahoe in 1997 by James Oris of Miami (Ohio) University found that some PAHs combined with sunlight to kill zooplankton and stunt fish growth.

And the problem could be particularly acute at Lake Tahoe, where the high altitude and remarkably clear water combine to allow sunlight to penetrate for far greater depths than most bodies of water.

"We don't know what the ecological impacts are. We do know the chemicals are there and they can be extremely toxic," Miller said.



Source: James T. Oris, Miami University of Ohio

Reno Gazette-Journal

It's believed PAHs can be toxic in concentrations ranging from 5 to 20 parts per trillion, what TRPA water quality specialist Jon Paul Kiel called "extremely small concentrations." Sampling at Lake Tahoe this summer found some areas in mid-lake with no PAH contamination. At the Tahoe Keys in mid-August, PAH concentrations of 12 parts per trillion were found.

"It may not take that much discharge for this to be a problem," Kiel said.

Miller is confident most of the PAHs found in Lake Tahoe are associated with motorized watercraft but there are other potential sources, ranging from chimney smoke to controlled burning and wildfires. Expanded studies would help address that issue.

"We need to continue to study this stuff," said Juan Palma, TRPA's new executive director. "This topic is extremely critical."

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Agricultural Research Service

TEKTRAN

EVIDENCE FOR ATMOSPHERIC TRANSPORT AND DEPOSITION OF POLYCHLORINATED BIPHENYLS TO THE LAKE TAHOE BASIN, CALIFORNIA-NEVADA

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Interpretive Summary:

Polychlorinated biphenyls are industrial fluids used for many years in the US and other industrialized countries. These compounds are extremely persistent in the environment and have been shown to accumulate in wildlife such as fish and birds. This project provides evidence to suggest that polychlorinated biphenyl are entering the Lake Tahoe basin through atmospheric processes. Concentrations of PCBs were measured in the water and fish of Lake Tahoe and Marlette Lake, a small lake in the Lake Tahoe basin. Concentrations in both lakes were similar suggesting that there are no major local sources to Lake Tahoe. Since the only source of water to Lake Marlette is from rain and snow, it is likely that the atmosphere is the only major source to this area

Keywords:

atmosphere volatilization rain run off watershed chesapeake bay agrochemicals pesticides sustainable production vegetable air water partitioning organic matter soil transport modeling deposition quality transformation sorption micro meterology analytical photolysis hydrolysis oxidation henrys law constant

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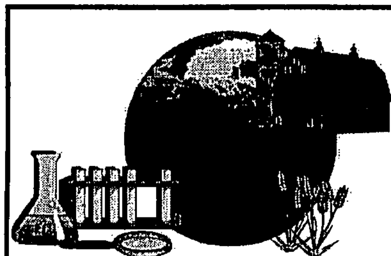

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EDUCATION

- Ph.D. Agricultural and Environmental Chemistry, University of California, Davis. June 1997. Dissertation: Studies on atmospheric transport and deposition of polychlorinated biphenyls and pesticides in Sierra Nevada Aquatic Ecosystems. Advisor: Prof. J.N.Seiber.
- MSc. Food Science, Major Analytical Chemistry, University of British Columbia, Vancouver, B.C., November 1990. Thesis: Application of simplex optimization experimental design for blending wine using profiles of wine aroma from headspace gas chromatography.
- BSc. Food Science, Major Food Chemistry, University of British Columbia, Vancouver, B.C., April 1986.

AWARDS AND ACTIVITIES

- Non-resident Tuition Fellowships, 1993 to 1996.
- Agricultural and Environmental Chemistry Graduate Group Fellowship for 1995-1996.
- Jastro-Shields Scholarship, June 1995.
- Ecotoxicology Research Support Award, 1995.
- Vice-chair of the Graduate Students Association. 1991-1992.
- University of British Columbia Education Abroad Award for study at UC Davis, 1989.
- Undergraduate Research Paper Award for the Western North America Region. IFT 1986.
- Member of SETAC and ACS (American Chemical Society).

PUBLICATIONS AND CONFERENCES

Datta, S, McConnell, LL, Baker, JE, LeNoir, J, Seiber, JN. (1998) Evidence for atmospheric transport and deposition of polychlorinated biphenyls in the Lake Tahoe basin, California-Nevada. Environ Sci Technol. 32:1378-85.

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HEAVENLY SKI RESORT

1997

ENVIRONMENTAL MONITORING REPORT

Excerpt from longer Report

Prepared By

Sherry Hazelhurst & Birgit Widegren
USDA Forest Service, Lake Tahoe Basin Management Unit

HEAVENLY SKI RESORT

1997 ENVIRONMENTAL MONITORING REPORT

Prepared by:
Sherry Hazelhurst & Birgit Widegren

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CHAPTER 1

INTRODUCTION

Heavenly's Environmental Monitoring Program was initiated in 1995 to assess the state of water, vegetation, and soil resources at the ski area. The program is intended to monitor changing conditions as a result of management activities. Details are outlined in Chapter 7, Section 6, of Heavenly Ski Resort Master Plan. This is the third annual report which summarizes monitoring accomplished at Heavenly Ski Resort by the USDA Forest Service during 1997.

Four major emphases are identified in the monitoring program as critical to understanding environmental conditions at the ski area. Water quality monitoring began at Heavenly in 1981, with data illustrating cumulative effects of management on streams. Effective soil cover measurements are used to estimate erosion prevention as well as energy and nutrient cycling capabilities. Best management practices (BMPs) are intended to inhibit soil movement and stream sedimentation, thus evaluating permanent and temporary measures indicates those practices that are most effective. Finally, riparian areas tend to be more sensitive to management than uplands, so condition ratings are indicative of overall watershed stability.

Each emphasis area is discussed individually by chapter. Chapter 2 is an annual review of water quality constituents measured at three creeks within the resort. Chapter 3 discusses results of various soil cover monitoring efforts. Chapter 4 summarizes BMPs evaluations as implemented during restoration, maintenance, new construction, and at existing structures. Chapter 5 reports riparian and channel condition at Daggett and Edgewood Creeks, as well as changes from last year at Heavenly Valley Creek. Chapter 6 summarizes all monitoring by noting the general environmental conditions at the resort. All chapters describe survey locations, measured parameters, results and discussion of data collected to this point, general conditions and trends, and management recommendations.

Water Quality Monitoring

Water samples were collected at seven monitoring stations throughout the year from three creeks that drain the resort. Runoff sampling began March 18 and continued weekly through June 10 at Edgewood Creek and through July 9 at Heavenly Valley Creek. Routine samples were analyzed at the Forest Service laboratory for specific conductivity, turbidity, suspended sediment, total nitrate/nitrite, total phosphorus, and dissolved orthophosphorus. Samples were also sent to Sierra Environmental Laboratories and Lahontan Regional Water Quality Control Board's (Lahontan) laboratory for total Kjeldahl nitrogen and chloride analysis. Three samples from each parking lot station were also analyzed during runoff and storm events for oil and grease, total iron, and total lead. Quarterly reports were prepared and submitted to Heavenly, Lahontan, U.S. Army Corps of Engineers, Tahoe Regional Planning Agency, and Nevada Division of Environmental Protection staffs in June, July, and October.

Effective Soil Cover Monitoring

Soil protective cover was quantified on runs, roads, and undeveloped areas. Fifteen ski runs, with 110 segments identified in the original CWE, were randomly selected and reevaluated. Additionally, fixed plots were established on 20 ski runs and 5 undeveloped sites for long-term monitoring. Nineteen abandoned road segments were evaluated for cover and management recommendations.

Best Management Practices Effectiveness Monitoring

Temporary and permanent best management practices (BMPs) were monitored at many sites throughout the resort. New construction, associated with Tamarack lift, snowmaking, and electric lines, was inspected weekly for adequate temporary BMPs. Some permanent BMPs were installed at these sites and will be monitored next year. Permanent BMPs that were not installed due to time and weather constraints are scheduled for implementation next year. All other construction, restoration, and maintenance sites requiring soil disturbance were monitored for appropriate BMPs thru project completion. Some of these projects included adding BMPs to 35 road segments and obliterating 22 others. Existing BMPs were evaluated at 20 structures, including eight lifts, two lodges, five maintenance/patrol facilities, one parking lot, one snowmaking building, and three miscellaneous sites.

Riparian Condition Monitoring

Riparian and stream channel evaluations were completed for three creeks. All reaches of Daggett and Edgewood Creek, within the ski resort boundary, were rated for general condition using the Pfankuch method. The two permanent stream channel inventory (SCI) reaches installed in 1996 were measured again this year to detect changes in channel cross-sectional area.

Condition and Trend

This chapter summarizes results from all monitoring, formal and informal, to illustrate the general environmental condition of the resort. Conclusions stated here only represent observations from 1997. A comprehensive report to be compiled in 2000, will quantify condition and trend as compared with baseline data collected in 1991.

CHAPTER 2

WATER QUALITY

Water quality is measured at three creeks that drain the ski resort. Samples from Heavenly Valley, Heavenly Parking, and Edgewood Creeks were collected throughout 1997 to monitor specified constituent levels. Heavenly Valley and California Parking Lot Creeks are regulated through a waste discharge permit from the California Water Quality Control Board, Lahontan Region. Edgewood Creek is administered by the Nevada Department of Environmental Protection. Five of the seven stations on these creeks are classified as general forest sites, monitored for discharge, specific conductivity, turbidity, suspended sediment, total nitrite/nitrate, total Kjeldahl nitrogen, total nitrogen, soluble reactive phosphorus, total phosphorus, and chloride. The other two stations are located below parking lots, thus in addition to the constituents listed above, oil and grease, total iron, and total lead are also measured periodically.

One reference stream outside the resort is also monitored and used as a comparison for Heavenly Valley Creek. Hidden Valley Creek drains an undeveloped watershed south of the resort. This watershed is similar in size, geology, and soil type to Heavenly Valley Creek, thus data collected here provides good baseline information. Samples are collected at Hidden Valley Creek from the runoff period in March through snowfall in November. The samples are analyzed for the same constituents as the other forested sites on Heavenly Valley Creek.

Among all stations, 160 samples were obtained during 1997. Collection took place once monthly during baseflow and weekly during spring runoff. Precipitation during the past year was above average, with a greater than average proportion falling as rain. Spring runoff proceeded normally with both warm and cool periods melting the snow slowly. Most of the snow throughout the resort had completely melted by the end of July. Summer rain and thundershowers were more common this year producing storms of varying intensity, yet not exceeding one-inch during any single event.

Water samples were analyzed in the field, at the Forest Service water lab, and at Sierra Laboratories in Reno. Sampling and analysis procedures are explained in Chapter 7 of the Heavenly Ski Resort Master Plan. Constituent values measured during 1997 are reported for each sample and station, with monthly and annual averages also computed. California and Nevada state standards apply to individual constituents and are evaluated based on annual mean, single event, or 90th percentile rating, as specified. Creeks are discussed individually, followed by tables displaying full data sets for the respective stations.

Heavenly Valley and Hidden Valley Creeks

Data collected from Heavenly Valley and Hidden Valley Creek stations are reported together to show a comparison between developed and undeveloped watersheds. The largest stream draining the California side, Heavenly Valley Creek originates from springs at the high elevations to flow through the resort, undeveloped forest, and housing tracts before merging witl Trout Creek. Four stations have been established on the creek, including HV-C1A Sky Meadow (elev. 8.560 ft.), HV-C1 Undisturbed Tributary (8,240 ft.), HV-C2 Below Patsy's (8,020 ft.), anc HV-C3 Property Line (6,620 ft.). A map of these locations may be found in Chapter 4, map 4.1-4, of the Heavenly Ski Resort Master Plan Environmental Impact Statement. The watershed covers approximately 1,639 acres to the Property Line station, and main channel is about 3.0 miles long to this point.

Hidden Valley Creek originates from springs below Freel Peak (T. 12 N, R. 18 E, S. 24), approximately 3.5 miles south of the Heavenly Valley Creek watershed. There is one monitoring station established on the creek, 43-H5 Baseline Station (6,680 ft.). This station is about 0.15 miles from the confluence with Trout Creek. The watershed drainage area to this station is approximately 1,162 acres and the channel length is 2.8 miles. This watershed is about 1/3 smaller than Heavenly Valley Creek, but both channels maintain similar flows when measured at the Baseline Station of Hidden and Property Line of Heavenly.

Individual constituents measured at each station are compared relative to one another and state standards. Results for 1997 are summarized for each constituent. Most of the figures throughout this section show the monthly average for individual constituents to improve graphic depiction. Complete data sets for the measured parameters are listed by station in Tables 2-1 thru 2-5.

Discharge

The Undisturbed Tributary site consistently records the lowest flows, as the watershed drainage area is very small (165 acres). Highest flows were recorded at the Property Line site and at Hidden Valley Creek. Flow among all stations ranged from lows of less than 0.01 to 0.42 cfs and highs of 0.7 to 12.86 cfs. Peak flows occurred in May and June, similar to last year's peak flow dates. The table below shows the date and flow rate at the peak for each station.

Station	Date	Peak Flow (cfs)
Heavenly Valley Creek		
Sky Meadows (HV-C1A)	6 - 5	5.21
Undisturbed Tributary (HV-C1)	5 - 15	0.70
Below Patsy's (HV-C2)	6 - 5	8.56
Property Line (HV-C3)	6 - 5	12.86
Hidden Valley Creek		
Baseline Station (43-H5)	5 - 19	12.50

Discharge (con't)

Spring runoff sampling continued through the second week of July, when flows had decreased significantly from snow melt. Storm samples were collected during rain-on-snow events in June and during a summer thundershower in July. Data collected from the July thundershower are discussed later in this section. Figure 2-1 shows the hydrograph for flow all stations.

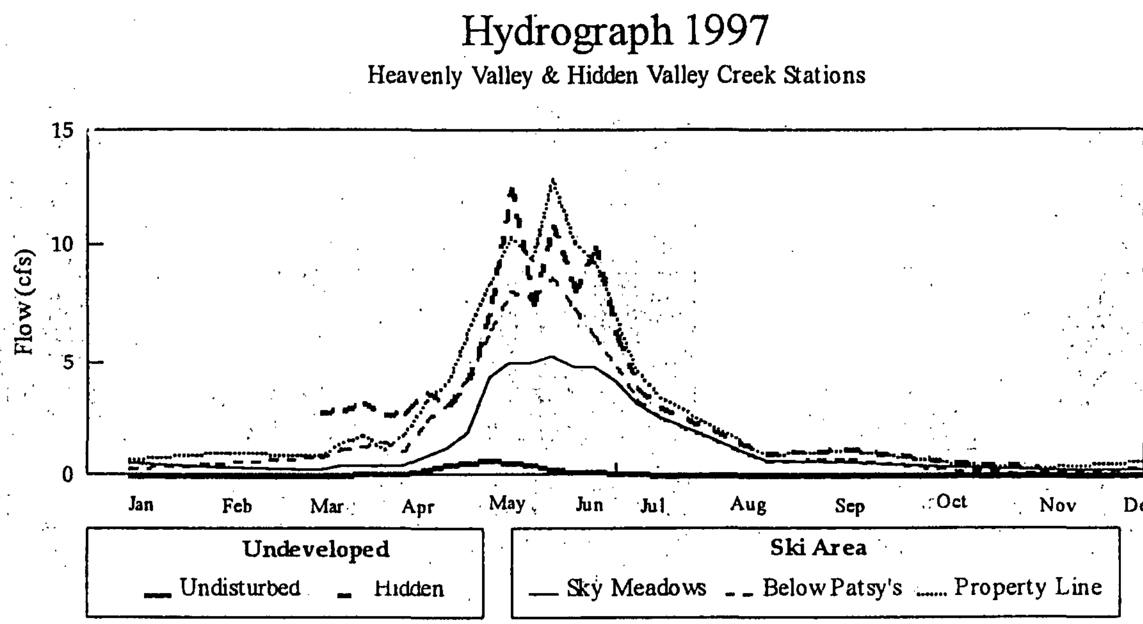

Figure 2-1. Hydrograph for Heavenly Valley and Hidden Valley Creek Stations in 1997. Undeveloped sites include the Undisturbed Tributary to Heavenly Valley Creek and the Baseline station at Hidden Valley Creek.

Specific Conductivity

Conductivity values were somewhat consistent among the Heavenly Valley Creek stations, but had higher fluctuations at the Hidden Valley Creek site. Concentrations ranged between lows of 11 to 27 µmhos and highs of 41 to 61 µmhos. The annual means are within 10 µmhos of one another, with 27 µmhos at Sky Meadows, 34 µmhos at Undisturbed Tributary, 36 µmhos at Hidden, and 37 µmhos at both Below Patsy's and Property Line. Lowest values were often found during the highest or lowest flows.

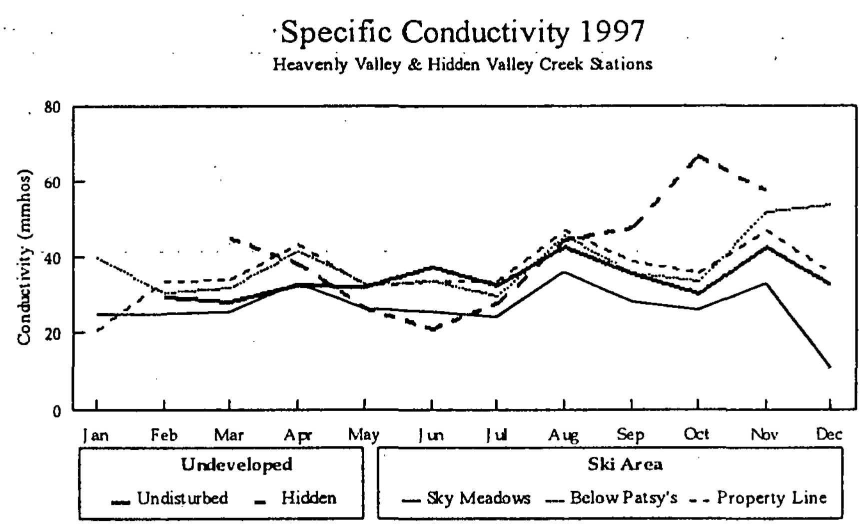

Figure 2-2. Specific conductivity values at Heavenly Valley and Hidden Valley Creeks Stations during 1997.

Turbidity

Turbidity values were generally highest during runoff, with maximum measures between 0.98 and 2.80 ntu's. Annual average turbidity levels range between 0.49 and 1.03 ntu's, with the former recorded at Undisturbed Tributary and the later at the Property Line. Figure 2-3 shows turbidity fluctuations over the year at the individual stations, and actual measures are listed in Tables 2-1 thru 2-5. Turbidity levels, as illustrated in the figure, appear greater at the ski area stations than the undisturbed ones. This result shows that more particles are moving through channels within and below the ski area, and that further erosion control measures may be needed to stabilize soils and prevent sedimentation.

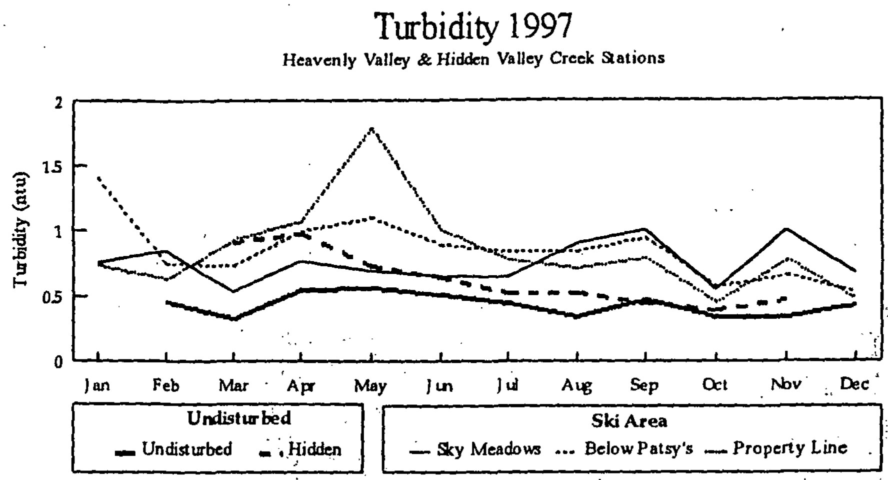

Figure 2-3. Average monthly turbidity levels at Heavenly Valley and Hidden Valley Creek stations.

Suspended Sediment

Similar to turbidity, suspended sediment levels were also greatest during peak flow. The State standard of 60 mg/L is applied to the 90th percentile of samples measured. Consequently, the Property Line station exceeded the standard, with 3 of 24 samples in excess of 60 mg/L (see Table 2-4). Samples from all other stations met this standard. The average annual means among the stations range from 2.3 to 31.4 mg/L. As shown in Figure 2-4 and Tables 2-1 thru 2-5, suspended sediment was almost always greater at the ski area sites versus the undeveloped stations. This result indicates that more sediment is moving through the channels affected by ski area development, particularly during high flows. The sediment source may be from developed areas or the channels themselves, and further analysis may show proportional contributions.

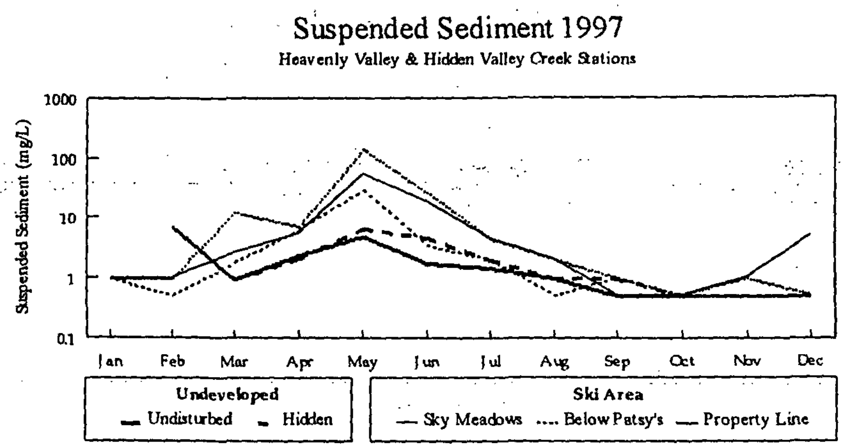

Figure 2-4. Average monthly suspended sediment values for Heavenly Valley and Hidden Valley Creeks during 1997. Suspended sediment values are plotted on a log scale.

Total Nitrogen

Several chemical forms of nitrogen (N) occur in surface waters. Inorganic N is measured as nitrite-N (NO_2^-) and nitrate-N (NO_3^-). All forms of organically bound N and inorganic ammonia (NH_3) are measured by the Kjeldahl method. Together, these forms constitute total N. Average NO_2^-/NO_3^- ranged between 0.005 and 0.040 mg/L at all stations. These inorganic forms were less at the undeveloped stations than at the ski area sites. Additionally, the trend at ski area sites shows the greatest concentration at the Below Patsy's site, with a decrease at Property Line. Total Kjeldahl N concentrations are usually an order of magnitude greater than NO_2^-/NO_3^- at every site throughout the year. The minimum value for TKN was less than 0.10 mg/L at all stations. The value 0.10 mg/L was used for reporting and analysis since it is unknown how far below this method detection limit the actual concentration may have been. The annual average for TKN ranged between 0.10 and 0.18 mg/L. Compliance with the State standard of 0.19 mg/L total N is considered to be achieved if no more than 10% of the samples collected exceed this level. This approach uses the 90th percentile, rather than the artificially high annual average. The Below Patsy's station had 4 of 24 samples exceeding the State standard. All other stations met the standard. TKN values during January were inaccurate, thus total N cannot be reported for this month.

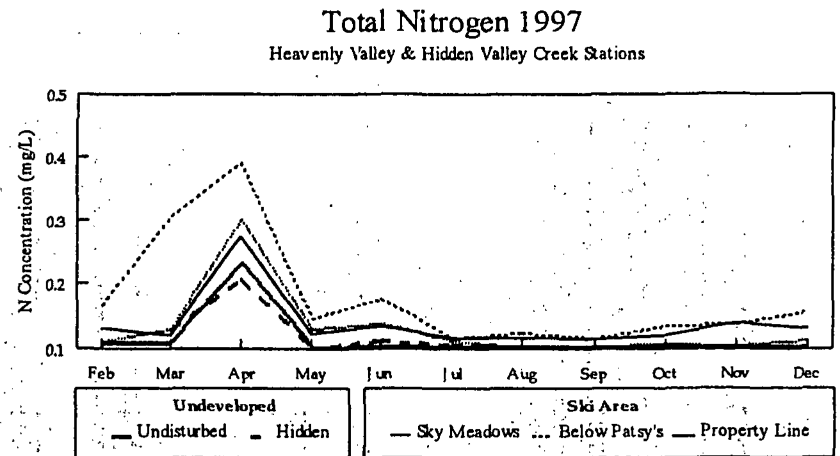

Figure 2-5. Average monthly total N concentrations measured at Heavenly Valley and Hidden Valley Creek stations during 1997.

Total Phosphorus

Annual average total P values measured at creeks throughout Lake Tahoe continually exceed the State standard of 0.015 mg/L. The range of total P averages for Heavenly Valley and Hidden Valley Creeks during 1997 were between 0.019 and 0.026 mg/L. Below Patsy's, Property Line, and Hidden recorded the same annual mean of 0.021 mg/L P. Figure 2-6 shows high concentrations of P just prior to peak flows, and generally low

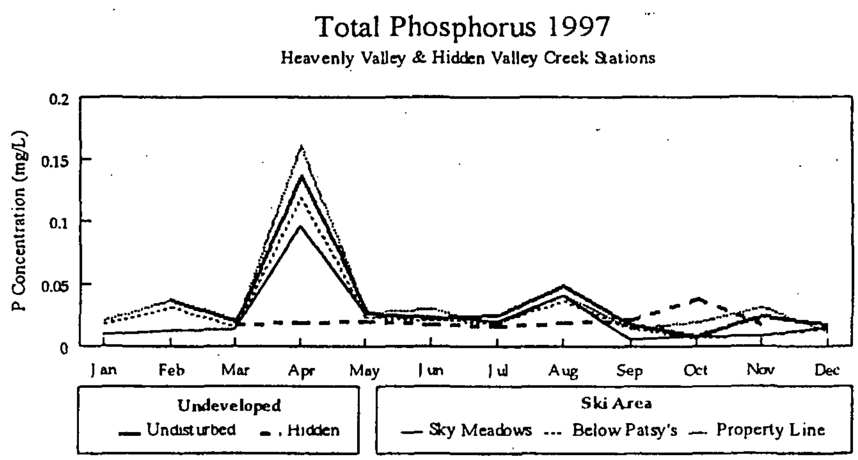

Figure 2-6. Average monthly total P concentrations measured at Heavenly Valley and Hidden Valley Creek stations during 1997.

Total Phosphorus (con't)
fluctuation during the remainder of the year. Tables 2-1 thru 2-5 list the actual total P measurements for the year. One interesting result is that the maximum values reported for all stations show that the ski area highs lie between the values found at the undeveloped areas, 0.03 mg/L at Hidden and 0.05 mg/L at the Undisturbed Tributary.

Soluble Reactive Phosphorus

Soluble reactive phosphorus (SRP) is that fraction of total P found in a dissolved form, usually orthophosphates. These dissolved portions are generally available to plants and can stimulate algae production. For this reason, SRP is of particular concern in the Lake Tahoe Basin. At Heavenly Valley Creek stations, SRP accounts for 19 - 42% of total P, and at Hidden Valley Creek SRP is 33% of total P. The average annual means for all stations are between 0.004 and 0.011 mg/L. Figure 2-7 shows that SRP concentration is generally greater at the undeveloped stations than at the ski area sites. The reason for this result is unknown, however, future analysis may show why this trend occurs.

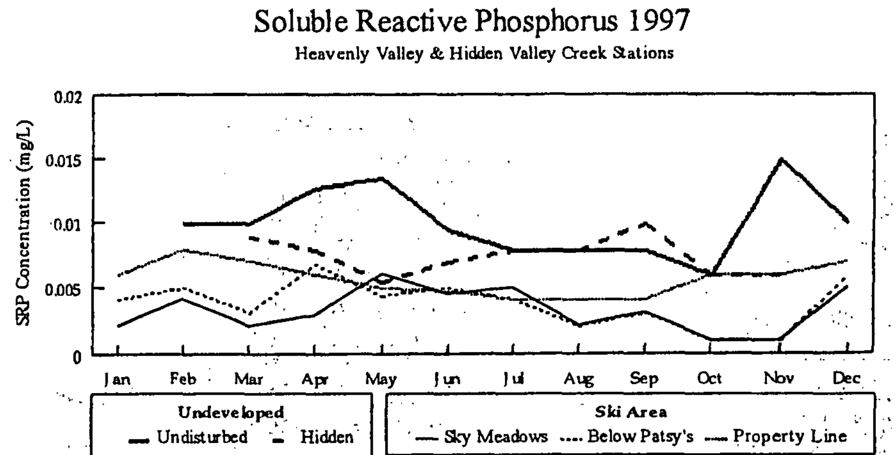

Figure 2-7. Average monthly soluble reactive P measured at Heavenly Valley and Hidden Valley Creek stations during 1997.

Chloride

Chloride concentrations were highest during peak flow at all stations, decreased through the summer, and began to increase again in December. Maximum values recorded were between 1.0 and 1.9 mg/L. The annual average at all stations exceeds the State standard of 0.2 mg/L. Mean chloride concentrations range from 0.4 at the undeveloped sites to 0.6 mg/L at Below Patsy's and Property Line stations. Generally, chloride appears to be lower at the two undeveloped sites, as shown in Figure 2-8. It is unknown why the concentration is greater at

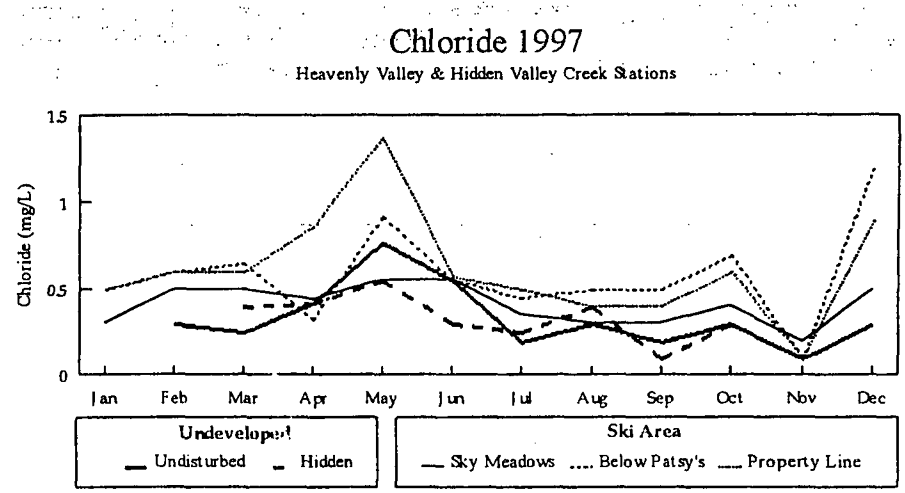

Figure 2-8. Average monthly chloride values for Heavenly Valley and Hidden Valley Creek stations during 1997.

Chloride (con't)
the ski area sites, since chloride is assumed to enter streams through salts in precipitation. Future monitoring and analysis may identify other potential sources of chloride.

Storm Event Data
Storm samples were collected simultaneously at Sky Meadows and Below Patsy's during a July thundershower. The storm lasted for about one-hour, with 0.2 inches of rain measured at the Sky Meadows NRCS SNOTEL site. Water was drawn near the peak and thereafter, at 20-minute intervals. Samples were analyzed for all of the usual constituents, except chloride. There are no standards for single events on this creek, and the short duration of the event did not contribute significantly to the overall sediment and nutrient loads of the stream. Table 2-6 displays the data collected during the storm and Figure 2-9 shows how concentrations varied at both stations.

Table 2-6. Storm data collected on July 28, 1997 at Sky Meadows and Below Patsy's stations on Heavenly Valley Creek.

Time	Discharge (cfs)	Specific Conductivity (umhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total NO_2/NO_3 (mg/L)	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)	SRP (mg/L)
HV - C1A Sky Meadows									
1320	2.57	43	54.0	211	0.036	1.55	1.586	0.070	0.006
1340	2.33	44	25.0	70	0.019	0.82	0.839	0.035	0.010
1400	2.16	46	5.1	19	0.018	0.50	0.518	0.038	0.004
1420	2.06	42	3.8	14	0.015	0.22	0.235	0.015	0.004
1440	2.00	43	2.8	14	0.015	0.28	0.295	0.012	0.004
Means	2.22	44	18.1	66	0.021	0.67	0.695	0.034	0.006
HV - C2 Below Patsy's									
1320	2.60	58	162.0	3548	0.059	4.54	4.599	0.212	0.012
1340	2.32	44	260.0	1686	0.060	1.40	1.460	0.200	0.014
1400	2.07	45	140.0	393	0.042	0.71	0.752	0.112	0.018
1420	2.00	47	52.0	139	0.038	0.44	0.478	0.060	0.006
1440	2.00	47	14.0	48	0.023	0.83	0.853	0.025	0.004
1500	2.00	46	9.7	30	0.018	0.32	0.338	0.022	0.004
Means	2.08	48	106.3	974	0.040	1.37	1.413	0.105	0.010

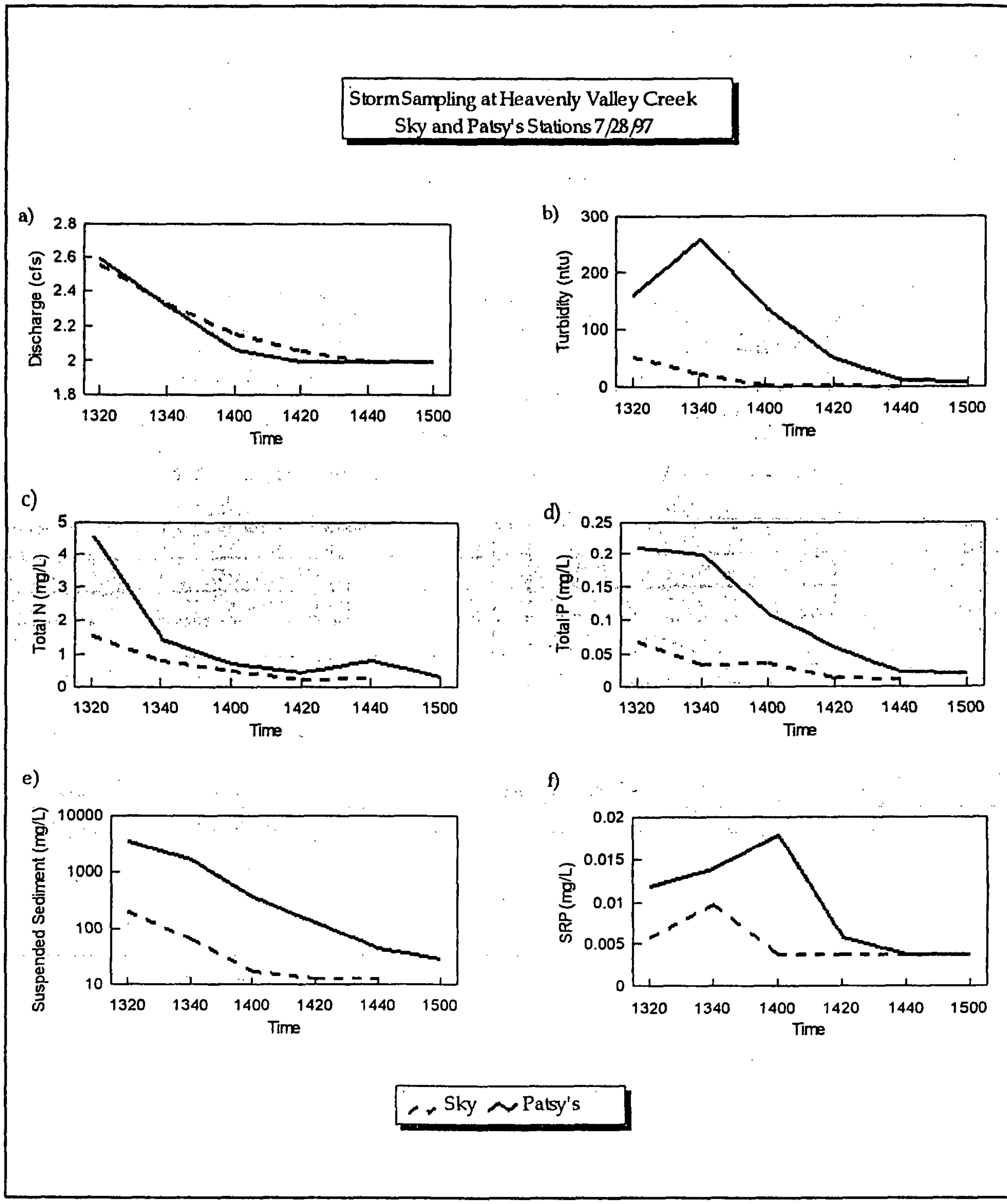

Figure 2-9. Constituents measured during a thunderstorm on July 28, 1997, at Sky Meadows and Below Patsy's stations on Heavenly Valley Creek: a) hydrograph; b) turbidity; c) total Kjeldahl nitrogen; d) total phosphorus; e) suspended sediment; f) soluble reactive phosphorus.

Table 2-1: Heavenly Ski Resort 1997 water quality monitoring data from station HV-C1, the Undisturbed Tributary to Heavenly Valley Creek. This station is located at Maggies Corner, at an elevation of 8,315 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total NO2/NO3 (mg/L)	Total Kjeldahl N2 (mg/L)*	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		---	---	---	**60**	---	---	**0.19**	**0.015**	---	**0.2**
First Quarter											
970215	1415	0.004	30	0.47	7	0.012	0.10	0.112	0.038	0.010	0.3
970318	1220	0.010	31	0.34	1	0.014	0.10	0.114	0.022	0.010	0.2
970327	1130	0.060	26	0.34	1	0.011	0.10	0.111	0.020	0.010	0.3
	Minimum	0.004	26	0.34	1	0.011	0.10	0.111	0.020	0.010	0.2
	Maximum	0.060	31	0.47	7	0.014	0.10	0.114	0.038	0.010	0.3
Second Quarter											
970404	1420	0.130	32	0.67	3	0.008	0.20	0.208	0.032	0.012	0.1
970412	1230	0.138	43	0.40	1	0.006	0.63	0.636	0.022	0.012	0.7
970416	1205	0.162	28	0.40	2	0.007	0.10	0.107	0.028	0.012	0.1
970422	1040	0.360	37	0.54	1	0.006	0.10	0.106	0.025	0.012	0.8
970430	940	0.509	25	0.80	5	0.008	0.10	0.108	0.031	0.016	0.4
970508	1000	0.597	25	0.40	5	0.002	0.10	0.102	0.025	0.016	0.1
970515	941	0.700	25	0.50	7	0.005	0.10	0.105	0.025	0.014	1.3
970522	1126	0.640	41	0.60	3	0.005	0.10	0.105	0.030	0.012	0.8
970527	936	0.510	39	0.78	5	0.005	0.10	0.105	0.028	0.012	0.9
970605	1330	0.340	46	0.40	1	0.005	0.10	0.105	0.022	0.010	0.6
970610	1600	0.240	32	0.38	2	0.004	0.10	0.104	0.022	0.010	1.0
970619	1100	0.178	32	0.98	2	0.005	0.10	0.105	0.025	0.008	0.3
970625	1415	0.120	41	0.35	2	0.006	0.10	0.106	0.028	0.010	0.3
	Minimum	0.120	25	0.35	1	0.002	0.10	0.102	0.022	0.008	0.1
	Maximum	0.700	46	0.98	7	0.008	0.63	0.636	0.032	0.016	1.3
Third Quarter											
970702	1415	0.089	32	0.43	2	0.005	0.10	0.105	0.030	0.010	0.2
970709	1110	0.064	34	0.48	1	0.006	0.10	0.106	0.022	0.006	0.2
970812	1500	0.040	43	0.35	1	0.006	0.10	0.106	0.050	0.008	0.3
970911	1115	0.002	36	0.48	0.5	0.005	0.10	0.105	0.018	0.008	0.2
	Minimum	0.002	32	0.35	0.5	0.005	0.1	0.105	0.018	0.006	0.2
	Maximum	0.089	43	0.48	2	0.006	0.1	0.106	0.050	0.010	0.3
Fourth Quarter											
971016	1020	0.002	31	0.35	0.5	0.007	0.10	0.107	0.010	0.006	0.3
971112	1240	0.004	43	0.35	0.5	0.006	0.10	0.106	0.025	0.015	0.1
971217	1045	0.001	33	0.45	0.5	0.006	0.10	0.106	0.018	0.010	0.3
	Minimum	0.001	31	0.35	0.5	0.006	0.1	0.106	0.010	0.006	0.1
	Maximum	0.004	43	0.45	0.5	0.007	0.1	0.107	0.025	0.015	0.3
Annual Summary	**Minimum**	**0.001**	**25**	**0.34**	**0.5**	**0.002**	**0.10**	**0.102**	**0.010**	**0.006**	**0.1**
	Maximum	**0.700**	**46**	**0.98**	**7.0**	**0.014**	**0.63**	**0.636**	**0.050**	**0.016**	**1.3**
	Average	**0.213**	**34**	**0.49**	**2.3**	**0.007**	**0.13**	**0.134**	**0.026****	**0.011**	**0.4****

* Total Kjeldahl N values reported as 0.10 mg/l are actually less than this minimum detection limit for all quarters, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent.

Table 2-2: Heavenly Ski Resort 1997 water quality monitoring data from station HV-C1A, Heavenly Valley Creek at Sky Meadows. This station is located above the snowmaking pond at an elevation of 8,525 ft.

Date	Time	Discharge	Specific Conductivity	Turbidity	Suspended Sediment	Total NO2/NO3	Total Kjeldahl N2	Total Nitrogen	Total Phosphorus	Soluble Reactive P	Chloride
		(cfs)	(mmhos)	(ntu)	(mg/L)	(mg/L)	(mg/L)*	(mg/L)	(mg/L)	(mg/L)	(mg/L)
CRWQCB Standards		---	---	---	**60**	---	---	**0.19**	**0.015**	---	**0.2**
First Quarter											
970114	1415	0.47	25	0.8	1	0.027	---	---	0.010	0.002	0.3
970215	1215	0.28	25	0.8	1	0.029	0.10	0.129	0.012	0.004	0.5
970318	1200	0.23	26	0.4	3	0.020	0.10	0.120	0.012	0.002	0.5
970327	1110	0.43	25	0.7	2	0.018	0.10	0.118	0.015	0.002	0.5
	Minimum	0.23	25	0.4	1	0.018	0.10	0.118	0.010	0.002	0.3
	Maximum	0.47	26	0.8	3	0.029	0.10	0.129	0.015	0.004	0.5
Second Quarter											
970404	1400	0.39	28	1.00	7	0.022	0.22	0.242	0.028	0.002	0.1
970412	1205	0.38	41	0.70	2	0.019	0.73	0.749	0.015	0.002	0.3
970416	1150	0.43	29	0.60	4	0.022	0.10	0.122	0.015	0.003	0.1
970422	1030	0.80	40	0.75	8	0.025	0.10	0.125	0.018	0.003	1.4
970430	950	1.17	27	0.82	5	0.027	0.10	0.127	0.020	0.004	0.3
970508	944	1.90	25	0.75	9	0.018	0.10	0.118	0.020	0.004	0.1
970515	1000	4.30	20	0.56	24	0.017	0.10	0.117	0.025	0.006	0.7
970522	1107	4.99	29	0.79	87	0.017	0.10	0.117	0.032	0.008	0.5
970527	955	4.99	31	0.65	91	0.029	0.10	0.129	0.030	0.006	0.9
970605	1300	5.21	33	0.55	22	0.033	0.10	0.133	0.025	0.004	0.6
970610	1545	4.80	20	0.54	32	0.039	0.10	0.139	0.022	0.004	0.9
970619	1045	4.76	21	1.00	14	0.033	0.10	0.133	0.025	0.004	0.4
970625	1400	4.07	28	0.54	7	0.023	0.10	0.123	0.025	0.006	0.3
	Minimum	0.38	20	0.54	2	0.017	0.10	0.117	0.015	0.002	0.1
	Maximum	5.21	41	1.00	91	0.039	0.73	0.749	0.032	0.008	1.4
Third Quarter											
970702	1400	3.12	23	0.47	6	0.015	0.10	0.115	0.022	0.006	0.4
970709	1050	2.57	25	0.80	3	0.020	0.10	0.120	0.018	0.004	0.3
970812	1430	0.65	36	0.90	2	0.017	0.10	0.117	0.040	0.002	0.3
970911	1100	0.48	28	1.00	0.5	0.014	0.10	0.114	0.005	0.003	0.3
	Minimum	0.48	23	0.47	0.5	0.014	0.10	0.114	0.005	0.002	0.3
	Maximum	3.12	36	1.00	6	0.020	0.10	0.120	0.040	0.006	0.4
Fourth Quarter											
971016	1040	0.31	26	0.55	0.5	0.019	0.10	0.119	0.008	0.001	0.4
971112	1220	0.25	33	1.00	1	0.038	0.10	0.138	0.008	0.001	0.2
971217	1015	0.20	11	0.68	5	0.019	0.11	0.129	0.014	0.005	0.5
	Minimum	0.20	11	0.55	0.5	0.019	0.10	0.119	0.008	0.001	0.2
	Maximum	0.31	33	1.00	5	0.038	0.11	0.138	0.014	0.005	0.5
Annual Summary	**Minimum**	**0.200**	**11**	**0.42**	**0.5**	**0.014**	**0.10**	**0.114**	**0.005**	**0.001**	**0.1**
	Maximum	**5.210**	**41**	**1.00**	**91.0**	**0.039**	**0.73**	**0.749**	**0.040**	**0.008**	**1.4**
	Average	**1.965**	**27**	**0.72**	**14.0**	**0.023**	**0.13**	**0.156**	**0.019****	**0.004**	**0.5****

* Total Kjeldahl N values reported as 0.10 mg/l are actually less than this minimum detection limit for all quarters, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent

Table 2-3: Heavenly Ski Resort 1997 water quality monitoring data from station HV-C2, Heavenly Valley Creek below Patsy's Chair. This station is located just beyond ski area development within this watershed, at an elevation of 8,000 ft.

Date	Time	Discharge	Specific Conductivity	Turbidity	Suspended Sediment	Total NO2/NO3	Total Kjeldahl N2	Total Nitrogen	Total Phosphorus	Soluble Reactive P	Chloride
		(cfs)	(mmhos)	(ntu)	(mg/L)	(mg/L)	(mg/L)*	(mg/L)	(mg/L)	(mg/L)	(mg/L)
CRWQCB Standards		---	---	---	**60**	---	---	**0.19**	**0.015**	---	**0.2**
First Quarter											
970114	1445	0.36	40	1.40	1.0	0.084	---	---	0.018	0.004	0.5
970215	1445	0.50	31	0.76	0.5	0.065	0.10	0.165	0.031	0.005	0.6
970318	1240	0.84	34	0.48	0.5	0.044	0.10	0.144	0.014	0.004	0.6
970327	1150	1.20	30	1.00	3.0	0.048	0.42	0.468	0.019	0.002	0.7
	Minimum	0.36	30	0.48	0.5	0.044	0.10	0.144	0.014	0.002	0.5
	Maximum	1.20	40	1.40	3.0	0.084	0.42	0.468	0.031	0.005	0.7
Second Quarter											
970404	1445	1.30	33	0.76	0.5	0.049	0.10	0.149	0.022	0.006	0.2
970412	1220	1.47	39	1.30	12.0	0.052	1.30	1.352	0.029	0.006	0.3
970416	1240	1.14	55	1.00	2.0	0.014	0.30	0.314	0.022	0.006	0.3
970422	1050	2.46	46	0.72	6.0	0.041	0.10	0.141	0.025	0.008	0.7
970430	1000	3.24	37	1.20	11.0	0.063	0.10	0.163	0.022	0.008	0.1
970508	1010	4.42	31	1.20	42.0	0.068	0.10	0.168	0.031	0.006	0.1
970515	923	6.47	29	1.00	39.0	0.035	0.10	0.135	0.022	0.004	1.1
970522	1030	7.94	33	1.20	27.0	0.020	0.12	0.140	0.025	0.003	1.4
970527	918	7.64	40	1.00	14.0	0.040	0.10	0.140	0.015	0.004	1.1
970605	1400	8.56	42	0.88	4.0	0.036	0.10	0.136	0.021	0.005	0.6
970610	1615	7.30	30	0.94	3.0	0.036	0.15	0.186	0.018	0.006	0.8
970619	1115	6.19	27	1.20	6.0	0.031	0.22	0.251	0.025	0.003	0.4
970625	1450	4.76	37	0.60	1.0	0.026	0.10	0.126	0.022	0.006	0.4
	Minimum	1.14	27	0.60	0.5	0.014	0.10	0.126	0.015	0.003	0.1
	Maximum	8.56	55	1.30	42.0	0.068	1.30	1.352	0.031	0.008	1.4
Third Quarter											
970702	1430	3.32	28	0.85	1.0	0.014	0.10	0.114	0.022	0.004	0.4
970709	1125	2.56	32	0.85	3.0	0.020	0.10	0.120	0.018	0.004	0.5
970812	1515	0.63	46	0.85	0.5	0.023	0.10	0.123	0.037	0.002	0.5
970911	1130	0.67	36	0.95	1.0	0.017	0.10	0.117	0.014	0.003	0.5
	Minimum	0.63	28	0.85	0.5	0.014	0.1	0.114	0.014	0.002	0.4
	Maximum	3.32	46	0.95	3	0.023	0.1	0.123	0.037	0.004	0.5
Fourth Quarter											
971016	1000	0.23	34	0.57	0.5	0.034	0.10	0.134	0.008	0.001	0.7
971112	1300	0.15	52	0.66	0.5	0.036	0.10	0.136	0.010	0.001	0.1
971217	945	0.32	54	0.54	0.5	0.056	0.10	0.156	0.015	0.006	1.2
	Minimum	0.15	34	0.54	0.5	0.034	0.10	0.134	0.008	0.001	0.1
	Maximum	0.32	54	0.66	0.5	0.056	0.10	0.156	0.015	0.006	1.2
Annual Summary	**Minimum**	**0.15**	**27**	**0.48**	**0.5**	**0.014**	**0.10**	**0.114**	**0.008**	**0.001**	**0.1**
	Maximum	**8.56**	**55**	**1.40**	**42.0**	**0.084**	**1.30**	**1.352**	**0.037**	**0.008**	**1.4**
	Average	**3.07**	**37**	**0.91**	**7.5**	**0.040**	**0.18**	**0.221****	**0.021****	**0.004**	**0.6****

* Total Kjeldahl N values reported as 0.10 mg/l are actually less than this minimum detection limit for all quarters, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent.

Table 2-4: Heavenly Ski Resort 1997 water quality monitoring data from station HV-C3, Heavenly Valley Creek at the Property Line. This station is located just above the Forest Service property line and subdivision development, at an elevation of 6,620 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total NO2/NO3 (mg/L)	Total Kjeldahl N2 (mg/L)*	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		---	---	---	60	---	---	0.19	0.015	---	0.2
First Quarter											
970114	930	0.74	21	0.74	1.0	0.021	---	---	0.021	0.006	0.5
970215	1615	0.96	34	0.64	1.0	0.012	0.10	0.112	0.038	0.008	0.6
970318	1015	0.89	36	0.58	0.5	0.008	0.13	0.138	0.015	0.008	0.7
970327		1.48	33	1.30	23.0	0.019	0.10	0.119	0.025	0.006	0.5
	Minimum	0.74	21	0.58	0.5	0.008	0.10	0.112	0.015	0.006	0.5
	Maximum	1.48	36	1.3	23.0	0.021	0.13	0.138	0.038	0.008	0.7
Second Quarter											
970404	1710	1.80	37	0.68	2	0.016	0.10	0.116	0.040	0.006	0.3
970412	1035	1.17	61	0.75	2	0.005	1.00	1.005	0.025	0.006	0.6
970416	1030	1.83	36	0.95	2	0.022	0.10	0.122	0.022	0.006	0.3
970422	915	3.34	45	1.20	14	0.024	0.10	0.124	0.032	0.006	1.3
970430	830	4.18	39	1.80	15	0.043	0.10	0.143	0.042	0.006	1.8
970508	1130	6.48	34	2.80	432	0.038	0.10	0.138	0.032	0.006	1.9
970515	815	8.39	24	1.50	4	0.026	0.10	0.126	0.035	0.004	1.0
970522	900	10.34	34	1.70	70	0.016	0.10	0.116	0.025	0.006	1.3
970527	800	9.31	38	1.20	67	0.032	0.10	0.132	0.020	0.004	1.3
970605	1030	12.86	39	1.20	47	0.026	0.10	0.126	0.045	0.004	0.8
970610	1430	10.10	32	1.00	38	0.025	0.15	0.175	0.028	0.006	0.7
970619	930	9.23	28	1.20	10	0.026	0.11	0.136	0.025	0.003	0.4
970625	1545	6.93	37	0.67	12	0.012	0.10	0.112	0.025	0.006	0.4
	Minimum	1.17	24	0.67	2	0.005	0.10	0.112	0.020	0.003	0.3
	Maximum	12.86	61	2.80	432	0.043	1.00	1.005	0.045	0.006	1.9
Third Quarter											
970702	1030	4.60	32	0.86	3	0.010	0.10	0.110	0.020	0.004	0.4
970709	930	3.41	36	0.70	6	0.008	0.11	0.118	0.018	0.004	0.6
970812	1630	0.92	47	0.72	2	0.004	0.10	0.104	0.042	0.004	0.4
970911	845	1.11	39	0.80	1	0.005	0.10	0.105	0.015	0.004	0.4
	Minimum	0.92	32	0.70	1	0.004	0.10	0.104	0.015	0.004	0.40
	Maximum	4.60	47	0.86	6	0.010	0.11	0.118	0.042	0.004	0.60
Fourth Quarter											
971016	900	0.47	36	0.46	0.5	0.009	0.10	0.109	0.020	0.006	0.6
971112	1300	0.30	47	0.78	1	0.005	0.10	0.105	0.032	0.006	0.1
971217	1400	0.59	36	0.48	0.5	0.014	0.10	0.114	0.012	0.007	0.9
	Minimum	0.30	36	0.46	0.5	0.005	0.10	0.105	0.012	0.006	0.1
	Maximum	0.59	47	0.78	1	0.014	0.10	0.114	0.032	0.007	0.9
Annual Summary	**Minimum**	**0.30**	**21**	**0.46**	**0.5**	**0.004**	**0.10**	**0.104**	**0.012**	**0.003**	**0.1**
	Maximum	**12.86**	**61**	**2.80**	**432.0**	**0.043**	**1.00**	**1.005**	**0.045**	**0.008**	**1.9**
	Average	**4.23**	**37**	**1.03**	**31.4**	**0.018**	**0.14**	**0.161**	**0.021****	**0.006**	**0.6****

* Total Kjeldahl N values reported as 0.10 mg/l are actually less than this minimum detection limit for all quarters, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent.

Table 2-5: Heavenly Ski Resort 1997 water quality monitoring data from station 43-H5, Hidden Valley Creek baseline station. This station is located just above the confluence with Trout Creek, at an elevation of 6,680 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total NO2/NO3 (mg/L)	Total Kjeldahl N2 (mg/L)*	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		**---**	**---**	**---**	**60**	**---**	**---**	**0.19**	**0.015**	**---**	**0.2**
First Quarter											
970320	1045	2.80	50	0.84	1	0.006	0.15	0.156	0.018	0.010	0.5
970327	1330	2.90	41	1.00	1	0.002	0.10	0.102	0.020	0.008	0.3
Second Quarter											
970403	1240	3.20	39	1.60	0.5	0.006	0.15	0.156	0.018	0.008	0.1
970410	900	2.70	43	0.88	4	0.002	0.56	0.562	0.020	0.008	0.2
970417	930	2.80	40	0.89	1	0.007	0.10	0.107	0.018	0.008	0.1
970422	1030	3.70	37	0.85	1	0.007	0.10	0.107	0.012	0.010	0.8
970430	1320	3.10	35	0.72	4	0.004	0.10	0.104	0.030	0.006	0.9
970506	1030	4.30	31	0.53	1	0.003	0.10	0.103	0.015	0.006	0.2
970513	1230	7.60	20	0.85	5	0.004	0.10	0.104	0.019	0.006	0.8
970519	1600	12.50	25	0.85	14	0.006	0.10	0.106	0.030	0.004	1.0
970529	1430	7.50	31	0.75	6	0.004	0.10	0.104	0.022	0.006	0.2
970603	1530	10.90	18	0.65	12	0.004	0.10	0.104	0.025	0.006	0.1
970611	1130	7.97	20	0.73	5	0.003	0.14	0.143	0.018	0.006	0.6
970616	1445	9.90	25	0.75	1	0.002	0.10	0.102	0.015	0.010	0.3
970623	1125	6.10	23	0.46	1	0.005	0.10	0.105	0.018	0.006	0.2
	Minimum	2.70	18	0.46	0.5	0.002	0.10	0.102	0.012	0.004	0.1
	Maximum	12.50	43	1.60	14	0.007	0.56	0.562	0.030	0.010	1.0
Third Quarter											
970703	1530	3.90	34	0.56	1	0.006	0.10	0.106	0.015	0.006	0.2
970709	1530	3.00	22	0.50	3	0.009	0.10	0.109	0.020	0.010	0.3
970813	1620	1.00	45	0.54	1	0.005	0.10	0.105	0.020	0.008	0.4
970911	1410	1.20	48	0.46	1	0.005	0.10	0.105	0.022	0.010	0.1
	Minimum	1.00	22	0.46	1	0.005	0.10	0.105	0.015	0.006	0.1
	Maximum	3.90	48	0.56	3	0.009	0.10	0.109	0.022	0.010	0.4
Fourth Quarter											
971020		0.59	67	0.40	0.5	0.007	0.10	0.107	0.039	0.006	0.3
971125		0.42	58	0.48	0.5	0.004	0.10	0.104	0.018	0.006	0.1
Annual	**Minimum**	**0.42**	**18**	**0.40**	**0.5**	**0.002**	**0.10**	**0.102**	**0.012**	**0.004**	**0.1**
Summary	**Maximum**	**12.50**	**50**	**1.60**	**14.0**	**0.009**	**0.56**	**0.562**	**0.030**	**0.010**	**1.0**
	Average	**4.67**	**36**	**0.73**	**3.1**	**0.005**	**0.13**	**0.133**	**0.021****	**0.007**	**0.4****

* Total Kjeldahl N values reported as 0.10 mg/l are actually less than this minimum detection limit for all quarters, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent.

Heavenly Ski Resort

1998

includes quarterly report not on disk –

Environmental Monitoring Report

Prepared By

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USDA Forest Service, Lake Tahoe Basin Management Unit

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CHAPTER 1

INTRODUCTION

Heavenly's Environmental Monitoring Program was initiated in 1995 to assess the state of water, vegetation, and soil resources at the ski area. The program is intended to monitor changing conditions as a result of management activities. Details are outlined in Chapter 7, Section 6, of Heavenly Ski Resort Master Plan. This is the fourth annual report, summarizing monitoring accomplished at Heavenly Ski Resort by the USDA Forest Service during 1998.

Four major emphases are identified in the monitoring program as critical to understanding environmental conditions at the ski area. Water quality monitoring began at Heavenly in 1981, with data illustrating cumulative effects of management on streams. Effective soil cover is assessed and monitored to determine relative success of revegetation effort and develop an understanding of soil cover components that adequately prevent soil loss and protect water quality. Best management practices (BMPs) are intended to inhibit soil movement and prevent stream sedimentation, thus evaluating permanent and temporary measures delineates the practices that are most effective. Finally, riparian areas tend to be more sensitive to management than uplands, so condition ratings are indicative of overall watershed stability.

Each emphasis area is discussed individually by chapter and the final chapter summarizes the results of this monitoring. Chapter 2 is an annual review of water quality constituents measured at three creeks within the resort. Chapter 3 discusses results of various soil cover monitoring efforts. Chapter 4 summarizes BMP evaluations as implemented during restoration, maintenance, new construction, and at existing structures. Chapter 5 reports riparian and channel condition at Mott and Corsser Creeks, as well as changes from last year at Heavenly Valley Creek. Chapter 6 summarizes all monitoring by noting the general environmental conditions at the resort. All chapters describe survey locations, measured parameters, results and discussion of data collected to this point, general conditions and trends, and management recommendations.

Water Quality Monitoring

Water samples were collected at seven monitoring stations throughout the year from three creeks that drain the resort. Among all stations, 162 samples were obtained during 1998. Peak flows occurred during the last week of June at some sites and the first week in July at others. Weekly spring runoff sampling continued through the first week of August. Routine samples were analyzed at the Forest Service laboratory for specific conductivity, turbidity, suspended sediment, total nitrate/nitrite, total phosphorus, and dissolved orthophosphorus. Samples were also sent to Sierra Environmental Laboratories for total Kjeldahl nitrogen and chloride analysis.

Effective Soil Cover Monitoring

Soil protective cover was quantified on runs, roads, and undeveloped areas. Eighteen ski runs were randomly selected and reevaluated. Nineteen fixed plots established in 1995 and 1996

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were revisited to determine changes in vegetative cover and erosion. Eight obliterated roads were evaluated to determine if infiltration has been improved and ensure enough protective soil cover.

Best Management Practices Effectiveness Monitoring

Temporary and permanent best management practices (BMPs) were monitored at many sites throughout the resort. Active construction, restoration, and maintenance sites requiring soil disturbance were monitored for appropriate BMPs weekly thru project completion. Existing BMPs were evaluated at many structures, including chairlifts, lodges, maintenance/patrol facilities, parking lots, and miscellaneous sites.

Riparian Condition Monitoring

Riparian and stream channel evaluations were completed for three creeks. Mott Creek, the North Fork of Mott Creek, and Corsser Creek were rated for general condition using the Pfankuch method. The two permanent stream channel inventory (SCI) reaches installed in 1996 were surveyed this year using the full SCI protocol. Permanent cross-sections, random cross-sections, pool-riffle ratios, pebble counts, bed composition surveys, pool depths, and bank stability evaluations were all performed as a part of these surveys.

Condition and Trend

This chapter summarizes results from all monitoring, formal and informal, to illustrate the general environmental condition of the resort. Conclusions stated here only represent observations from 1998. A comprehensive report to be compiled in 2000, will quantify condition and trend as compared with baseline data collected in 1991.

CHAPTER 2

WATER QUALITY

Water quality is measured at three creeks that drain the ski resort. Samples from Heavenly Valley, Heavenly Parking, and Edgewood Creeks were collected throughout 1998 to monitor specified constituent levels. Heavenly Valley and California Parking Lot Creeks are regulated through a waste discharge permit from the California Water Quality Control Board, Lahontan Region. Edgewood Creek is administered by the Nevada Department of Environmental Protection. Five of the seven stations on these creeks are classified as general forest sites, monitored for discharge, specific conductivity, turbidity, suspended sediment, total nitrite/nitrate, total Kjeldahl nitrogen, total nitrogen, soluble reactive phosphorus, total phosphorus, and chloride. The other two stations are located below parking lots, thus in addition to the constituents listed above, oil and grease, total iron, and total lead are also measured periodically.

One reference stream outside the resort is also monitored and used as a comparison for Heavenly Valley Creek. Hidden Valley Creek drains an undeveloped watershed south of the resort. This watershed is similar in size, geology, and soil type to Heavenly Valley Creek, thus data collected here provides good baseline information. Samples are collected at Hidden Valley Creek from the runoff period in March through snowfall in November. The samples are analyzed for the same constituents as the other forested sites on Heavenly Valley Creek.

Among all stations, 162 samples were obtained during 1998. Collection took place once monthly during baseflow and weekly during spring runoff. Precipitation during the past year was above average at 128% of normal. A cooler and wetter than average spring prolonged the runoff period from April through July. Most of the snow at the resort had completely melted by the end of August. Summer rain and thundershowers were generally absent, with low-intensity fall rains beginning early in September.

Water samples were analyzed in the field, at the Forest Service water lab, and at Sierra Laboratories in Reno. Sampling and analysis procedures are explained in Chapter 7 of the Heavenly Ski Resort Master Plan. Constituent values measured during 1998 are reported for each sample and station, with monthly and annual averages also computed. California and Nevada state standards apply to individual constituents and are evaluated based on annual mean, single event, or 90th percentile rating, as specified. Creeks are discussed individually, followed by tables displaying full data sets for the respective stations.

Heavenly Valley and Hidden Valley Creeks

Data collected from Heavenly Valley and Hidden Valley Creek stations are reported together to show a comparison between developed and undeveloped watersheds. The largest stream draining the California side, Heavenly Valley Creek originates from springs at the high elevations to flow through the resort, undeveloped forest, and housing tracts before merging with Trout Creek. Four stations have been established on the creek, including HV-C1A Sky Meadows (elev. 8.560 ft.), HV-C1 Undisturbed Tributary (8,240 ft.), HV-C2 Below Patsy's (8,020 ft.), and HV-C3 Property Line (6,620 ft.). A map of these locations may be found in Chapter 4, map 4.1-4, of the Heavenly Ski Resort Master Plan Environmental Impact Statement. The watershed covers approximately 1,639 acres to the Property Line station, and main channel is about 3.0 miles long to this point.

Hidden Valley Creek originates from springs below Freel Peak (T. 12 N, R. 18 E, S. 24), approximately 3.5 miles south of the Heavenly Valley Creek watershed. There is one monitoring station established on the creek, 43-H5 Baseline Station (6,680 ft.). This station is about 0.15 miles upstream of the confluence with Trout Creek. The watershed drainage area to this station is approximately 1,162 acres and the channel length is 2.8 miles. This watershed is about 1/3 smaller than Heavenly Valley Creek, but both channels maintain similar flows when measured at the Baseline Station of Hidden and Property Line of Heavenly.

Individual constituents measured at each station are compared relative to one another and state standards. Results for 1998 are summarized for each constituent. Most of the figures throughout this section show the monthly average for individual constituents to improve graphic depiction. Complete data sets for the measured parameters are listed by station in Tables 2-1 thru 2-5.

Discharge

The Undisturbed Tributary site consistently records the lowest flows, as the watershed drainage area is very small (165 acres). Highest flows were recorded at the Property Line site and at Hidden Valley Creek. Flow among all stations ranged from lows of less than 0.01 to 1 cfs and highs of 1.28 to 17.30 cfs. Peak flows occurred in June and July, about one month later than last year's peak flows. The table below shows the peak flow and date measured for each station.

Station	Peak Flow (cfs)	Date
Heavenly Valley Creek		
Sky Meadows (HV-C1A)	7.5	7 - 6
Undisturbed Tributary (HV-C1)	1.28	6 - 22
Below Patsy's (HV-C2)	11.1	6 - 29
Property Line (HV-C3)	12.6	7 - 6
Hidden Valley Creek		
Baseline Station (43-H5)	17.30	6 - 29

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Discharge (con't)

Spring runoff sampling continued through the first week of August, when flows had decreased significantly from snow melt. Due to the lack of intense thundershowers, storm samples were not collected. Some of the regular samples were collected during spring and fall precipitaiton events; however the data do not indicate obvious constituent increases over background levels, as discussed later in this chapter. Figure 2-1 shows the hydrograph for flow all stations.

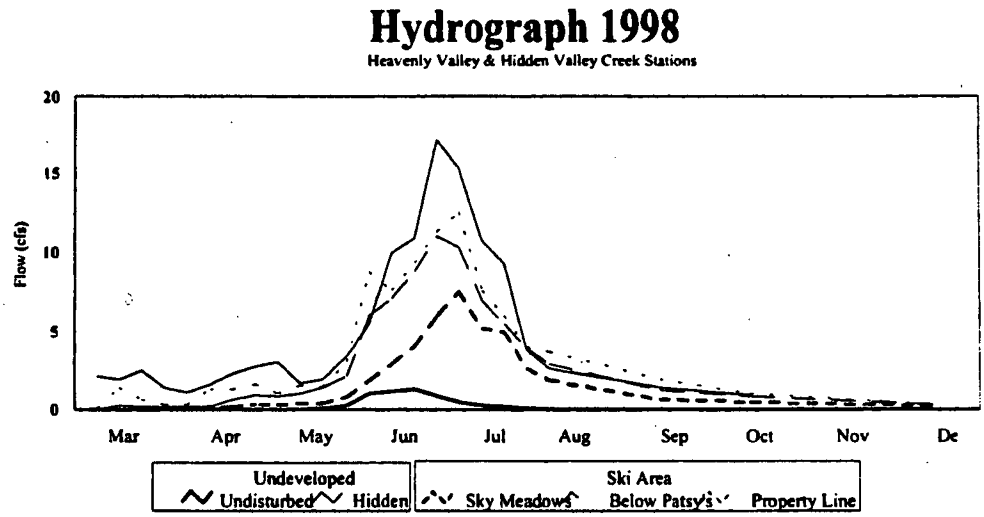

Figure 2-1. Hydrograph for Heavenly Valley and Hidden Valley Creek stations in 1998. Undeveloped sites include the Undisturbed Tributary to Heavenly Valley Creek and the Baseline station at Hidden Valley Creek.

Specific Conductivity

Conductivity values were highest prior to peak flow, and generally declined at all stations thereafter (Figure 2-2). Concentrations ranged between highs of 42 to 73 µmhos and lows of 11 to 24 µmhos. The annual means are within 11 µmhos of one another, with 31 µmhos at Sky Meadows, 32 µmhos at Undisturbed Tributary, 38 µmhos at Hidden, 40 µmhos at Property Line, and 42µmhos Below Patsy's.

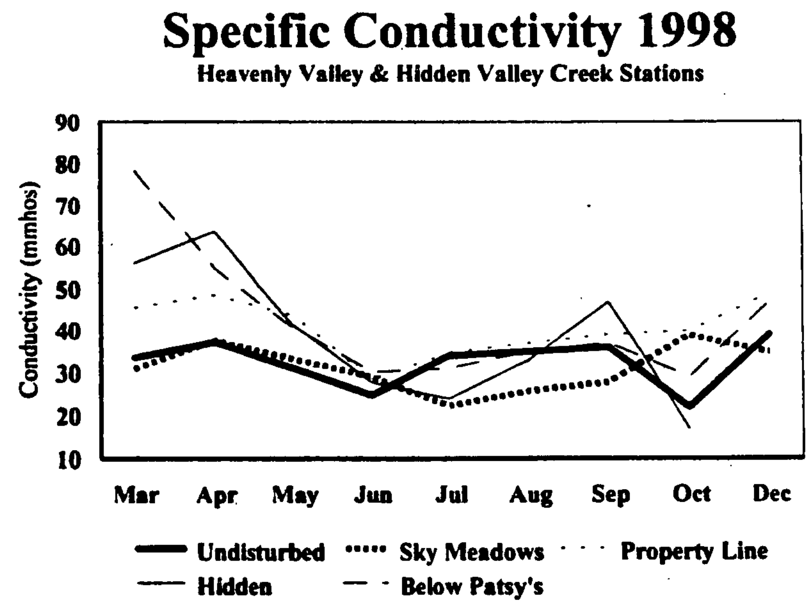

Figure 2-2. Average monthly specific conductivity values at Heavenly Valley and Hidden Valley Creek stations during 1998.

Total Nitrogen

Several chemical forms of nitrogen (N) occur in surface waters. Inorganic N is measured as nitrite-N (NO_2^-) and nitrate-N (NO_3^-). All forms of organically bound N and inorganic ammonia (NH_3) are measured by the Kjeldahl method. Together, these forms constitute total N. Average NO_2^-/NO_3^- ranged between 0.007 and 0.040 mg/L at all stations. These inorganic forms were less at the undeveloped stations than at the ski area sites (Tables 2-1 to 2-5). Additionally, the trend at ski area sites shows the greatest concentration at the Below Patsy's site, with a decrease at Property Line. Total Kjeldahl N concentrations are usually an order of magnitude greater than NO_2^-/NO_3^- at every site throughout the year. The minimum value for TKN was less than 0.10 mg/L at all stations. The value 0.10 mg/L was used for reporting and analysis since it is unknown how far below this method detection limit the actual concentration may have been. The annual average for TKN ranged between 0.13 and 0.36 mg/L. Compliance with the State standard of 0.19 mg/L for total N is considered to be achieved if no more than 10% of the samples collected exceed this level. All stations exceeded this standard with 3 of 24 to 7 of 24 samples greater than 0.19 mg/L, as shown in Tables 2-1 to 2-5. The reason for high N concentration in March and April is unknown. Suspended sediment and turbidity levels were not substantially greater than in other sites, so nutrients were not likely attached to soil particles.

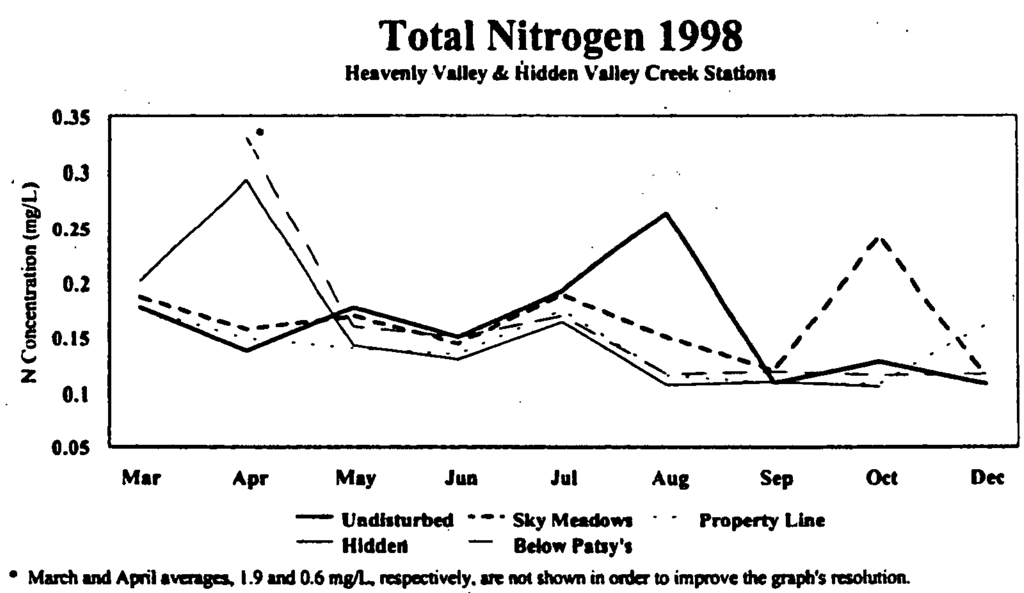

Figure 2-5. Average monthly total N concentrations measured at Heavenly Valley and Hidden Valley Creek stations during 1998.

Total Phosphorus

Annual average total phosphorus(P) values measured at creeks throughout Lake Tahoe continually exceed the State standard of 0.015 mg/L. The range of total P averages for Heavenly Valley and Hidden Valley Creeks during 1998 were between 0.021 and 0.054 mg/L, measured at Sky Meadows and Below Patsy's, respectively. Figure 2-6 shows high concentrations of P just prior to peak flows, and generally low fluctuation during the remainder of the year. The reason

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for very high total P concentrations at the Below Patsy's station in March and April is unkn
These high levels were not found downstream at the Property Line station, indicating signifi
dilution and a possible point-source of P near the Patsy's station.

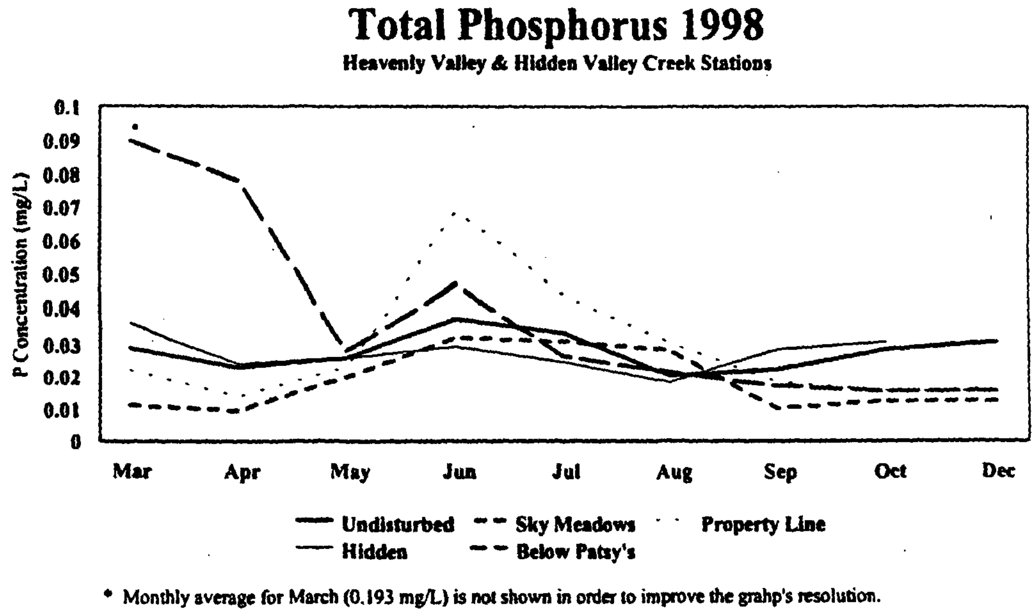

Figure 2-6. Average monthly total P concentrations measured at Heavenly Valley and Hidden Valley Creek stations during 1998.

<u>Soluble Reactive Phosphorus</u>

Soluble reactive phosphorus (SRP) is that fraction of total P found in a dissolved form, usually orthophosphates. These dissolved portions are generally available to plants and can stimulate algae production. For this reason, SRP is of particular concern in the Lake Tahoe Basin. At Heavenly Valley Creek stations, SRP accounts for 18 - 46% of total P, and at Hidden Valley Creek SRP is 30% of total P. The average annual means for all stations are between 0.004 and 0.025 mg/L. Figure 2-7 shows that SRP concentration is generally constant, with only a few large increases. As with total P, SRP values for March and April at Below Patsy's were very high. Again, the reason for this high value is unknown.

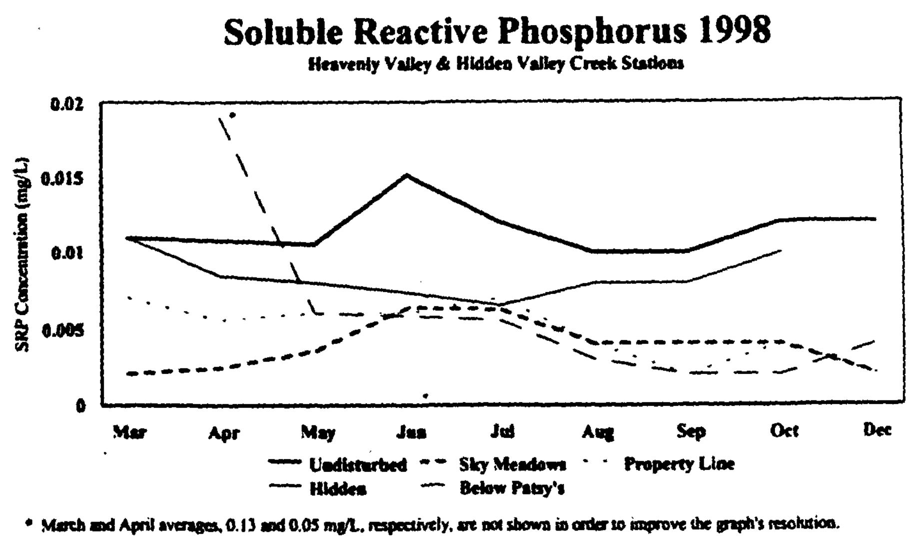

Figure 2-7. Average monthly soluble reactive phosphorus (SRP) measured at Heavenly Valley and Hidden Valley Creek stations during 1998.

Chloride

Chloride concentrations were highest prior to peak flow at all stations, decreasing through summer and increasing again in December. Maximum values recorded were between 1.0 and 3.2 mg/L. The annual average at all stations exceeds the State standard of 0.2 mg/L. Mean chloride concentrations range from 0.4 at the undeveloped sites to 1.3 mg/L at Below Patsy's station. Generally, chloride appears to be lower at the two undeveloped sites, as shown in Figure 2-8. It is unknown why the concentration is greater at the ski area sites, since chloride is assumed to enter streams through salts in precipitation. Future monitoring and analysis may identify other potential sources of chloride.

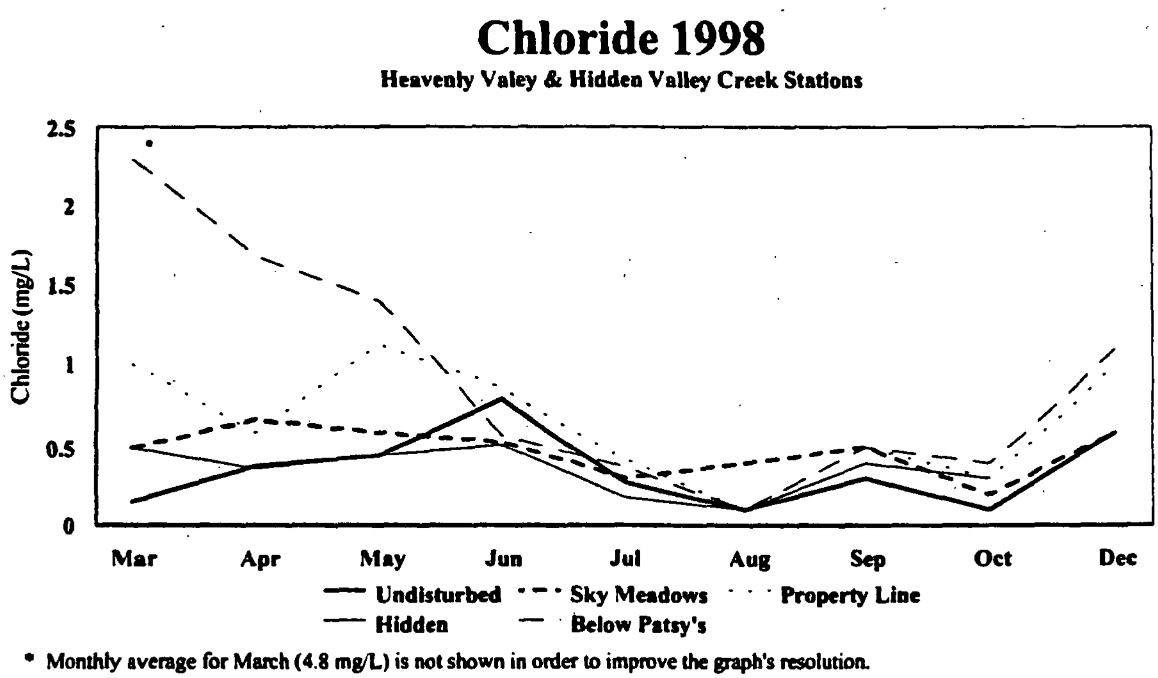

Figure 2-8. Average monthly chloride values for Heavenly Valley and Hidden Valley Creek stations during 1998.

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Table 2-1: Heavenly Ski Resort 1998 water quality monitoring data from station HV-C1, the Undisturbed Tributary to Heavenly Valley Creek. This station is located at Magies Corner, at an elevation of 8,315 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total Nitrite/Nitrate (mg/L)	Total Kjeldahl N (mg/L)*	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		---	---	---	**60**	---	---	**0.190**	**0.015**	---	**0.2**
First Quarter											
980316	1530	0.00	34	0.38	3.0	0.015	0.16	0.175	0.028	0.010	0.2
980325	1400	0.00	33	0.42	9.0	0.022	0.16	0.182	0.030	0.012	0.1
Second Quarter											
980402	1015	0.00	40	0.40	0.5	0.018	0.14	0.158	0.018	0.010	0.2
980409	1150	0.00	41	0.47	0.5	0.015	0.10	0.115	0.022	0.010	0.3
980416	1330	0.00	42	0.35	0.5	0.017	0.16	0.177	0.020	0.010	0.2
980423	1255	0.03	36	0.32	10.0	0.022	0.10	0.122	0.028	0.012	0.8
980428	1220	0.03	27	0.36	4.0	0.024	0.10	0.124	0.025	0.012	0.4
980507	1230	0.05	33	1.30	2.0	0.013	0.10	0.113	0.020	0.010	0.6
980515	1130	0.04	25	0.45	1.0	0.018	0.35	0.368	0.022	0.010	0.2
980521	1200	0.06	33	0.95	1.0	0.020	0.10	0.120	0.030	0.010	0.3
980528	1530	0.09	33	0.56	2.0	0.014	0.10	0.114	0.030	0.012	0.7
980603	1230	0.23	36	0.54	4.0	0.004	0.10	0.104	0.038	0.012	1.4
980609	1445	0.99	20	1.50	58.0	0.009	0.19	0.199	0.028	0.016	0.3
980615	1315	1.13	22	1.10	29.0	0.004	0.10	0.104	0.055	0.016	0.5
980622	1100	1.28	22	0.73	10.0	0.002	0.10	0.102	0.040	0.018	0.7
980629	1400	0.86	24	0.52	4.0	0.007	0.24	0.247	0.030	0.014	1.1
Third Quarter											
980706	1220	0.46	31	0.55	1.0	0.004	0.15	0.154	0.032	0.016	0.5
980716	1345	0.24	31	0.60	47.0	0.026	0.22	0.246	0.038	0.012	0.2
980720	1145	0.18	32	0.65	2.0	0.020	0.10	0.120	0.038	0.010	0.2
980728	930	0.12	42	0.45	0.5	0.007	0.25	0.257	0.024	0.010	0.2
980804	1050	0.07	35	0.46	1.0	0.006	0.26	0.266	0.020	0.010	0.1
980908	1255	0.02	36	0.36	0.5	0.010	0.10	0.110	0.022	0.010	0.3
Fourth Quarter											
981007	1245	0.03	22	0.56	0.5	0.009	0.12	0.129	0.028	0.012	0.1
981202	1100	0.06	39	0.38	0.5	0.008	0.10	0.108	0.030	0.012	0.6
Annual	**Minimum**	**0.00**	20	**0.32**	**0.5**	**0.002**	**0.10**	**0.102**	**0.018**	**0.010**	**0.1**
Summary	**Maximum**	**1.28**	42	**1.50**	**58.0**	**0.026**	**0.35**	**0.368**	**0.055**	**0.018**	**1.4**
	Average	**0.25**	32	**0.60**	**8.0**	**0.013**	**0.15**	**0.163 ****	**0.029 ****	**0.012**	**0.4 ****

* Total Kjeldahl N values reported as 0.10 mg/L are actually less than this minimum detection limit, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent.

Table 2-2: Heavenly Ski Resort 1998 water quality monitoring data from station HV-C1A, Heavnely Valley Creek at Sky Meadows. This station is located above the snowmaking pond at an elevation of 8,525 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total Nitrite/Nitrate (mg/L)	Total Kjeldahl N (mg/L)*	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		---	---	---	**60**	---	---	**0.190**	**0.015**	---	**0.2**
First Quarter											
980316	1315	0.05	31	0.46	0.5	0.037	0.18	0.217	0.012	0.002	0.4
980325	1330	0.07	31	0.65	2.0	0.020	0.14	0.160	0.010	0.002	0.6
Second Quarter											
980402	935	0.05	33	0.76	0.5	0.019	0.14	0.159	0.008	0.002	0.5
980409	1130	0.06	41	0.76	0.5	0.031	0.19	0.221	0.008	0.002	0.5
980416	1250	0.08	39	1.10	0.5	0.019	0.15	0.169	0.010	0.002	0.3
980423	1245	0.20	38	1.30	1.0	0.020	0.10	0.120	0.010	0.002	1.1
980428	1200	0.20	38	0.70	12.0	0.023	0.10	0.123	0.012	0.004	1.0
980507	1215	0.31	32	1.20	1.0	0.018	0.10	0.118	0.010	0.004	0.6
980515	1120	0.31	38	0.90	1.0	0.034	0.28	0.314	0.010	0.002	0.5
980521	1145	0.38	28	1.20	1.0	0.025	0.10	0.125	0.030	0.006	0.7
980528	1515	0.39	35	1.00	3.0	0.026	0.10	0.126	0.028	0.002	0.6
980603	1215	0.76	36	0.68	2.0	0.024	0.10	0.124	0.020	0.010	0.6
980609	1430	1.80	43	1.20	14.0	0.024	0.10	0.124	0.015	0.006	0.6
980615	1345	2.90	28	0.76	25.0	0.020	0.10	0.120	0.045	0.002	0.3
980622	1040	4.10	20	0.80	29.0	0.020	0.10	0.120	0.025	0.006	0.4
980629	1315	6.00	19	1.00	38.0	0.028	0.21	0.238	0.055	0.008	0.8
Third Quarter											
980706	1145	7.50	19	1.10	47.0	0.031	0.15	0.181	0.050	0.008	0.3
980716	1300	5.20	20	1.70	40.0	0.026	0.17	0.196	0.040	0.010	0.4
980720	1130	5.00	21	0.95	18.0	0.035	0.23	0.265	0.017	0.005	0.4
980728	1000	2.60	30	0.90	3.0	0.022	0.10	0.122	0.015	0.002	0.1
980804	1110	1.80	26	0.78	4.0	0.021	0.13	0.151	0.028	0.004	0.4
980908	1315	0.65	28	0.86	1.0	0.021	0.10	0.121	0.010	0.004	0.5
Fourth Quarter											
981007	1230	0.48	39	0.64	0.5	0.014	0.23	0.244	0.012	0.004	0.2
981202	1030	0.28	35	0.78	0.5	0.015	0.10	0.115	0.012	0.002	0.6
Annual	**Minimum**	**0.05**	**19**	**0.68**	**0.5**	**0.018**	**0.10**	**0.118**	**0.008**	**0.002**	**0.3**
Summary	**Maximum**	**7.50**	**43**	**1.30**	**38.0**	**0.034**	**0.28**	**0.314**	**0.055**	**0.010**	**1.1**
	Average	**1.72**	**31**	**0.92**	**10.2**	**0.024**	**0.14**	**0.166 ****	**0.021 ****	**0.004**	**0.5 ****

* Total Kjeldahl N values reported as 0.10 mg/L are actually less than this minimum detection limit, however, this minimum value was used to calculate total N concentration.
** These values exceed the annual average or 90th percentile state standard for the constituent.

Table 2-3: Heavenly Ski Resort 1998 water quality monitoring data from station HV-C2, Heavenly Valley Creek below Patsy's Chair. This station is located just beyond ski area development within this watershed, at an elevation of 8,000 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbitity (ntu)	Suspended Sediment (mg/L)	Total Nitrite/Nitrate (mg/L)	Total Kjeldahl N (mg/L)*	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		---	---	---	**60**	---	---	**0.19**	**0.015**	---	**0.2**
First Quarter											
980316	1530	0.06	96	0.62	3.0	0.042	1.80	1.842	0.288	0.180	6.8
980325	1445	0.29	61	0.83	2.0	0.058	1.90	1.958	0.098	0.080	2.8
Second Quarter											
980402	1040	0.17	53	0.42	0.5	0.072	0.67	0.742	0.030	0.020	1.4
980409	1230	0.17	50	0.70	0.5	0.050	0.16	0.210	0.088	0.076	2.0
980416	1350	0.20	73	0.95	1.0	0.060	1.90	1.960	0.195	0.100	3.2
980423	1315	0.22	50	0.90	1.0	0.052	0.10	0.152	0.040	0.023	0.8
980428	1240	0.67	48	0.72	1.0	0.050	0.10	0.150	0.038	0.024	1.0
980507	1245	0.94	42	1.70	1.0	0.054	0.10	0.154	0.018	0.008	1.7
980515	1150	0.85	40	0.75	1.0	0.074	0.10	0.174	0.011	0.004	0.9
980521	1215	1.00	38	1.20	1.0	0.057	0.10	0.157	0.050	0.006	1.8
980528	1545	1.40	43	0.75	4.0	0.060	0.10	0.160	0.033	0.006	1.2
980603	1245	2.10	32	1.30	4.0	0.039	0.10	0.139	0.028	0.004	0.9
980609	1515	6.00	46	5.60	98.0	0.035	0.14	0.175	0.080	0.008	0.7
980615	1415	7.10	29	2.60	49.0	0.029	0.10	0.129	0.043	0.005	0.4
980622	1115	8.80	22	1.10	8.0	0.025	0.10	0.125	0.038	0.004	0.8
980629	1420	11.10	22	1.90	2.0	0.028	0.16	0.188	0.051	0.008	0.1
Third Quarter											
980706	1230	10.4	28	1.60	5.0	0.039	0.21	0.249	0.032	0.008	0.5
980716	1230	6.9	25	1.60	9.0	0.025	0.10	0.125	0.028	0.008	0.5
980720	1200	5.5	28	1.50	17.0	0.032	0.15	0.182	0.032	0.004	0.4
980728	1020	3.9	43	1.00	1.0	0.019	0.11	0.129	0.012	0.002	0.1
980804	1145	2.9	35	1.20	1.0	0.018	0.10	0.118	0.021	0.003	0.1
980908	1230	1.2	37	1.00	0.5	0.020	0.10	0.120	0.017	0.002	0.5
Fourth Quarter											
981007	1300	0.894	29	0.96	0.5	0.016	0.10	0.116	0.015	0.002	0.4
981202	1115	0.358	47	1.30	0.5	0.017	0.10	0.117	0.015	0.004	1.1
Annual	**Minimum**	**0.17**	22	**0.42**	**0.5**	**0.025**	**0.10**	**0.125**	**0.011**	**0.004**	**0.1**
Summary	**Maximum**	**11.10**	73	**5.60**	**98.0**	**0.074**	**1.90**	**1.960**	**0.195**	**0.100**	**3.2**
	Average	**3.05**	42	**1.34**	**8.8**	**0.040**	**0.36**	**0.399 ****	**0.054 ****	**0.025**	**1.3 ****

* Total Kjeldahl N values reported as 0.10 mg/L are actually less than this minimum detection limit, however, this minimum value was used to calculate total N concentration.
** These values exceed the annual average or 90th percentile state standard for the constituent.

Table 2-4: Heavenly Ski Resort 1998 water quality monitoring data from station HV-C3, Heavenly Valley Creek at the Property Line. This station is located just above the Forest Service property line and subdivision development, at an elevation of 6,620 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbitity (ntu)	Suspended Sediment (mg/L)	Total Nitrite/Nitrate (mg/L)	Total Kjeldahl N (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		---	---	---	60	---	---	**0.19**	**0.015**	---	**0.2**
First Quarter											
980316	1015	0.08	44	1.50	3.0	0.026	0.12	0.146	0.022	0.006	0.9
980325	1100	1.40	47	2.40	2.0	0.019	0.19	0.209	0.022	0.008	1.1
Second Quarter											
980402	1100	0.62	46	0.75	1.0	0.027	0.13	0.157	0.010	0.004	
980409	1000	0.32	55	1.00	1.0	0.025	0.18	0.205	0.010	0.004	0.5
980416	915	0.34	58	0.98	0.5	0.031	0.12	0.151	0.015	0.006	0.9
980423	1500	1.30	40	1.10	1.0	0.019	0.10	0.119	0.015	0.006	0.4
980428	1420	1.30	44	0.82	1.0	0.015	0.10	0.115	0.018	0.008	0.6
980507	1415	1.60	43	1.10	2.0	0.016	0.10	0.116	0.018	0.006	1.3
980515	1315	1.00	41	0.72	1.0	0.024	0.16	0.184	0.015	0.004	0.6
980521	1515	1.50	46	1.00	4.0	0.015	0.10	0.115	0.028	0.008	1.4
980528	1530	1.40	45	0.76	2.0	0.050	0.10	0.150	0.030	0.006	1.2
980603	1400	3.00	37	1.30	7.0	0.015	0.10	0.115	0.075	0.004	0.9
980609	1600	8.80	25	5.00	88.0	0.028	0.15	0.178	0.090	0.008	1.2
980615	1530	7.60	27	4.00	207.0	0.020	0.10	0.120	0.060	0.006	0.5
980622	915	9.30	29	1.40	42.0	0.024	0.10	0.124	0.050	0.004	1.6
980629	1130	11.40	24	1.50	23.0	0.021	0.12	0.141	0.070	0.008	0.9
Third Quarter											
980706	1340	12.60	29	1.70	66.0	0.022	0.12	0.142	0.065	0.008	0.7
980716	1110	7.60	36	2.00	30.0	0.021	0.29	0.311	0.080	0.010	0.4
980720	1030	6.00	29	1.10	6.0	0.019	0.11	0.129	0.020	0.004	0.5
980728	1130	4.00	45	1.20	4.0	0.013	0.11	0.123	0.015	0.006	0.1
980804	930	3.70	37	0.95	2.0	0.016	0.10	0.116	0.030	0.004	0.1
980908	1130	1.90	39	0.70	1.0	0.010	0.10	0.110	0.018	0.002	0.5
Fourth Quarter											
981007	1115	1.00	40	0.86	0.5	0.008	0.10	0.108	0.015	0.004	0.3
981202	1230	0.37	49	1.00	0.5	0.012	0.15	0.162	0.015	0.002	1.0
Annual	**Minimum**	**0.32**	**24**	**0.72**	**0.5**	**0.015**	**0.10**	**0.115**	**0.010**	**0.004**	**0.4**
Summary	**Maximum**	**11.40**	**58**	**5.00**	**207.0**	**0.050**	**0.18**	**0.205**	**0.090**	**0.008**	**1.6**
	Average	**3.67**	**40**	**1.45**	**20.6**	**0.021**	**0.13**	**0.148 ****	**0.034 ****	**0.006**	**0.8 ****

* Total Kjeldahl N values reported as 0.10 mg/L are actually less than this minimum detection limit, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent.

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Table 2-5: Heavenly Ski Resort 1998 water quality monitoring data from station 43-H5, Hidden Valley Creek baseline station. This station is located just avor the confluence with Trout Creek, at an elevation of 6,680 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total Nitrite/Nitrate (mg/L)	Total Kjeldahl N (mg/L)*	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)	Chloride (mg/L)
CRWQCB Standards		---	---	---	**60**	---	---	**0.19**	**0.015**	---	**0.2**
First Quarter											
980320	1345	2.1	NS	0.8	1	0.007	0.23	0.237	0.045	0.010	0.3
980327	1125	1.9	56	2.6	1	0.007	0.16	0.167	0.028	0.012	0.7
980330	1500	2.5	57	2.0	2	0.008	0.19	0.198	0.032	0.008	0.8
Second Quarter											
980409	1100	1.4	69	1.4	1	0.005	0.36	0.365	0.022	0.008	0.1
980414	1300	1.1	64	1.7	1	0.006	0.45	0.456	0.020	0.008	0.3
980420	1515	1.6	66	1.5	2	0.006	0.34	0.346	0.020	0.008	0.1
980427	1415	2.3	62	1.8	2	0.008	0.10	0.108	0.025	0.010	0.5
980504	1300	2.7	11	1.6	3	0.009	0.10	0.109	0.025	0.008	0.8
980511	1250	3.0	50	1.5	1	0.006	0.24	0.246	0.020	0.006	0.4
980520	1530	1.7	54	1.4	2	0.009	0.10	0.109	0.040	0.010	0.2
980528	1330	1.9	50	1.3	2	0.010	0.10	0.110	0.018	0.008	0.4
980603	1500	3.4	48	1.0	3	0.002	0.10	0.102	0.030	0.014	0.7
980610	930	5.5	28	1.0	4	0.006	0.10	0.106	0.018	0.005	0.2
980615	915	10.0	23	1.4	15	0.008	0.10	0.108	0.028	0.006	0.1
980624	805	11.0	20	1.3	9	0.004	0.11	0.114	0.022	0.004	0.6
980629	1000	17.3	20	1.3	16	0.005	0.22	0.225	0.048	0.008	1.0
Third Quarter											
980707	1340	15.4	18	1.0	10	0.005	0.16	0.165	0.032	0.006	0.1
980715	1340	10.8	20	1.0	11	0.005	0.10	0.105	0.022	0.008	0.3
980720	915	9.3	19	0.8	5	0.007	0.24	0.247	0.020	0.004	0.2
980728	1330	3.8	39	0.6	4	0.005	0.14	0.145	0.022	0.008	0.1
980804	840	2.6	33	0.7	1	0.007	0.10	0.107	0.018	0.008	0.1
980908	1030	1.4	47	0.8	1	0.011	0.10	0.111	0.028	0.008	0.4
Fourth Quarter											
981007	1500	1.0	17	0.5	1	0.006	0.10	0.106	0.030	0.010	0.3
Annual	**Minimum**	**1.0**	**11**	**0.5**	**1**	**0.002**	**0.10**	**0.102**	**0.018**	**0.004**	**0.1**
Summary	**Maximum**	**17.3**	**69**	**2.6**	**16**	**0.011**	**0.45**	**0.456**	**0.048**	**0.014**	**1.0**
	Average	**4.9**	**38**	**1.3**	**4**	**0.007**	**0.17**	**0.178**	**0.027 ****	**0.008**	**0.4 ****

NS= not sampled

* Total Kjeldahl N values reported as 0.10 mg/L are actually less than this minimum detection limit, however, this minimum value was used to calculate total N concentration.

** These values exceed the annual average or 90th percentile state standard for the constituent.

California Parking Lot Drainage (Bijou Creek)

Flow from above and within the California Base parking lot drains into a system of underground vaults that are designed to absorb and retain oils, metals, and sediment. The filtered water then flows through a culvert and reenters an open channel on a tributary to Bijou Creek, approximately 200 feet northwest of the parking lot. There is one station immediately below the parking lot's culvert outlet (HV-C4, 6,530 ft.). Two samples were collected at this site during the year: a runoff sample in March and a fall rain event (> 24 hours) in September. Table 2-6 shows all constituent concentrations measured and applicable standards for the 90th percentile values. Most constituents were lowest during the September rain event when precipitation was lite and steady, accumulating about one inch of rain over more than one day. All constituents with state standards (turbidity, suspended sediment, total N, total P, oil & grease, and total iron) were exceeded during the March snowmelt (Table 2-6). During the September event, only total P and total iron concentrations exceeded the standards (0.25 mg/L and 3.7 mg/L, respectively). Total iron was 7 to 13 times greater than the standard. Compliance with the oil and grease standard is unknown for the September sample, since the result was less than the method detection limit of 5 mg/L while the standard is 2 mg/L.

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Table 2-6: Heavenly Ski Resort 1998 water quality monitoring data from station HV-C4, Bijou Creek below California Parking Lot. This station is located below the culvert outlet draining the parking lot off of Wildwood Ave., at an elevation of 6,530 ft.

Date	Time	Discharge (cfs)	Specific Conductivity (mmhos)	Turbidity (ntu)	Suspended Sediment (mg/L)	Total Nitrite/Nitrate (mg/L)	Total Kjeldahl N (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Soluble Reactive P (mg/L)
CRWQCB Standards		---	---	**20**	**50**	---	---	**0.5**	**0.1**	---
First Quarter										
980311	1230	0.4	278	***28***	***364***	0.039	0.52	***0.559***	***0.19***	0.016
Third Quarter										
980909	800	0.4	173	16	22	0.054	0.1	0.154	***0.25***	0.07

Date	Time	Chloride (mg/L)	Oil and Grease (mg/L)	Total Iron (mg/L)	Total Lead (mg/Ll)
CRWQCB Standards		---	**2**	**0.5**	---
First Quarter					
980311	1230	250	***6***	***6.6***	0.01
Thrid Quarter					
980909	800	34	***< 5***	***3.7***	0.01

Values in bold italics exceed State standard for the specified constituent on that collection date only.

Reno Gazette-Journal 11/22/99

Tahoe gas pollution plunging

Dramatic drop: Officials credit crackdown on marine engines.

By Jeff DeLong
RENO GAZETTE-JOURNAL

Gasoline compounds found in Lake Tahoe decreased dramatically this summer from 1998 levels, suggesting that a crackdown on polluting marine engines is having the desired effect.

Scientists from the University of Nevada, Reno, University of California-Davis and U.S. Geological Survey said Monday that gasoline pollutants found in the lake dropped "by an order of magnitude."

Mean levels of the fuel additive MTBE fell by more than 95 percent, while levels of the compound toluene dropped some 88 percent, said John Reuter, a scientist with UC-Davis Tahoe Research Group.

"There definitely was a fairly substantial decrease in all of the areas we measured," UNR's Glenn Miller said. "At a minimum, there's been a 50 percent decrease. Sometimes it's as much as 90 percent."

Scientists agree the reduction appears directly linked to the Tahoe Regional Planning Agency's June 1999 ban on the carbureted two-stroke marine engines that power most types of Jet Skis and other personal watercraft, as well as many outboard motorboats. The agency targeted the engines because they discharge 25 percent or more of their fuel unburned.

Extensive sampling of the lake's waters was conducted in 1997 and 1998. When scientists returned in summer 1999, levels of gasoline compounds had decreased substantially.

"We found levels were much lower this summer than they were the previous summer," said Mike Lico, a USGS researcher. "It's pretty clear-cut the actual source probably was two-stroke engines. Now that we've taken them off the lake, we're seeing that source taken away."

Told of the findings Monday, TRPA Executive Director Jim Baetge said they vindicate his agency's highly con-

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THE NUMBERS

Gasoline compounds measured at Lake Tahoe. Measurements are micrograms per liter. (MTBE is methyl tertiary butyl ether.)

Emerald Bay
MTBE
1998: 4.0
1999: 0.33
Toluene
1998: 1.5
1999: 0.24

Tahoe City
MTBE
1997: 2.85
1998: 1.1
1999: 0.04
Toluene
1997: 1.24
1998: 0.64
1999: 0.14.

Incline Village
MTBE
1997: 0.45
1998: 0.84
1999: 0.05
Toluene
1997: 0.13
1998: 1.0
1999: 0.14

Mid-lake
MTBE
1997: 0.54
1998: 0.28
1999: 0.04

Tahoe Meadows
MTBE
1997: 1.4
1999: 0.4
Toluene
1997: 0.84
1999: 0.18

Ski Run
MTBE
1997: 0.17
1999: 0.4
Toluene
1997: 7.8
1999: 3.9

Source: Selected examples of water samples taken by University of California, Davis and University of Nevada, Reno

Tahoe

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troversial crackdown.

"That's where we were headed with this thing, and I'm delighted," Baetge said. "After all the trouble that we went through with this thing, it makes me feel good."

The Tahoe Research Group took samples at 10 locations around the lake as well as in mid-lake.

Decreases in methyl tertiary butyl ether — which could be attributed to more MTBE-free gasoline being sold in the area — were matched with drops in toluene levels.

Foul-smelling MTBE, added to gasoline to make it cleaner burning, is suspected to cause cancer; toluene is a known carcinogen.

The test results indicate the two-cycle ban probably is responsible for the change, Reuter said.

The USGS also measured a dramatic drop in MTBE at Echo Lake west of Lake Tahoe.

High levels of MTBE still were found at some marinas and other places of high boating activity, a fact Reuter attributes to bilge draining and possible spillage of gasoline during refueling.

"I believe the regulation was very much responsible for the reduction of gasoline in the lake," UNR's Miller said.

Baetge praised the level of cooperation between often-competing researchers at UNR, UC-Davis and USGS. He said scientific studies conducted in the past three years and associated regulations his agency adopted should serve "as a perfect model of how things should happen at Lake Tahoe."

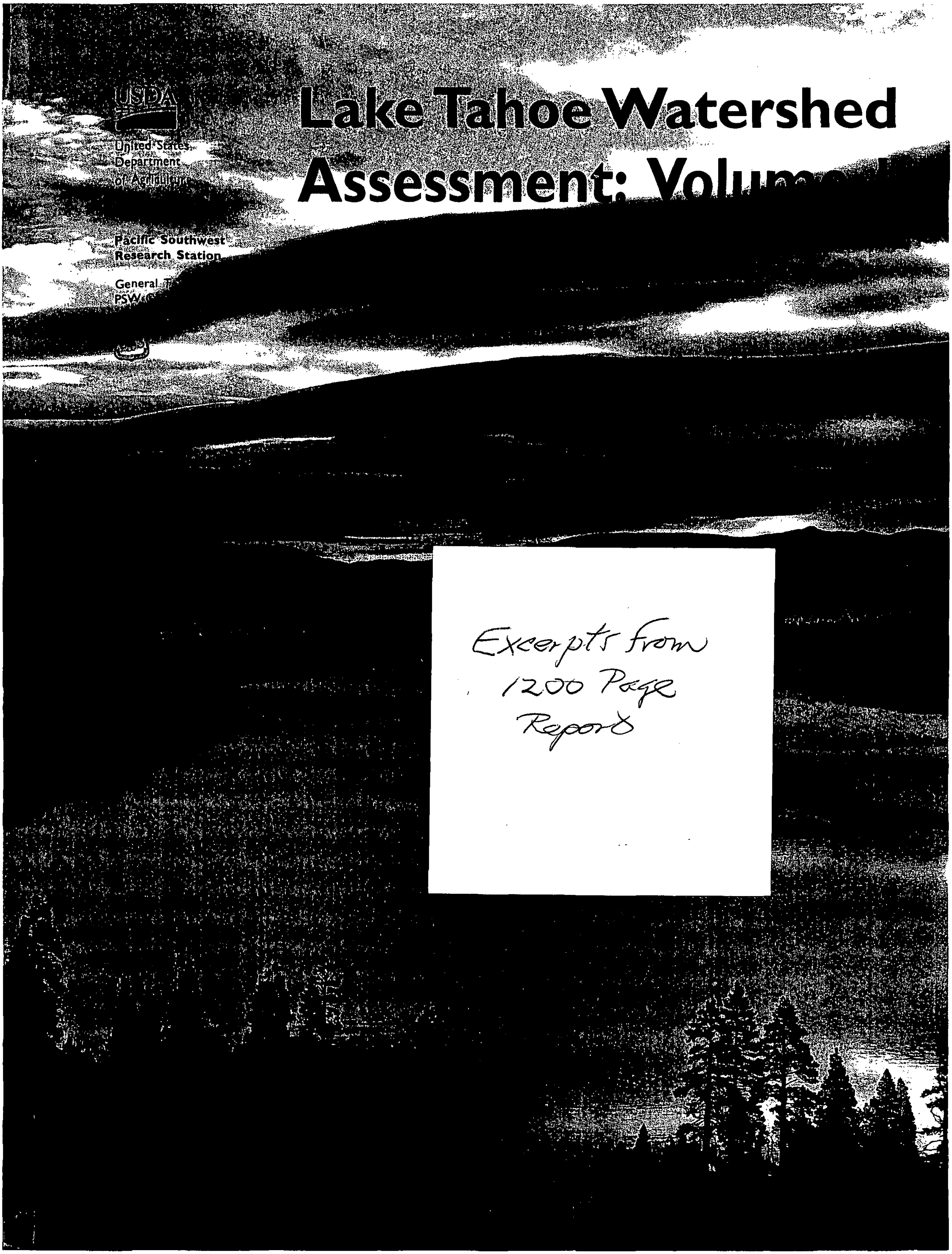
USDA

United States
Department
of Agriculture

Pacific Southwest
Research Station

General T
PSW

Lake Tahoe Watershed Assessment: Volum



Excerpts from
1200 Page
Report

CHAPTER FOUR

AQUATIC RESOURCES, WATER QUALITY, AND LIMNOLOGY OF LAKE TAHOE AND ITS UPLAND WATERSHED

John E. Reuter and Wally W. Miller

Water quality in Lake Tahoe has been evaluated continuously since the early 1960s, and algal growth has been increasing at a rate greater than five percent per year. Correspondingly, there has been a decline of clarity at an alarming rate of nearly one foot per year. This long-term trend is statistically significant and now can be perceived by even the casual observer. If the loss of clarity continues, it is predicted that the lake will have only approximately 20 meters of transparency by 2030. The resulting Secchi depth of 12 meters will no doubt be accompanied by a change of lake biota and a permanent change in trophic status.

Today, significant portions of the once pristine basin are urbanized. Studies from 1962 to 2000 have shown that many factors, such as land disturbance, habitat destruction, air pollution, soil erosion, and roads, have all interacted to degrade the basin's air quality, terrestrial landscape, and streams, as well as the lake itself. However, some of the same features that maintained the exceptional historical water quality in Lake Tahoe now threaten its future. Once nutrients enter the lake, they remain in the water and can be recycled for decades. As a consequence, these pollutants accumulate over time and contribute to Lake Tahoe's progressive decline. The ability of the lake to dilute nutrient and sediment loading to levels where there is no significant affect on lake water quality has been lost.

The Tahoe basin is a complex ecosystem of 63 individual watersheds and numerous intervening areas. Much urbanization is in the intervening areas that drain directly to the lake. It is unrealistic to expect that completing any single mitigation project will have a significant effect on lake water quality. It is clear that future research and monitoring must address such issues as the effectiveness of best management practices (BMP), the potential reduction of nutrient and sediment loading, with its subsequent impact on the nutrient budget and lake response, project design, project monitoring, and priority ranking. This approach is critical to the future of restoration efforts in the basin. Management needs a comprehensive watershed approach. Agencies require technical products to more specifically identify sources of nutrients and sediment, to assess the effectiveness of restoration BMPs, and to help guide erosion control prioritization as project implementation begins to ramp up in magnitude.

While sediments and nutrients are the major problems that must be addressed to meet desired conditions for lake clarity and algal growth, other pollutants also affect aquatic ecosystem processes. These include MTBE and other boat fuel chemicals, toxic organic chemicals, such as pesticides and PCBs, and materials leaking into the ground water from underground storage tanks. The scope of this portion of the watershed assessment focuses primarily on the issue of lake clarity; however, this focus does not imply that these additional water quality issues are not of concern.

The Role of Science-based Decision-making in Adaptive Watershed Management

For effective lake management, understanding is needed of the following:

- What are the specific sources of sediment and nutrients to the lake and what are their respective contributions?
- How much of a reduction in loading is necessary to achieve the desired thresholds or total daily maximum loads (TMDL) for Lake Tahoe (i.e., lake response)?
- How will this reduction be achieved?

The watershed approach taken at Lake Tahoe for many decades recognizes that lake water quality is linked to upland watershed processes and air quality. Natural watershed processes have been affected by the disruption of natural ecosystem processes that treat runoff naturally (e.g., wetlands, ground water infiltration, and vegetation) and a changed landscape that alters hydrology and promotes the accelerated loading of nutrients and sediment (e.g., impervious cover, road network, habitat disruption, and land disturbance). Successfully implementing land, air, and water quality restoration projects is considered the only realistic avenue to arrest further decline in lake clarity. Scientific efforts must be focused on restoration objectives and must be coordinated to obtain information needed for adaptive management.

Hundreds of scientific papers and reports have been written on many aspects of Lake Tahoe, its watershed, and its water quality since studies first began more than 40 years ago. This chapter of the watershed assessment uses a significant portion of this information to answer a series of questions associated with the following three critical issues:

- Issue 1—The need to understand and quantify, where possible, the links between urban and natural features of the watershed landscape and the loading of nutrients and sediments to Lake Tahoe.
- Issue 2—The need to determine the extent to which discharge of sediment and nutrients from basin watersheds can be effectively reduced by management or restoration activities.
- Issue 3—The need to understand how Lake Tahoe will respond to watershed restoration projects.

The goals of this chapter can be summarized by the products it provides, which include:

- A comprehensive review of past studies, with the focus of assessing both upland and lake water quality (a review of this magnitude is lacking for the Tahoe basin);
- A focal point that consolidates current and future knowledge;
- A roadmap for future proposed research and monitoring;
- New scientific information on a number of critical issues, including the decline in dissolved oxygen in portions of Lake Tahoe and the effects of fire (prescribed or natural) on nutrient cycling; and
- A review of important hydrologic and ecological processes in the Tahoe basin that require consideration during formulation and implementation of restoration projects and strategy.

The assessment was successful even prior to the publication of this final report in that it has served to galvanize scientific thought in the basin and to reinforce the importance of applying adaptive management at the watershed level.

In the remainder of this summary, the salient findings reported in this portion of the assessment are presented. In particular, focus is placed on those findings with direct and immediate application to restoration and adaptive management. This chapter does not provide a prescriptive formula for restoration; rather it provides key information for science-based decision making. Equally as important, it emphasizes those areas where the existing knowledge is insufficient.

Environmental Setting

Lake Tahoe lies at the crest of the Sierra Nevada at an elevation of 1,898 m within both California and Nevada. The drainage area is [illegible] square kilometers (km^2), with a lake surface of 501 km^2, producing a ratio of only 1.6. The lake is in a montane-subalpine watershed dominated by coniferous vegetation and nutrient-poor soils. Sixty-three streams flow into the lake. At 50[illegible] m, Lake Tahoe is the world's tenth deepest lake, with a mean depth of 313 m. Its volume is km3 with a residence time of about 700 years, and the lake is ice-free year-round. The depth of vertical mixing varies from 100 m to >450 m, depending on winter storm intensity. The extent of mixing is directly related to interannual differences in algal growth because of the introduction of nutrient-rich water from the deeper portions of the lake (Goldman and Jassby 1990). The amount of algal primary productivity during the extended summer season is fueled by nutrients that mix up from the bottom waters, enter the lake via surface and subsurface runoff, are loaded by atmospheric deposition to the lake surface, or are recycled by bacteria and other aquatic micro-biota. Lake Tahoe was once classified as ultra-oligotrophic (Goldman 1974); i.e., low nutrient content, low plant productivity, and high transparency. However, because of the ongoing decline in clarity and rise in algal growth rate, its trophic status (level of fertility) has been moving toward a meso-oligotrophic status.

Changing Water Quality

Many of the world's lakes have been subject to cultural eutrophication. The anthropogenic enrichment of waters usually results from nutrients reaching a stream or lake from septic tanks and sewage treatment plants, agricultural and urban runoff, or the disturbance of land during lumbering or urban development. These additional sources typically occur at rates that greatly exceed natural inputs. When nutrient content is too high the resulting dense growth of algae causes a change in the lake's color, reduce light penetration, and lower dissolved oxygen to a point where aquatic organisms can no longer survive. Because of Lake Tahoe's naturally low fertility it historically has been a pristine waterbody. However, extensive research and monitoring has provided clear evidence of the onset of cultural eutrophication in oligotrophic Lake Tahoe (Goldman 1988). Continuous long-term evaluation of lake chemistry and biology since the early 1960s has shown that algal production is increasing at a rate greater than five percent per year, with a corresponding decline of clarity at the alarming rate of approximately 0.3 meters, or 1.2 feet, per year. Not only is the long-term trend of declining clarity statistically significant ($p<0.001$), it is now visually obvious. Secchi depths typically range from >15 to <25 m, depending on season and year.

Lake water clarity is measured using a number of techniques. Most commonly, clarity is expressed as a Secchi depth: the depth at which an eight-inch white disk is no longer visible from the surface as it is lowered into a waterbody. Regular measurements at the UC Davis/Tahoe Research Group Index Station began in 1967 and have been made on average every 12.2 days since then (Jassby et al. 1999). In earlier synoptic studies of lake primary productivity, Goldman found the Index Station to represent whole lake conditions (Goldman 1974). Scientific data shows that Secchi depth is directly related to the amount of suspended matter in the water (Jassby et al. 1999). This suspended matter is composed of both biotic materials and suspended inorganic silt or sediment

Extensive research on the spatial distribution of free-floating algae indicates a marked correspondence between the highest algal growth rates and the most extensive shoreline development. Lakewide studies have shown that the central portion of the lake historically has been characterized by relatively fewer algae, with areas near south and north shore developments exhibiting enhanced production. Similar studies of the attached algae also demonstrate this pattern. The dramatic differences in algal growth on rocks at various shoreline locations are linked to nearby development and are immediately visible to the largely shore-bound populace.

Ironically, some of the same features that maintained the exceptional historical water quality in Lake Tahoe now threaten its health under current conditions of increased nutrient and sediment loading. Tahoe's large depth and volume once acted to dilute pollutants to a level of no significant affect; this is no longer the case. Once nutrients enter the lake they accumulate in the water and are available for use over and over for decades. This phenomenon has crucial implications when the results of watershed mitigation and restoration projects are evaluated.

Research also has shown a fundamental shift of algal growth by nitrogen additions from frequent stimulation to almost exclusive phosphorus stimulation (Goldman et al. 1993). This response of Lake Tahoe algae to nutrient or TP was calculated to be roughly equivalent to the load in urban runoff from five acres of medium-developed residential or two to three acres of tourist-commercial property.

Summary of Inputs—The summary values presented below represents an initial estimate at quantifying the nutrient sources to Lake Tahoe. Depending on the amount and form of precipitation, individual water years will differ. Efforts are underway to provide estimates of both interannual and measurement variation to these values (Reuter, unpublished).

Our estimates suggest that approximately 17 MT, or about one-third of the TP load, is in the form of soluble-P and is immediately available for biological uptake. Values of this magnitude are not uncommon in the scientific literature (Reckhow and Chapra 1983; Hatch 1997). While it is important to understand the sources and process that render phosphorus available for algal uptake, it is noteworthy that many of the empirical models developed for lakes to relate phosphorus loading to trophic status or algal biomass are based on total-P (Reckhow and Chapra 1983). Studies are underway, but more are needed to elucidate the factors controlling transformations between the TP and soluble-P pools. This research must look at both watershed and in-lake processes.

The results at this time clearly suggest the importance of direct runoff from urban areas and highlight the need for additional study in this area. As restoration projects are targeted and adaptive management proceeds, it will be very helpful to have more detailed data on the specific sources of nutrients within each of the major categories discussed above. Restoration should give priority to those areas that contribute most to the nutrient loading budget.

INPUTS	**Nitrogen** (MT)	**Phosphorus** (MT)	
	Total	Total	Soluble
Atmospheric deposition	233.9 (56%)	12.4 (27%)	5.6
Stream loading	81.6 (20%)	13.3 (29%)	2.4
Direct runoff	41.8 (10%)	15.5 (34%)	5.0
Ground water	60 (14%)	4 (9%)	4
Shoreline erosion	0.75 (<1%)	0.45 (1%)	No Data
Total	**418.1**	**45.7**	**17.0**

Losses—As discussed in much further detail as part of Issue #3 (Mass Balance Considerations), Heyvaert and Reuter (in unpublished) have found that nutri[ent] sedimentation losses to the bottom of La[ke] Tahoe are 401.7 MT for total nitrogen and 5[...] MT for total phosphorus. These numbers ag[ree] remarkably well with the independent load[ing] estimates given above. This close agreement g[ives] increased confidence that the loading rates [are] representative.

Characteristics of Nutrient Loading in [...] Tahoe Tributaries, over Daily, Seasonal, An[nual] and Interannual Time Scales—with Emphasis [on] Phosphorus

Prior to 1980, tributary nutrient loading [was] monitored as part of basic research, as pa[rt of] existing, albeit limited, water quality and stream monitoring, or as part of specific project stu[dies], many of which were focused on highway cu[ts] and discharge. By the late 1970s, these prog[rams] were no longer of sufficient scope or organized [in] such a manner as to provide the extensive data needed for land use planning and water[shed] management. In 1979, the LTIMP was established [to] meet these growing needs. LTIMP now consist[s of] 10 to 15 federal, state, and local agencies.

Nearly 20 years of data from LTIMP [have] been used for many purposes, including ero[sion] control planning, capital improvement constru[ction] projects, environmental policy, community [...] planning, and basic research support. State [and] federal planning and enforcement agencies [...] base their decisions on data that will withstand [the] most careful scrutiny. Long-term monitoring of [the] lake and its tributary streams, as presen[tly] accomplished by the LTIMP program, is required [as] part of the adoption of the Basin 208 Plan.

LTIMP Tributary Monitoring

Sampling Design and Schedule—Th[e] basic, long-term tributary monitoring und[er] LTIMP is currently operational on ten of th[e] basin's 63 tributaries at primary sites wh[ere] sampling is done near the point of inflow to La[ke] Tahoe. These streams include five in Califo[rnia] (Ward Creek, Blackwood Creek, General Cre[ek], Upper Truckee River, and Trout Creek) and fi[ve] in Nevada (Edgewood Creek, Logan Hou[se] Creek, Glenbrook Creek, Incline Creek, [...]

Third Creek). However, LTIMP includes an additional 22 upstream sites on these tributaries, plus First, Second, Wood, and North Logan House Creeks. The reader is referred to excellent summaries of the LTIMP stream monitoring program by Rowe and Stone (1997) and Boughton et al. (1997).

Estimated runoff volumes from each of the 63 tributaries and for each intervening zone is given in Marjanovic (1989). The watershed coverage that drains into LTIMP streams comprises just under 50 percent of the total basin area and slightly greater than 50 percent of the total tributary runoff. The Upper Truckee River alone contributes 24 percent of the total tributary flow. Snow Creek in California was part of the LTIMP sampling design between 1980 and 1985, but it is no longer monitored.

The LTIMP streams are monitored by the USGS and TRG. TRG performs nutrient chemistry, and the USGS analyzes sediment. Field measurements include instantaneous and total discharge, specific conductance, and temperature. Over the period of record, the following forms of phosphorus and nitrogen have been measured: nitrate (+nitrite), ammonium, TKN, dissolved Kjeldahl-N (DKN), SRP, total reactive-P (TRP), total hydrolyzable-P (THP), dissolved hydrolyzable-P (DHP), total dissolved-P (TDP), TP, total biologically available iron (BAFe), and dissolved BAFe. Since 1994, nutrient analysis routinely includes nitrate, ammonium, TKN, SRP, TDP, TP, and total BAFe. Typically, 30 to 50 samples are taken each year representing stream hydrology, precipitation, and surface runoff events. Samples are collected with a depth-integrating sampler and are mixed in a churn splitter. Samples for dissolved P analysis are filtered on-site through 0.45 μm membranes. Water samples for SRP, TDP, and TP raw stream water are stored at 4°C for transport and storage at the laboratory until analysis. Detailed LTIMP laboratory standard operating procedures and quality assurance/control protocol can be found in Hunter et al. (1993). Hatch (1997) provides details on specific methodologies used to measure P concentrations.

Three important milestones exist for the LTIMP tributary monitoring activities. The first milestone was its inception in Water Year (WY) 1980 (October 1979 to September 1980). At that time only Ward Creek, Blackwood Creek, Trout Creek, Upper Truckee River, and Third Creek were sampled. By WY 1981 this was expanded to include General Creek and Snow Creek. The *second milestone* was in WY 1988 when the number of stations in Nevada was increased as the USGS Carson City extended its activities in the Tahoe basin. By 1991 all of the 10 current stations were in operation. Because of funding difficulties, only Ward Creek, Blackwood Creek, General Creek, and the Upper Truckee River were sampled in WY 1986 and WY 1987. The third milestone was in the early 1990s when the basic LTIMP tributary program was again enhanced to include multiple stations (a total of three per tributary) on Incline Creek, Trout Creek, Ward Creek, and the Upper Truckee River. This multiple station monitoring on these tributaries has been continuous since WY 1991.

Data for the LTIMP nutrient (and sediment) sampling is available from a number of sources. From WY 1980 to WY 1988 the TRG published a series of annual reports, but ensuing LTIMP budgets were significantly reduced, and support was no longer available to produce these reports. In calendar year 1994, the TRG submitted a data report to the Lahontan Regional Water Quality Control Board that summarized stream nutrient concentration and load calculations from WY 1989 to 1993. Since then, the TRPA produces an annual report that summarizes the nutrient loading data calculated by the TRG. The raw concentration data also is published in the water resources data reports issued by the USGS-Nevada. Research papers and technical reports on this topic are available from the USGS, the TRG, and the TRPA.

A Brief Description of LTIMP Watersheds—In addition to the following brief descriptions of the primary LTIMP watersheds, data characterizing all the Tahoe basin watersheds (e.g., drainage area, channel length, elevation ranges, and slope) are available from the USGS (Jorgensen 1978; Cartier et al. 1995).

Ward Creek on the west shore of Lake Tahoe is primarily underlain with volcanic soils scoured by glaciers. The watershed is bound within a steep-walled canyon, with extensive human development near the mouth. As with the other nine LTIMP watersheds, the Ward Creek watershed experienced heavy logging during the late 19th century (Leonard and Goldman 1982). The upper portion of Ward Creek's north fork contains a recreational ski operation.

The Blackwood Creek watershed (west shore) is primarily underlain by volcanic and surficial deposits. The watershed is largely undeveloped, except for housing within 0.5 km of the lake; however, past disturbance has included logging, gravel excavation from the streambed/streambank, grazing, and fire. Most roads in this watershed are unpaved and subjected to intensive recreational off-road vehicle use.

General Creek (west shore), adjacent to Blackwood Creek, has been considered a "control" watershed because it has remained relatively undisturbed due to its location within a state park. This watershed has the lowest road density of the nine LTIMP watersheds. The upper regions of this watershed are underlain by glaciated granite and are in the Desolation Wilderness Area. Lower watershed areas are primarily underlain by surficial deposits.

The Upper Truckee River (south shore) watershed has the greatest area and stream discharge of all Tahoe watersheds (Dugan and McGauhey 1974). The lower meadowland reaches of the stream are extensively developed with housing, roads, commercial/industrial areas, golf courses, and an airport (Leonard and Goldman 1982). The lower watershed is composed of deep alluvial soils, while the upper undeveloped reaches contain steep granitic soils with some volcanics at the south end.

The Trout Creek (south shore) watershed is immediately to the east of the Upper Truckee River, with two major subwatersheds of Cold Creek and Saxon Creek. The lower reaches of Trout Creek flow through flat meadowlands subjected to extensive human development, but the undeveloped upper watershed is composed of steeper gradients and mixed coniferous forests above 2,800 m (Leonard and Goldman 1982). A large ski resort covers a significant amount of the steeper watershed areas. Trout Creek and Upper Truckee River converge near the lake in the Upper Truckee Marsh, which was disturbed extensively by excavation and construction of a large housing subdivision/marina in the 1960s.

Logan House Creek (east shore) is relatively steep along its entire length. Primarily underlain by metamorphic and granitic rock, the watershed has the lowest road length and the smallest area of the nine LTIMP watersheds. The watershed is largely undeveloped, and, as with other watersheds on the east shore, it typically receives half the precipitation of the west shore, due to a "rain shadow" effect.

Glenbrook Creek (east shore) is north of the Logan House Creek watershed and composed primarily of volcanic and decomposed granitic rock. The upper regions are steep and undeveloped, while the middle regions have extensive highway road cuts. The lower watershed area is relatively flat with light to moderate development. Glenbrook Golf Course is within this watershed.

The Incline Creek (northeast shore) watershed consists of mountainous canyons primarily underlain by granitic bedrock with scattered volcanic deposits. The upper parts of the watershed are forested subalpine bowls, while the lower sections are less steep and consist of alluvial wash deposits. Human development is extensive near the lakeshore, including residential and commercial structures, golf courses, and a ski resort.

The Third Creek (northeast shore) watershed is immediately west of Incline Creek and also has been subjected to extensive human disturbance, including two golf courses. Third Creek extends several hundred meters higher in elevation than Incline Creek, with the upper area consisting of a large subalpine bowl. The lower watershed is narrow and relatively steep. The Third and Incline Creek watersheds experienced heavy disturbance in the 1960s and 1970s while Incline Village was being constructed. The mouths of these two streams are less than 50 m apart. Third Creek was the site of a large snow avalanche above Highway 431 in February 1986.

Stream Phosphorus Concentrations and Transport

Phosphorus source/sink behavior is much more difficult to characterize than that for nitrogen. Although phosphate (PO_4^{-3}) is highly soluble and therefore quite mobile, it has a distinct propensity to become strongly attached to mineral and organic particulates. Consequently its mobility in watersheds is related to sediment transport. Dissolved P moving through the soil is affected by adsorption, desorption, and biological activity. Particulate P levels, on the other hand, changes with the condition of a stream channel and stream discharge. Recent research suggests that P also can form mobile complexes with mineral/organic colloids (Rhea et al. 1996; ...low 1998).

Relations among Movement of Nutrients, Water, and Sediment

Incline Village Tributaries—Glancy (1988) published a report on streamflow, sediment transport, and nutrient transport at Incline Village from 1970 to 1973. That study was designed to develop a basic knowledge of fundamental hydrologic parameters within the Incline Village study area, to provide some local perspective on alleged or suspected basin-wide problems, to demonstrate the technical and economic feasibility of acquiring certain types of essential hydrologic knowledge, to launch a first approximation effort to obtain data on nutrient transport by streamflow, and to provide databases and knowledge to allow and encourage more detailed and efficient future studies. The discussion below was taken directly from that report.

The nutrient data used in Glancy (1988) came from previously published progress reports (Glancy 1971, 1973, 1976a, b). (A review of the sediment portion of this work is summarized later in this section.) The nutrient data for this study were purposely collected during times of intensive sediment movement to assess conditions during periods of potentially intense erosion. The sampling strategy was not intended to document seasonal or long-term changes. While much of the evaluation focuses on Third and Incline Creeks, data from a similar study for Glenbrook Creek (Glancy 1977) also are analyzed. The studies include a discussion of a number of forms of phosphorus and nitrogen (dissolved, particulate, and total), as well as sediment and hydraulic discharge.

The measured concentration ranges for the three streams were similar, albeit, with a few notable exceptions. Glancy concluded that the "tentative study-period trends of ammonium and ortho-phosphate suggest accelerated nutrient movement during early phases of urban development when effects of land clearing and road construction may have triggered higher-than-normal nutrient releases from freshly disturbed surficial earth materials." He goes on to state, however, that such an implication is tenuous because of insufficient data.

Nutrient movements near the mouths of Third and Incline Creeks were analyzed both graphically and by statistical regression. Plots of nutrient transport rates versus streamflow and sediment transport showed some apparent relationships. This level of analysis indicated that most nutrients moving to the lake tended to increase as flow and sediment discharge increased. However, Glancy noted that the overall poor graphical correlations between most nutrient forms, and either streamflow or sediment transport suggest that nutrient movement may be influenced by other factors.

The statistical evaluations performed were intended to supplement the graphical categorizations. Reliance on the linear regression analyses was downplayed because many of the relationships among nutrient, flow, and sediment transport were curvilinear rather than linear. The correlation coefficients indicated that nutrient movement correlates better with sediment transport than with streamflow. These observations support the widely held contention that erosion and nutrient transport to the lake are related. The fact that the correlations for the less developed Glenbrook watershed were better than for either Third or Incline suggested that the relationship between erosion and nutrient transport is better defined in minimally developed areas. However, as Glancy stressed, the numerically small correlation coefficients suggest that the relations between erosion and nutrient transport are probably quite complex.

Data for Third and Incline Creeks further showed that fine-grained sediment (<63 μm and thus finer than sand) correlates better with nutrients than does coarse-grained sediment (≥ 63 μm) in about two-thirds of the regression analyses. The regression equation exponents were larger for the relationships between fine-grained sediment and nutrients versus coarse-grained sediment and nutrients, perhaps implying that nutrient transport is more sensitive to the movement of fine-grained material. However, many of the correlations for both coarse- and fine-grained sediment were observed to be only slight, and caution should be exercised in interpreting these results.

Ward Creek—A comprehensive paper on nutrient transport in surface runoff within the Ward Valley watershed was published by Leonard et al. (1979). Along with Glancy (1988), this remains one of the most comprehensive peer-reviewed works on tributaries in the Tahoe basin. These two documents have provided significant background and intellectual guidance for not only LTIMP but for many of the current investigations into discharge, nutrient transport, and sediment transport in Tahoe's tributaries. Below, excepts from the extended abstract and conclusions from the Leonard et al. paper are reviewed.

TRG investigations of nutrient and sediment transport in Ward Valley began in 1971. LTIMP monitoring has been continual since WY 1980 and current UC Davis-TRG hydrologic and sediment transport modeling focuses on Ward Valley (Kavvas et al. 1998). Quantitative data on selected stream water parameters were collected and evaluated by Leonard et al. (1979) for the period from 1972 to 1975 at three stations on Ward Creek, two on the main upper tributaries, and one near the stream mouth. Comparable data were collected at a stream mouth station on adjacent Blackwood Creek in the third year. The parameters were initially selected on the basis of their importance in eutrophication of Lake Tahoe. Sampling schedule and methodologies were similar to the current LTIMP program in that this study served as the precursor to LTIMP.

Sediment and nutrient loading to Lake Tahoe from Ward and Blackwood Creeks reflects a history of soil disturbance and vegetation removal. Logging, fire, and stream channel diversion have been dominant perturbations. Precipitation throughout the watershed during a normal year was primarily snow, but annual patterns varied widely, and rainfall at any time of year can be important in sediment and nutrient transport. Water discharge and the flux of suspended sediments, nitrate, phosphorus, iron, and trace metals was dominated by spring snowmelt runoff from mid-April to mid-June. However, in 1974 heavy fall and summer rain accounted for a large percentage of the annual flux of sediments and nutrients in a total of only 14 days (this phenomenon has been observed in other years since this study but is not common). Spring runoff was characterized by distinct diel water discharge patterns. Similar but not coincident patterns were found to exist for sediments and nutrients, including nitrate but not soluble-P. The Ward watershed has 87 percent of the area of Blackwood but discharged proportionately lower quantities of sediment and nutrients in terms of comparable water yield per hectare. This contrast may be explained in part by the history of greater disturbance in Blackwood Canyon.

The principal source of suspended sediments in Ward Creek was streambank erosion in the lower reaches of the channel. The dominant form of inorganic-N was nitrate derived from precipitation, terrestrial N_2-fixation, and the nitrification of organic-N in forest soils. As observed by Glancy for Incline and Third Creeks, organic-N dominated the total-N flux. Phosphorus and iron were almost entirely in particulate form; thus, their dominant periods of flux occurred during high flows and sediment transport.

Five Year LTIMP Review—In 1986, Byron and Goldman issued a report summarizing the first five years of LTIMP. Findings of climatic effects (precipitation and runoff) appeared to have a dominant influence on stream water quality. Variation in water discharge is known to have a confounding effect on studies of long-term changes in stream water quality. The dominance of strong seasonal, storm-related, and year-to-year variation in discharge patterns can result in large fluctuations in volume-weighted concentrations (Byron and Goldman 1986). The results of multivariate statistical techniques to remove the effects of water discharge showed that Blackwood and Trout Creeks had a significantly decreasing nitrate concentration over the period from 1976 to 1985. TP and TSS did not show significant trends over time, but this may have been related to the shorter data records for these constituents.

The improvement in Blackwood Creek nitrate concentration was attributed to the gradual stabilization of in-channel disturbance. The reduction of nitrate concentration in Trout Creek was a more uniform change from year-to-year. Land disposal of secondary treated sewage occurred in this watershed from 1960 to 1965. With continuous leaching over the years, residual storage of nitrate was hypothesized to be gradually depleted.

Multiple Watershed Scale

While nearly 19 years of data now exist for a few LTIMP streams, many did not enter the program until the late 1980s. The LTIMP stream data set is consistent from WY 1989 to WY 1998 for the nine streams described above. Hatch (1997) examined the LTIMP stream phosphorus database from WY 1989 through WY 1996. One objective of that study was to characterize the LTIMP stream P data set by examining and comparing the P concentration and load databases on watershed. The discussion below comes directly from Hatch (1997). These analyses are helpful in understanding the variability of stream P delivery to Lake Tahoe at different spatial and temporal scales. Identifying watershed characteristics that are potentially influencing P delivery is important to the future management of Tahoe basin resources.

Data Reduction—During WY 1995, TDP was assayed for all stream samples, along with TP and SRP (Hatch 1997). Subtraction of TDP from TP yields particulate P (PP), while subtraction of SRP from TDP yields dissolved organic P (DOP). Phosphate (PO_4^{-3}) is assumed to be estimated by SRP (dissolved inorganic P). These four operationally defined P fractions (TP, PP, DOP, and PO_4^{-3}) were examined only for WY 1995, due to minimal TDP analyses for the rest of the WY 1989 to 1996 period (typically only eight to [illegible] TDP assays per stream per year). Presentation of the entire WY 1989 to 1996 data set considered TP and PO_4^{-3} only.

The WY 1989 to 1996 period covered five years of drought (WY 1989, 1990, 1991, 1992, and 1994) and three wet years (WY 1993, 1995, and 1996). For comparison, the WY 1981 to 1986 period included two years of drought (WY 1987 and 1988) and six wet years (WY 1981, 1982, 1983, 1984, 1985, and 1986). The representativeness of the WY 1989 to 1996 data (eight years) must be interpreted in light of drought conditions common during this period. It is clear, however, that much of the interannual variability in stream nutrient loading is due to differences in annual precipitation.

Two common methods for calculating annual and monthly concentration means are unweighted and discharge-weighted averaging. Unweighted averaging involves adding all concentrations for a given period and dividing by the total number of samples. Discharge weighting sums the instantaneous concentration-discharge products for a given period, then dividing this number by the sum of all sampling event instantaneous discharges for the same period. Discharge weighting (Yaksich and Verhoff 1983) may be useful to normalize for differences in concentrations due to varying discharges between sampling periods on a single creek and between creeks with highly different discharge ranges. Discharge weighting also gives more importance to high discharge concentrations (Galat 1990). Lewis et al. (1984) assert that for highly variable discharge systems in mountainous areas, discharge weighting best represents the chemical constituents accumulated in proportion to discharge, more accurately reflecting the conditions of the receiving lake. Based on these considerations, the discharge weighting method of mean calculation is used in this study. Standard errors are calculated using the instantaneous concentration values.

P loads (mass per unit time) were calculated using the rating curve method for individual water years as follows:

$$\text{Log}(TP_i * Q_i) = a + b * (\text{Log } Q_i)$$

$$\text{Daily Load (kg)} = (Q_d^{\,b}) * (10^a) * 86{,}400 * (10^{-9}) * \exp(2.65 * \text{MSE}).$$

The first equation generates the regression constants a and b along with the mean squared error (MSE) using all TP_i (instantaneous TP concentrations) and Q_i (instantaneous discharges) for a given water year and stream station. The second equation uses a, b, MSE, and Q_d (mean daily discharge for a given day) to generate daily loads. The daily loading equation uses an adjustment of 86,400 seconds per day and 10^{-9} kilograms per microgram. The "anti-logging" procedure in the second equation is corrected by exp (2.65 * MSE) to account for the fact that anti-logging results in the geometric mean rather than the desired arithmetic mean (Ferguson 1986). This technique was recommended by the USGS in the Tahoe basin to compute stream loads. Daily loads were summed for monthly and annual loads. TP, PP, DOP, and PO_4^{-3} loads for the present study were calculated using this rating curve method.

Annual Variation in Stream Phosphorus Loads and Concentrations--Phosphorus loads were dominated by the particulate-P fraction (PP), which comprised 56 to 94 percent of the WY 1995 TP load for LTIMP streams (Figure 4-1). Maximum PP loads were 6,824 kg/year for the Upper Truckee River, followed by Third Creek (4,618 kg/year), Blackwood Creek (3,569 kg/year), Trout Creek (2,565 kg/year), and Ward Creek (2,465 kg/year). Mean annual WY 1989 to 1996 TP loads (Table 4-1) also were dominated by the Upper Truckee River (3,364 kg/yr), followed by Blackwood Creek (1,927 kg/yr), Trout Creek (1,281 kg/yr), Ward Creek (1,250 kg/yr), and Third Creek (1,120 kg/yr). Mean annual TP loads for the remaining streams ranged from 9 to 560 kg/yr. Annual TP load variation increased as load increased.

With respect to the dissolved P fraction the DOP contribution to TP load during W 1995 ranged from three to 29 percent, with the largest DOP loads coming from the Upp Truckee River (1,806 kg/year), Trout Creek kg/year), Blackwood Creek (655 kg/year) Ward Creek (445 kg/year). PO_4^{-3} compr three to 17 percent of TP load, with the lar loads from the Upper Truckee River (kg/year), Trout Creek (598 kg/year), Ward C (322 kg/year), and Blackwood Creek (kg/year). Annual WY 1989 to 1996 PO_4^{-3} were less variable than TP loads, although relative order of ranking by LTIMP stream similar (Table 4-2). The Upper Truckee R averaged the highest mean annual PO_4^{-3} with 451 kg/yr, followed by Trout Creek kg/yr), Blackwood Creek (158 kg/yr), and W Creek (149 kg/yr). The remaining stre contributed 1 to 80 kg/yr PO_4^{-3} per year.

Mean annual, discharge-weighted concentrations for LTIMP streams were present as PP, comprising 58 to 96 percent of TP concentration in WY 1995 (Figure 4-1). highest mean PP concentration was 544 µg/L Third Creek, followed by Incline Creek µg/L), Blackwood Creek (114 µg/L), and W Creek (103 µg/L). Standard deviations for P WY 1995 were similar in magnitude to the means (76 to 133 percent of annual mean). 1989 to 1996 TP mean concentrations (Table were also highly variable between the

Table 4-1—Mean annual phosphorus parameters for LTIMP streams, Water Years 1989-1996. All concentra means are discharge-weighted. TP = total P, PO_4 = phosphate. Parentheses: standard deviation for loads, SE for concentrations.

Stream	TP Load (kg)	PO_4 Load (kg)	TP Conc. (µg L^{-1})	PO_4 Conc (µg L^{-1})
Blackwood	1927 (1966)	158 (99)	77 (33)	6 (0)
General	324 (262)	63 (41)	24 (6)	4 (0)
Glenbrook	137 (184)	32 (45)	101 (16)	19 (1)
Incline	560 (550)	80 (63)	111 (20)	19 (1)
Loganhouse	9 (11)	1 (1)	33 (4)	4 (0)
Third	1120 (1315)	69 (39)	220 (76)	14 (1)
Trout	1281 (1115)	249 (197)	65 (5)	11 (0)
Upper Truckee	3364 (3010)	451 (372)	61 (5)	7 (1)
Ward	1250 (1261)	149 (116)	63 (40)	7 (1)

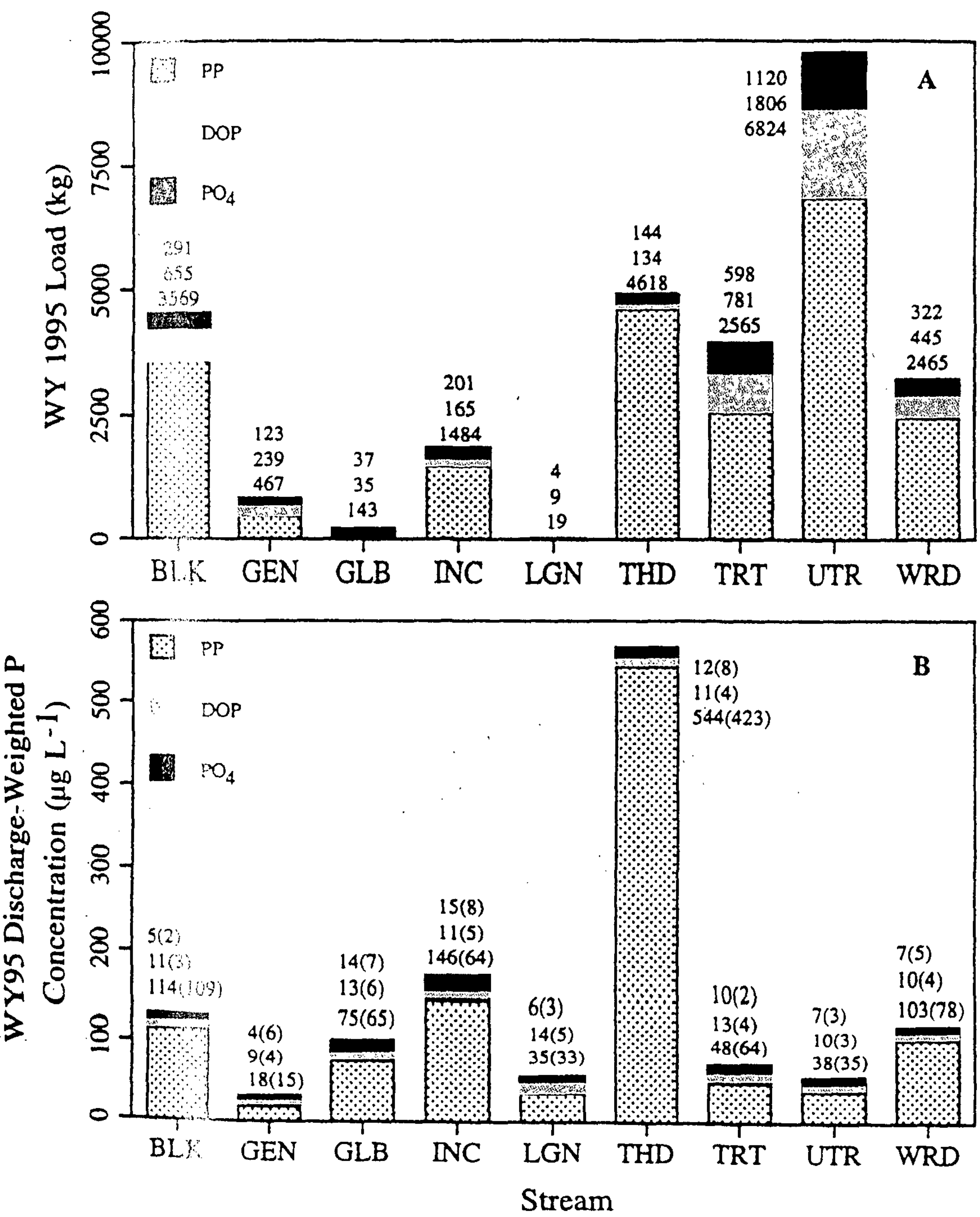


Figure 4-1—Concentrati... and total for PP, DOP, and PO4 at LTIMP stream mouth stations during Water Year 1995 (from Hatch 1997).

Table 4-2—Concentration and load rankings for LTIMP streams. Concentrations in $\mu g\ L^{-1}$, loads in kg (Hatch 1997). PO_4 = phosphate, TP = total P, PP = particulate P, DOP = dissolved organic P.

	WY95 Mean Annual Rankings[1]							
Stream	TP Conc. Rank	TP Load Rank	PP Conc. Rank	PP Load Rank	DOP Conc. Rank	DOP Load Rank	PO_4 Conc. Rank	PO_4 Load Rank
Blackwood	3	3	3	3	4	3	8	4
General	9	7	9	7	9	5	9	7
Glenbrook	5	8	5	8	2	8	2	8
Incline	2	6	2	6	4	6	1	5
Loganhouse	7	9	8	9	1	9	7	9
Third	1	2	1	2	4	7	3	6
Trout	6	4	6	4	2	2	4	2
Upper Truckee	7	1	7	1	7	1	5	1
Ward	4	5	4	5	7	4	5	3

	Peak Monthly Mean P Values and Rankings for the WY89-96 Period[2]							
Stream	TP Conc.	TP Conc. Rank	TP Load	TP Load Rank	PO_4 Conc.	PO_4 Conc. Rank	PO_4 Load	PO_4 Load Rank
Blackwood	185	3	713	2	6	6	43	4
General	45	7	114	7	4	9	17	5
Glenbrook	102	5	40	8	16	1	8	8
Incline	147	4	125	6	14	2	16	6
Loganhouse	52	6	4	9	5	8	0.5	9
Third	468	1	329	4	114	3	13	7
Trout	45	7	295	5	9	4	52	2
Upper Truckee	45	7	974	1	6	6	124	1
Ward	260	2	496	3	8	5	46	3

Notes:
[1]Rankings according to values in Figure 2.
[2]Values represent the annual peak mean monthly values.

streams. Third Creek had the largest annual discharge-weighted TP concentration (220 µg/L), followed by Incline Creek (111 µg/L), Glenbrook Creek (101 µg/L), and Blackwood Creek (77 µg/L). Trout Creek, the Upper Truckee River, and Ward Creek had moderate TP concentrations (61 to 65 µg/L), followed by Logan House Creek (33 µg/L) and General Creek (24 µg/L).

For dissolved P discharge-weighted concentrations, DOP comprised two to 29 percent of the mean annual TP in terms of concentration, with levels ranging from 9 to 14 µg/L for all streams during WY 1995 (Figure 4-1). DOP standard deviations were lower than those for PP, ranging between 27 and 46 percent of the annual DOP mean. PO_4^{-3} contributed two to 14 percent of the TP concentration, with values of 15 µg/L for Incline Creek, 14 µg/L for Glenbrook Creek, and 12 µg/L for Third Creek. The remaining streams had PO_4^{-3} concentrations ranging from 4 to 10 µg/L for annual means. PO_4^{-3} standard deviations were smaller in magnitude than those seen for PP but comprised 20 percent to 150 percent of the mean annual PO_4^{-3} concentration. Annual means and standard deviations for DOP and PO_4^{-3} were similar for WY 1995. WY 1989 to 1996 PO_4^{-3}

concentrations (Table 4-1) did not vary between streams on a mean annual basis (4 to 19 μg/L), and standard errors were small (≤ 1 μg/L). Glenbrook Creek and Incline Creek had the largest mean annual PO_4^{-3} concentrations of 19 μg/L, while General Creek and Logan House Creek had the smallest values at 4 μg/L. In general, annual TP and PO_4^{-3} concentrations for the WY 1989 to 1996 period were very similar to those for WY 1995.

Previous stream studies at Lake Tahoe from WY 1970 to 1973 on Glenbrook Creek, Incline Creek, and Third Creek also found TP concentration to consist of 83 percent, 83 percent, and 69 percent PP for these streams, respectively (Glancy 1977, 1988). Past studies on Ward Creek in the Tahoe basin showed that 84 percent of annual TP load was PP (Leonard et al. 1979), which is similar to the 76 percent value for Ward Creek in WY 1995. Relevant literature data from other high-mountain landscapes is rare. Leonard et al. (1979) found that PO_4^{-3} load comprised 11 percent of TP load for Ward Creek, which is very close to the 10 percent value for WY 1995. Several sources of DOP may be present in Tahoe streams, including periphyton exudates (Perkins 1976), senescing vegetation, streambank roots and fauna, and abandoned septic leach fields. Meyer (1979) argued that decomposing organics on the stream bottom (e.g., leaf litter) are important sources of DOP, while Kaplan et al. (1975) contended that the Ward Creek microbial community is important in breaking down stream organic material.

Monthly Variation in Stream Phosphorus Loads—Mean monthly P concentrations were highly variable for the LTIMP streams (Hatch 1997); monthly P loads, however, were greatest during the spring snowmelt. Using the Upper Truckee River during WY 1995 as an example, 77 percent of the PP load, 70 percent of the DOP load, and 73 percent of the PO_4^{-3} load occurred during the May-July period, while 92 percent of the PP load, 87 percent of the DOP load, and 89 percent of the PO_4^{-3} load occurred during the March-July period (Figure 4-2). During WY 1995, mean monthly PP loads ranged from 3 to 2,470

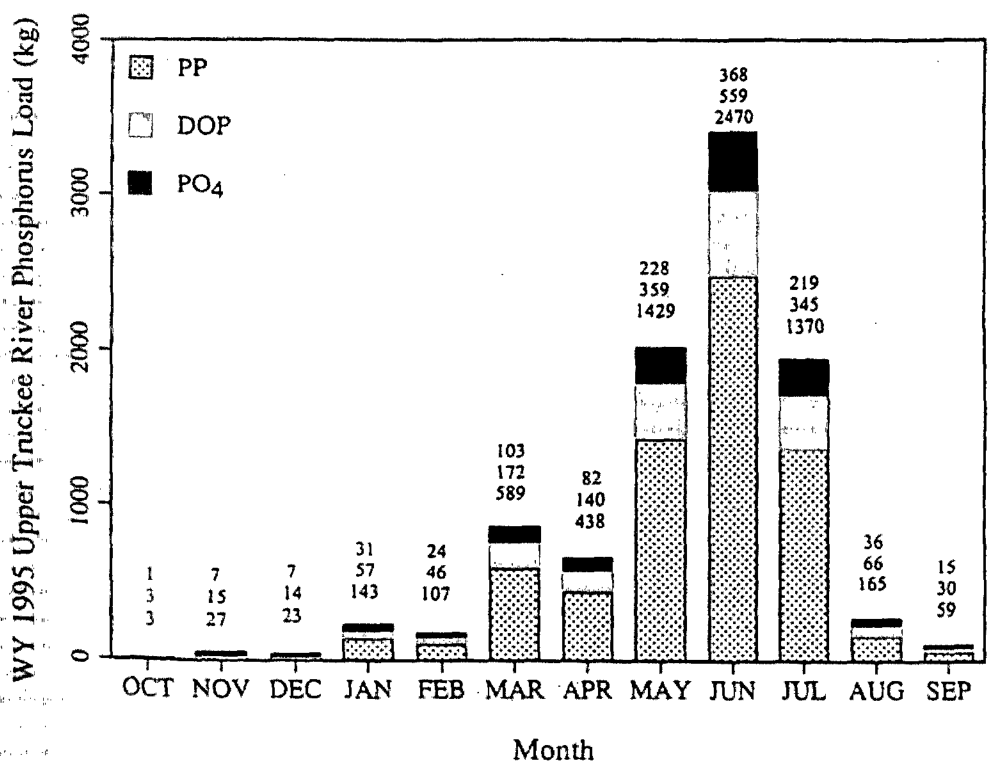


Figure 4-2—Seasonal distribution of PP, DOP, and PO4 at the mouth of the Upper Truckee River during Water Year 1995 (from Hatch 1997).

kg/month, DOP loads ranged from 3 to 559 kg/month, and PO_4^{-3} loads ranged from 1 to 368 kg/month. As expected, mean monthly WY 1989 to 1996 TP loads also peaked at the height of the spring snowmelt (Hatch 1997). Phosphorus and suspended sediment concentrations also have been reported as being higher during the rising stage of stream flow, as the channel is flushed (Drivas 1986).

Concentration versus Load—Examining P concentration-load ranking differences on a monthly basis is best represented by using TP and PO_4^{-3} data from WY 1989 to 1996 (Table 4-2). Peak monthly loads during this period occurred during either May or June. The top three TP concentration rankings were occupied by Third Creek, Ward Creek, and Blackwood Creek. These streams ranked fourth, third, and second for TP loads. The Upper Truckee River, however, was ranked first with respect to TP load, but seventh with respect to TP concentration. The remaining streams ranked lower for both TP concentration and load. Mean annual PO_4^{-3} concentration rankings behaved differently than TP rankings. Although Glenbrook, Incline, and Third Creeks ranked as the top three PO_4^{-3} concentrations for the May/June period, these streams ranked near the bottom with respect to loads (8th, 6th, and 7th, respectively). The streams ranking first, second, and third in peak PO_4^{-3} loads (Upper Truckee River, Trout Creek, and Ward Creek) occupied the middle range of PO_4^{-3} concentration ranks at sixth, fourth, and fifth, respectively. The lowest ranked streams for PO_4^{-3} concentration (Logan House and General Creeks) occupied PO_4^{-3} load rank positions of ninth and fifth, respectively. As seen for the WY 1995 rank comparisons for annual P means, the WY 1989 to 1996 peak monthly mean comparisons also indicate that LTIMP streams with the highest P concentrations do not necessarily have the highest P loads, and vice versa.

Precipitation, Discharge, and Suspended Sediments—Precipitation, discharge, and suspended sediment analyses can be used to help explain the observed P variations in LTIMP streams. Precipitation in the Tahoe basin falls predominantly from October to March. Although most of this precipitation is snow, the large heat capacity of Lake Tahoe, which never freezes, creates a microclimatic effect. Estimates that 90 percent of Sierra Nevada precipitation is in the form of snow (Kattelmann 1990) may not agree with precipitation behavior at the near-lake elevations in the Lake Tahoe basin, which included large amounts of rain.

A significant relationship exists between annual precipitation (over each individual watershed) and annual areal discharge (liters/hectare) in LTIMP streams (Hatch 1997). This relationship occurred for both the inter-watershed WY 1989 to 1996 annual mean (r^2 = 0.911, $p < 0.001$, n = 9 watersheds) and the individual intra-watershed WY 1989 to 1996 means (all r^2 values ≥ 0.802, all p-values < 0.001, n = 8 water years per stream).

The net result of heavy winter precipitation is large stream discharges during the spring snowmelt, as indicated by P loads in Figure 4-2. Hatch (1997) demonstrated that peak monthly discharges during the WY 1989 to 1996 period occurred in May for the Upper Truckee River (211 x 108 L/month), Blackwood Creek (89 x 10^8 L/month), Ward Creek (66 x 10^8 L/month), General Creek (47 x 10^8 L/month), Incline Creek (11 x 10^8 L/month), Glenbrook Creek (3 x 10^8 L/month), and Logan House Creek (1 x 10^8 L/month). June discharge peaks occurred for Trout Creek (57 x 10^8 L/month) and Third Creek (14 x 10^8 L/month).

Suspended sediment is an important substrate for transport of P in stream systems (Logan 1987). There was a strong significant relationship ($p < 0.05$, n = 7 water years per stream) between intra-watershed annual TSS and TP concentrations (Hatch 1997) and also for WY 1989 to 1996 annual inter-watershed stream means ($r^2 = 0.84$, $p < 0.001$, n = 9 streams). A similar and even stronger correlation was seen between inter-watershed TSS and PP concentrations (r2 = 0.90, $p < 0.001$, n = 9 streams), although there were fewer measures of PP (approximately 8 to 12 per year per stream) than for TP (approximately 30 to 50 per year per stream). Kronvang et al. (1997) argue that as the proportion of PP to TP increases, there is a stronger association of both PP and TP with TSS. These relationships were also significant for intra-watershed annual means for all nine LTIMP streams, although outliers were present for Incline Creek, Logan House Creek, and Third Creek (Hatch 1997).

Relationships between TSS and DOP and between TSS and PO_4^{-3} concentrations were very poor, with few significant ($p < 0.05$) relationships for either intra-watershed or inter-watershed comparisons. The general lack of significant relationships between TSS and either DOP (r^2 = 0.03, p = 0.633, n = 9 streams) or PO_4^{-3} (r^2 = 0.09, p = 0.430, n = 9 streams) concentrations is not surprising because dissolved P by definition is not directly bound to particles; i.e., dissolved P passes through a 0.45 μm membrane.

Single Watershed Scale

Justification for Approach—While point sources of phosphorus (P) can be readily identified and sometimes controlled in efforts to halt lake eutrophication, nonpoint sources of P are closely linked to land use and thus are more difficult to quantify due to the physical scale of the problem (Omernik 1977; Correll 1977; Bordas and Canali 1980). In lieu of collecting an unwieldy amount of data on the scale of hundreds of hectares, an effective way to approach this dilemma has been to divide a watershed into several areas of differing land uses. For example, Dillon and Kirchner (1975) found that there was an increase in P export as one moved from forest to pasture to agricultural/urban watersheds. This supports the use of a single watershed as a conceptual framework for studying sources and transport of nonpoint source nutrient and sediment loading.

Hatch (1997) and Hatch et al. (1999) also analyzed the LTIMP database at the watershed scale using concentration and load values for phosphorus collected during WY 1991 to 1996 for Incline Creek (INC), Ward Creek (WRD), Trout Creek (TRT), and the Upper Truckee River (UTR). Three stations were monitored as part of LTIMP on each of these tributaries.

Site Description—Stream station INC3 is above human development, integrating the effects of forested subalpine bowls upstream. Station INC2 is farther downstream, representing the cumulative east branch of the creek. Between stations INC3 and INC2, the stream passes through residential development, a ski resort, and a golf course. Station INC1 is near the stream mouth, a few hundred meters downstream of INC2. The location of INC1 allows one to infer the effects of the west branch of Incline Creek, which passes through residential areas and part of a golf course.

Station TRT3 is high in the Trout Creek watershed, above areas of human development. This station integrates the effects of steep gradients and mixed coniferous forests above 2,800 m (Leonard and Goldman 1982). Station TRT2 is farther downstream, where the effects of human development on the stream first occur. Station TRT1 is in relatively flat meadowlands near the stream mouth within extensive development.

The Upper Truckee River is directly west of the Trout Creek watershed and has the greatest area and stream discharge of all Tahoe watersheds. Station UTR5 is immediately above the first instances of human development on the stream, although a small summer cattle grazing operation occurs several kilometers upstream. Steep granitic soils are present, with some volcanics at the south end. Station UTR3 is downstream of station UTR5 and represents an area under moderate development. Station UTR1 is near the stream mouth and sits on deep alluvial soils. Human development is heavy between stations UTR3 and UTR1 and includes housing, roads, commercial/industrial areas, golf courses, and an airport. The Upper Truckee River and Trout Creek converge near the lake in the Upper Truckee Marsh, which has been disturbed extensively from the development of a large residential marina.

Within the steep-walled Ward Creek watershed, station WRD3A is below the confluence of the two major upstream bowls, with minimal effects of development (one back bowl of a ski resort). Station WRD7A is farther downstream just below the last tributary confluence. Station WRD8 is near the lake within a region of significant human development.

Data Reduction Techniques—Using topographic divides for delineation, each stream was divided into three subwatersheds according to water quality station locations. Areal P loads for each subwatershed represent that area contributing P to a given gauging station. For example, the INC2 subwatershed includes all the area below station INC3 and its drainage but above the area that drains solely into station INC1. Areal loads (kg P/ha/yr) were calculated by subtracting upstream loads (kg/yr) from downstream loads (kg/yr), then dividing by the area of the watershed draining solely into the downstream gauging station.

Station Differences on the Annual Time Scale

The LTIMP data on multistation streams from WY 1991 to WY 1996 allow examination of P trends on an annual scale. This period was composed of below-average, average, and above-average precipitation years (Tahoe City precipitation [1931-1994 WY mean = 81 cm/yr]: WY 1991 = 58 cm, WY 1992 = 48 cm, WY 1993 = 105 cm, WY 1994 = 42 cm, WY 1995 = 154 cm, WY 1996 = 124 cm). Mean annual discharges increased in the downstream direction for each stream due to the cumulative contributions of tributary and ground water sources (Figure 4-3). Incline Creek stations had the lowest discharge values, with larger values for Trout Creek and Ward Creek. The Upper Truckee River had the greatest mean discharge.

P Concentration—Within-stream TP behavior was not the same for the four LTIMP streams (Figure 4-2C). TP concentrations increased downstream for Incline Creek, although INC1 and INC2 were not statistically different ($p>0.05$). Conversely, Trout Creek TP concentrations decreased in the downstream direction. The UTR1 TP concentration (43 μg/L) was statistically different from UTR3 (33 μg/L), but UTR1-to-UTR5 and UTR3-to-UTR5 TP concentrations were not statistically different. Despite the statistical difference between UTR1 and UTR3, the absolute magnitude of this difference was not great and may be of little practical significance. WRD7A and WRD3A had the same mean annual TP concentration, both being approximately half that recorded at the most downstream station at WRD8.

Analysis of TDP for the multistation streams during WY 1995 facilitated the calculation of PP, DOP, and PO_4^{-3} concentrations and loads. Particulate-P concentrations were not statistically different for INC2 and INC3, but both these stations were less than INC1. There were no statistical PP concentration differences between the three Trout Creek stations. There were also no statistical PP concentration differences between the two upper stations for the Upper Truckee River and Ward Creek, but the two upper stations were different from their respective stream mouth stations.

Mean annual PO_4^{-3} concentrations were quite similar for stations on the same stream. Incline Creek had the highest PO_4^{-3} values, ranging from 12 to 15 μg/L. Trout Creek had relatively intermediate concentrations at about 8 to 10 μg/L, while Ward Creek and the Upper Truckee River showed the lowest values at approximately 5 to 7 μg/L.

The WY 1995 data show within-watershed differences for DOP and PO_4^{-3} were minimal and most likely of little ecological significance in the streamflow. In Incline Creek, PO_4^{-3} concentrations were a few μg/L higher than DOP (11 to 15 μg/L vs. 10 to 12 μg/L), while just the opposite was recorded for Trout Creek. DOP for the Upper Truckee River and Ward Creek were noticeably higher than PO_4^{-3} (9 to 12 μg/L vs. 4 to 7 μg/L).

P Load—TP loads and PO_4^{-3} loads for the WY 1991 to 1996 increased in the downstream direction for all four streams. This condition reflects the fact that discharge, a major component of load calculation, always increased in the downstream direction. WY 1995 PP, DOP, and PO_4^{-3} loads also typically increased in the downstream direction for all streams. In general, the greatest loading increases occurred between the upper and middle stream stations for all three P fractions for each stream. For example, PP load increased greatly between TRT3 (649 kg) and TRT2 (2,078 kg), with a smaller increase between TRT2 and TRT1 (2,551 kg). An exception was the change for PP load between UTR3 (2,533 kg) and UTR1 (6,816 kg).

Subwatershed Phosphorus Characteristics—Stream P loads, not concentrations, are what actually affect Lake Tahoe phytoplankton as a whole. Adjusting stream loads by basin area assigns P loading values to specific areas of land. Because direct comparison of subwatershed areal

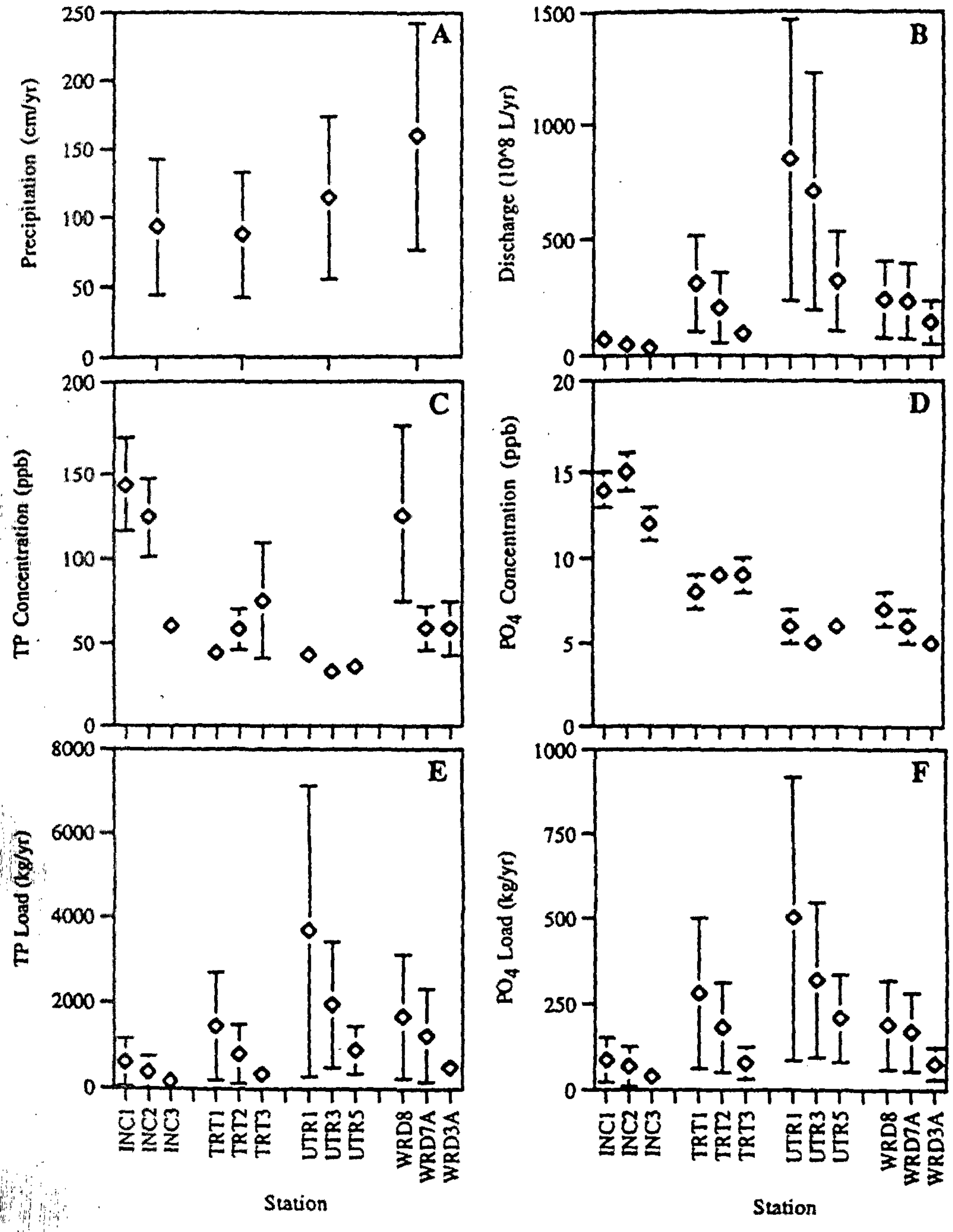


Figure 4-3—Annual precipitation, discharge, and phosphorus fractions for the multistation LTIMP creeks from Water Year 1991 to 1996 (from Hatch 1997).

P loads (kg/ha/yr) and discharge can result in spurious correlations due to a strong discharge-load relationship, it is more appropriate to compare areal P loads with precipitation.

Areal TP loads generally increased with increasing precipitation for the four LTIMP streams during the WY 1991 to 1996 period (Figure 4-4; note differences in axis ranges between creeks). The WRD3A (i.e., most upstream) subwatershed areal TP loads did not increase greatly with precipitation levels. Differences in areal TP loading between

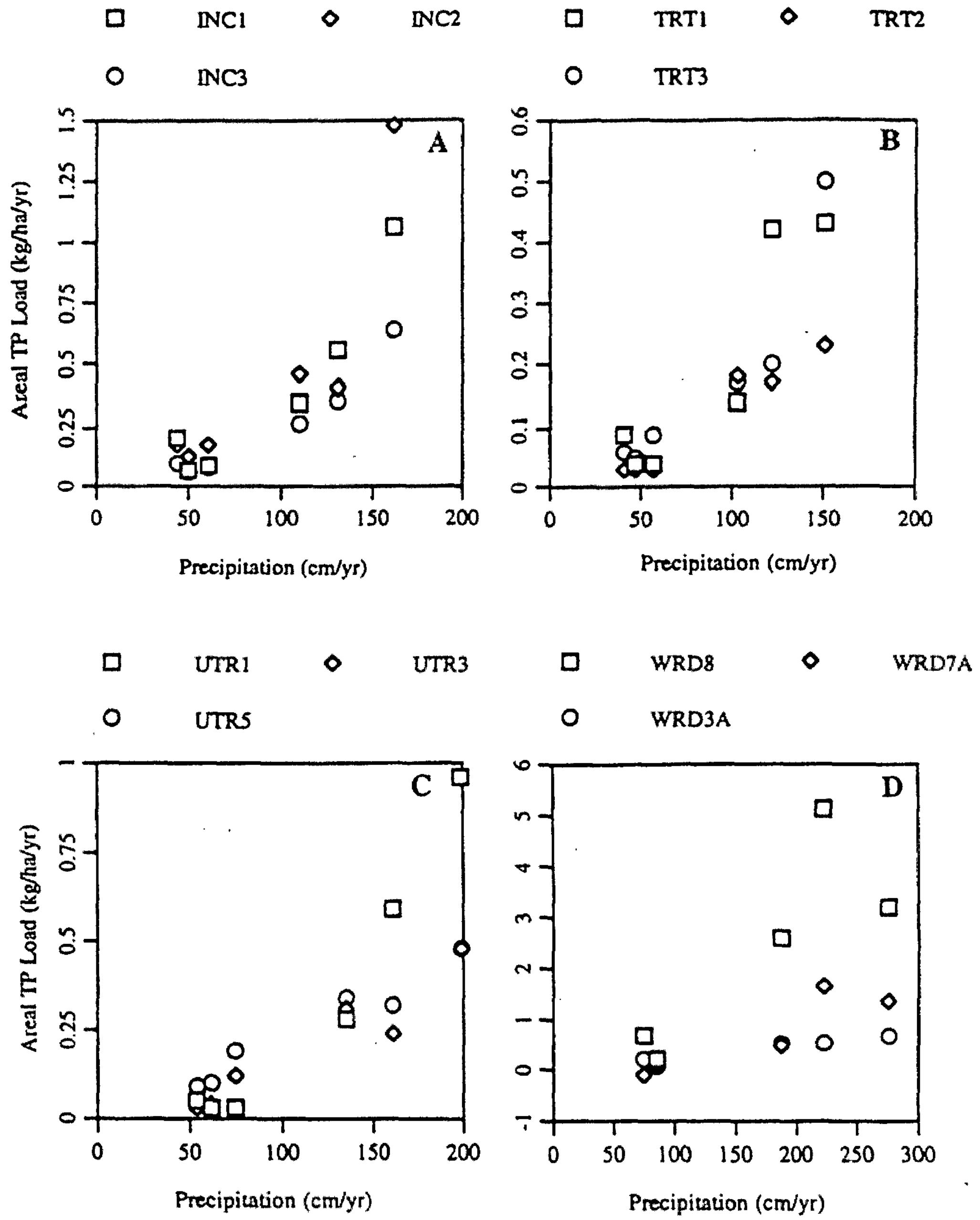


Figure 4-4—Relationship between areal TP load and precipitation for the subwatersheds defined by the multistation sampling design on four LTIMP creeks (from Hatch 1997).

subwatersheds on the same stream were minimal during relatively low precipitation years, but during high precipitation years obvious contrasts existed. For example, Incline Creek's areal TP loads were quite similar among the three subwatersheds when precipitation was around 50 cm/yr . However, at precipitation levels greater than 150 cm/yr there was a large difference among the three stations. This "threshold" precipitation value of approximately 150 cm/yr was similar for the Upper Truckee River and

Ward Creek but slightly different for Trout Creek (approximately 110 cm/yr).

There also appeared to be threshold precipitation values at which areal PO_4^{-3} load differences emerged between subwatersheds, but these values occurred at a lower level of precipitation than those seen for areal TP loads. Subwatershed areal PO_4^{-3} differences began occurring around precipitation values of 125 cm/yr for Incline Creek, 50 to 100 cm/yr for Trout Creek, 75 to 125 cm/yr for the Upper Truckee River, and 100 to 175 cm/yr for Ward Creek. Future data will most likely fill in the precipitation gaps and allow greater delineation of these precipitation thresholds.

According to Hatch (1997), instream and near-stream processes undoubtedly influence the P behavior observed in the four study streams. Stream PP sources, due in part to association with sediment particles and TSS, have been linked to streambank erosion. Leonard et al. (1979) suggested that streambank erosion in the lower reaches of Ward Creek was responsible for the large increase in PP between the mid-watershed and lower-watershed sampling stations. Work done on adjacent Blackwood Creek implies that 70 percent of stream TSS came from streambank and streambed erosion in low order channels, with the majority coming from the main channel and a much less amount coming from sheet/rill erosion next to stream channels (Nolan and Hill 1987).

Variation in Daily P Transport

Missing from stream studies at Lake Tahoe has been an assessment of how daily P transport varies, especially during the temperature-driven spring snowmelt cycle. In a study by Hatch (1997) and Hatch et al. (1999), P variability was assessed by conducting 24-hour sampling studies (once monthly) on three Incline Creek stations from May 1995 to March 1996. This analysis was necessary to understand the real-time variation of P because the hydrologic events that drive the movement of sediment-associated P from Tahoe streams to the lake occur on an hourly to daily time scale (Leonard et al. 1979).

Data Collection—Twenty-four hour (diel) monitoring took place during the first week of each month, from May 1995 through March 1996. Stations included INC3 (above human development), INC2 (representing the cumulative east branch), and INC1 located near the mouth (Figure 4-5). Sampling times for the sites during each diel study were at 11AM, 3PM, 6PM, 9PM, 12AM, 7AM, and 11AM. At each site the stream stage was determined by reading the staff gauge at the USGS gauge house. Sampling occurred during temperature-driven snowmelt and low-discharge conditions; no rain-on-soil or rain-on-snow events were sampled. A three-liter grab sample was taken in the main stream current. Particulate-P associated with different particle sizes was determined as sand-sized fraction of particulate-P (PP_{sand}), and silt- and clay-sized fraction of particulate-P (PP_{s+c}). Quality assurance procedures consisted of duplicates and spike recoveries, which were performed on 10 percent of the samples for a given analytical run. All sample analyses were within the LTIMP quality assurance tolerance limits (Hunter et al. 1993). Six P fractions were examined: TP, PP, PP_{sand}, PP_{s+c}, DOP, and PO_4^{-3}.

Station Differences on the Daily Time Scale

Diel Changes in P Concentration—The annual snowmelt runoff season was covered quite well by the Incline Creek diel studies. The effect of increasing discharge as one moves downstream from station INC3 to INC2 to INC1 was evident, as were the typical high discharges in May, June, and July.

Daily and seasonal diel behavior for the three Incline Creek stations indicates that the largest daily TP fluctuations coincided with the largest mean daily discharge (in WY 1995 this occurred in June). However, high mean daily discharges also occurred in July but without corresponding large values for TP. Hatch reported this behavior as indicative of the seasonal "first flush" phenomenon. Large quantities of P-bearing sediment appear to have been flushed from the stream during the initial high discharges of June, leaving less material readily available for transport in July.

PP was the dominant form of phosphorus during periods of high discharge. Mean monthly diel PP typically comprised 49 to

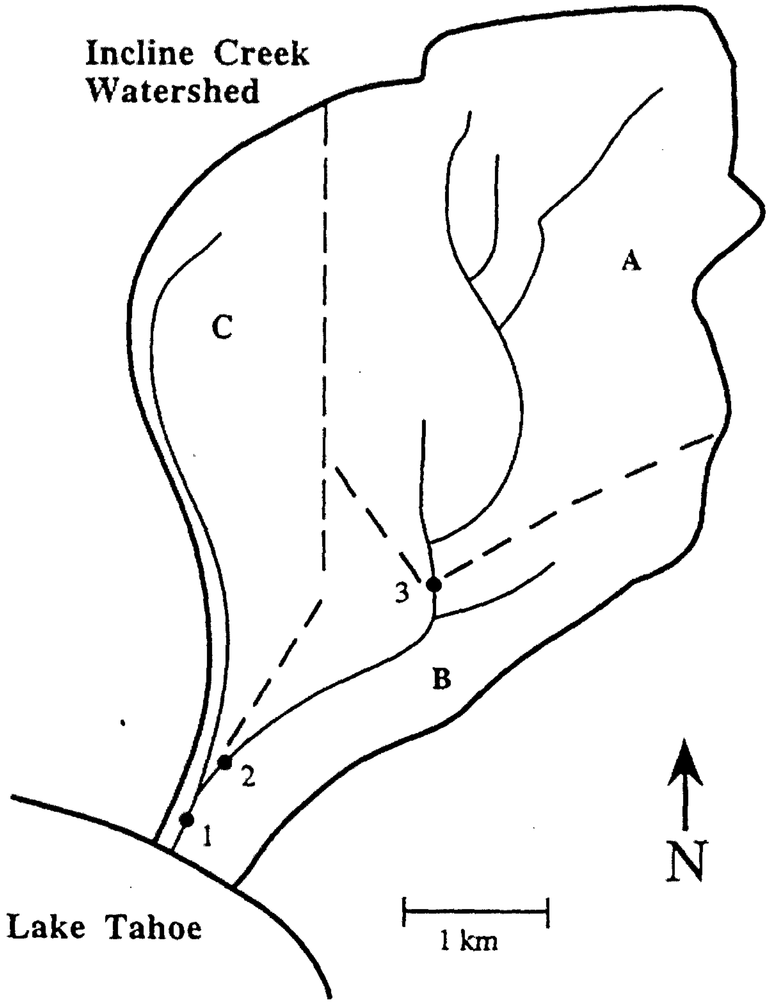


Figure 4-5—Diagram of Incline Creek watershed denotes location of three sampling stations and corresponding subwatershed drainages.

83 percent of the TP concentration at that time. PP concentrations for the June 1995 diel study fluctuated from 75 to 350 µg/L for INC1, 55 to 326 µg/L for INC2, and 40 to 210 µg/L for INC3. Peak PP concentrations were higher for both INC1 and INC2 than for INC3 during the May, June, and July studies, but PP values were similar for all three stations the remainder of the year (within 5 µg/L of one another). Leonard et al. (1979), working in Ward Creek, found that PP concentrations peaked around 250 ppb during May/June but remained below 10 ppb for the rest of the year.

The fluctuations in DOP concentration were not as great as those for PP, and the largest daily variations did not occur until August and September. At that time, mean diel DOP was 37 to 44 percent of TP. Peak DOP values at all three stations were nearly identical, at 10 to 30 µg/L. Throughout the study, never more than a 4 µg/L monthly mean DOP difference was found among the three Incline Creek stations. The elevated DOP levels in late summer and early fall are most likely due to peak summer production of stream periphyton exudates (Perkins 1976) and/or leaf-fall and in-stream litter processing.

Peak PO_4^{-3} concentration fluctuations were relatively small, with values ranging from 8 to 15 µg/L during the period of maximum discharge (i.e., June). PO_4^{-3} concentrations were greater than either PP or DOP during the November, January, and February studies, comprising 37 to 58 percent of mean diel TP concentrations. For each month from August 1995 to March 1996, PO_4^{-3} as a percentage of TP decreased in the downstream direction. This behavior was the opposite as that seen for PP, which increased its contribution in the downstream direction.

Relationship of P Concentration to Daily Discharge Cycle—The June 1995 diel study allowed for a more detailed examination of the relationship between P concentration and the daily snowmelt-driven discharge cycle. Peak discharges in Incline Creek at that time were observed at 9PM for INC1 (2,038 L/s), 6PM for INC2 (1,442 L/s), and 9PM for INC3 (1,333 L/s) (Figure 4-6). Although the exact time of peak discharge was probably not sampled, peak discharge was inferred to have occurred in the early evening during spring runoff as snowmelt water from upper portions of the watershed reaches the monitoring stations downstream (Hatch 1997). However, this conclusion may be valid for only Incline Creek. For example, peak snowmelt discharges for the Upper Truckee River generally occurs around 3AM due to the large watershed size and resultant time-to-concentration for discharge (Rowe 1999).

Maximum PP concentrations occurred prior to the observed peak in discharge at the mouth and upstream stations. At station INC2, both discharge and PP concentration peaked simultaneously at 6PM. INC1 displayed the largest changes in PP during the daily rising and falling hydrograph limbs, with INC2 and INC3 displaying smaller changes. PP appears to depend highly on discharge during the spring snowmelt for all three Incline Creek stations.

DOP concentrations ranged from 20 to 30 µg/L during the June diel study and were an order of magnitude lower than the observed PP concentrations. DOP concentrations were quite similar among the three stations, differing no more than 7 µg/L. Unlike PP, DOP concentrations continued to increase during the falling limb of the daily discharge cycle. Hatch et al. (1999) tentatively concluded that DOP did not directly depend on discharge. Ground water increases following the surface discharge peak may be possible sources of the increasing DOP, although ground water was not monitored.

PO_4^{-3} concentrations were quite similar among the three stations during June at approximately 10 µg/L. PO_4^{-3} remained relatively constant throughout the 24-hour period, implying independence from discharge.

Size Fractionation of Particulate P—Further insight into the large diel concentration fluctuations seen for PP during the period of maximum discharge was obtained by examining the behavior of PP_{sand} (particulate P associated with particles > 63 µm) and PP_{s+c} (particulate P associated with particles > 0.45 µm but < 63 µm, i.e., silts and clays). PP_{sand} displayed behavior similar to that of PP, with peak values occurring at 6PM (158 to 259 µg/L). Peak values for PP_{s+c} (54 to 83 µg/L) were much lower than those for PP_{sand} and were observed later in the diel period at 9PM. Peak concentrations increased in the downstream direction for both PP_{sand} and PP_{s+c}.

Stream hysteresis (changing relationship between phosphorus and flow over the diel period) varied according to P size fraction. For example, a counter-clockwise hysteresis was inferred for DOP concentration since DOP continued to rise as discharge decreased in the early morning hours. Walling and Webb (1980), using specific conductance, reported both clockwise and counter-clockwise hysteresis loops along different stretches of the same English stream system. These authors argued that this varying behavior was the result of differing source area chemical composition. Diel movement of hydraulic discharge and associated nutrients through the melting snowpack via ice lenses also may influence the hysteresis behavior of dissolved stream ions (Caine 1992) .

The differing hysteresis behavior for the PP_{sand} and PP_{s+c} fractions in Incline Creek may be explained by considering the physical conditions necessary to mobilize each fraction and the source of each fraction. Hatch et al. note that sand-sized particles require a higher velocity

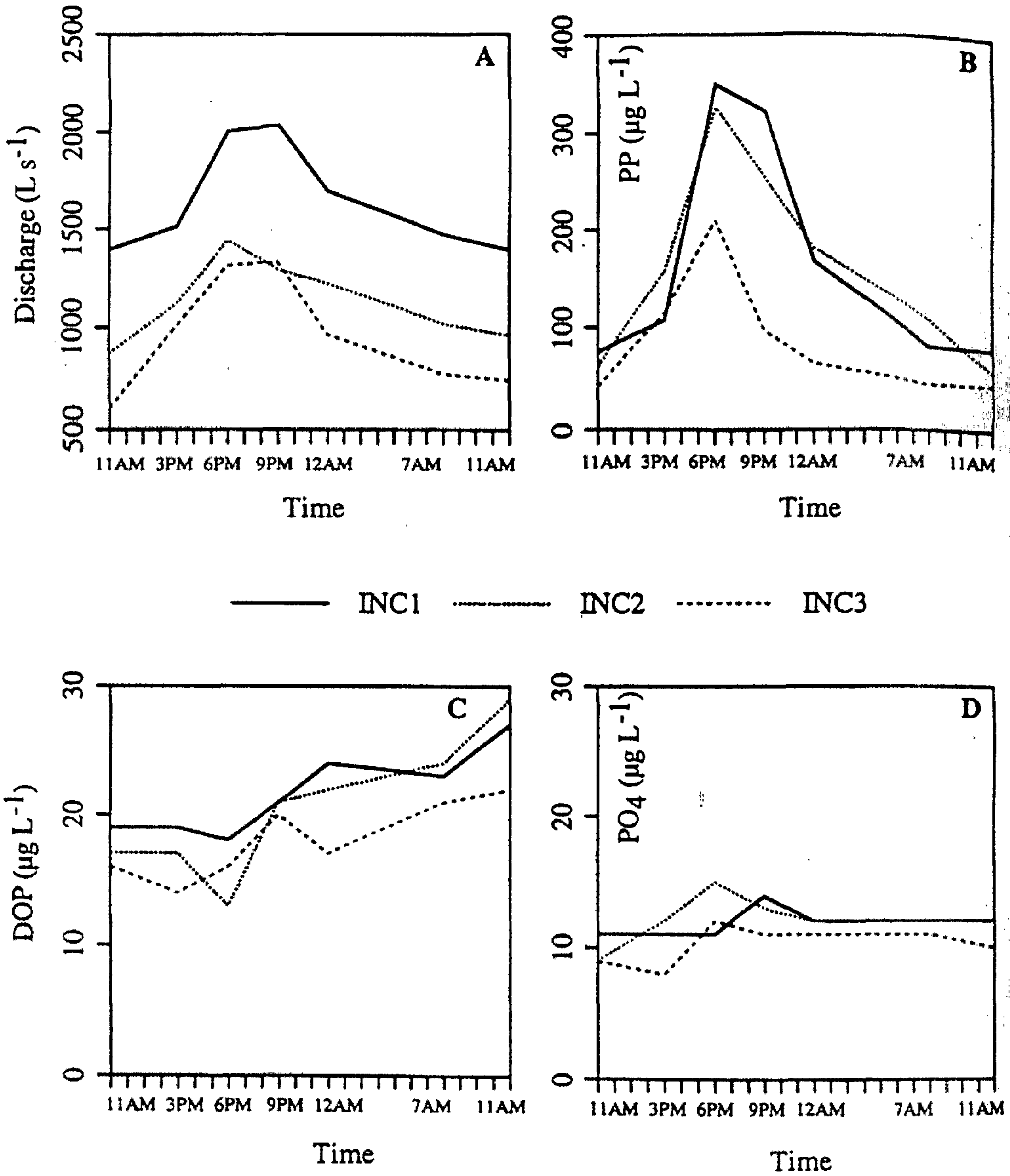


Figure 4-6—Diel pattern of discharge and phosphorus concentration at three stations on Incline Creek, June 1995 (from Hatch 1999).

and shear stress to become entrained in flow than smaller-sized particles. Hence a threshold-like behavior in which significant amounts of sands are mobilized once a certain discharge is reached; may be displayed. For stations INC1 and INC2 this threshold appears to occur around 1,000-1,500 L/s. Once the flow threshold is reached and the sediment flushing occurs, significant sources of sand-sized particles may be exhausted, resulting in lowered sediment levels for a given discharge during the falling hydrograph limb (i.e., clockwise hysteresis).

Silt- and clay-sized particles require lower shear stress to become entrained in the flow. It is possible that the shear stress required to suspend and entrain these smaller particles in Incline Creek is present at all hours of the day during the daily snowmelt cycle. There was little fluctuation in PP_{s+c} over the 24-hour period, and PP_{s+c} increased with rising flows even at low rates of discharge. The counter-clockwise hysteresis seen for PP_{s+c} also may be the result of a nonstream channel source, possibly subsurface (Loeb and Goldman 1979). Very small particulates may move within the coarse soil matrix of the Tahoe basin (Rhea et al. 1996), so it is possible that the heightened PP_{s+c} levels seen on the falling hydrograph limb are due to subsurface sources of P, which reach a maximum after the peak stream discharge occurs.

Hatch et al. concluded that instream and near-stream processes both influence the P behavior observed in Incline Creek. Stream PP sources, due in part to association with sediment particles and TSS, have been linked to streambank and streambed erosion. Dissolved P concentrations in Incline Creek are most likely the result of equilibrium processes between stream water, stream suspended sediments, and stream bottom/bank sediments (Meyer and Likens 1979). Incline Creek showed relatively small changes in PO_4^{-3} between stations. The extent to which stream bottom and suspended sediment P retention is influencing these similarities is unknown. Downstream subwatershed dissolved P contributions plus dissolved P from the upstream monitoring station may be offset by stream bottom P and suspended sediment buffering, resulting in similar dissolved P concentrations for the three Incline Creek stations. Stream bottom retention of dissolved P also was reported in Ward Creek (Perkins 1976; Leonard et al. 1979).

Colloids and Their Potential Importance to Nutrient Water Chemistry

Colloid nutrient transport also can play a significant role in organic and inorganic nutrients migrating to stream and lake ecosystems (Ryan and Gschwend 1990; Chin and Gschwend 1991; Qualls and Haines 1991; Backhus et al. 1993; Rhea et al. 1996). Lake Tahoe research in this regard is in its infancy. Rhea et al. (1996) investigated the presence and behavior of colloidal N and P in a Lake Tahoe subbasin before and after the application of a 10 cm/h one-hour artificial rainfall event. Colloidal rather than inorganic nutrient species were the dominant forms present in soil water extracts taken both before and after the artificial event (figures 4-7, 4-8, and 4-9). As a result of their findings, it is now apparent that colloidal nutrient forms must be considered a potential source of mobile nutrients in soils of the Sierra Nevada.

At the watershed scale, a number of factors, including geology, vegetation, and extent of erosion may affect the form and magnitude of phosphorus contained in tributary discharge. Harlow (1998) conducted a study in an undisturbed portion of Incline Creek to investigate the leachability of P from undisturbed soil cores taken from upland and riparian plant communities. No significant differences among plant communities for leachable inorganic ortho-phosphorus or dissolved organic/colloidal P were identified. Furthermore, no correlation was found between inorganic or dissolved organic/colloidal P concentrations in the leachate and any other soil properties, including oxalate extractable iron and aluminum. The median ratio of dissolved organic/colloidal P to PO_4^{-3} was 0.38, lower than that reported by Rhea et al. (1996). Although this study did not collect data on TP, several studies have indicated that the TP levels (which include both the digested and inorganic fraction) are typically significantly higher than the dissolved fraction alone (Leonard et al. 1979; Byron and Goldman 1989; Vaithiyanathan and Correll 1992; Hatch 1997). This is likely the case for the Incline Creek watershed as well. Harlow (1998) also identified a "delayed" inorganic phosphorus peak (figures 4-10 and 4-11) during leaching that was consistent with the findings of Marcus et al. (1998). Unlike other nonconservative nutrients, such as nitrate-N, the delayed phosphorus release could be significant when considering nutrient transport during longer duration snowmelt runoff events versus brief summer precipitation events. The transport of P through the riparian corridor and into the stream is in need of further investigation.

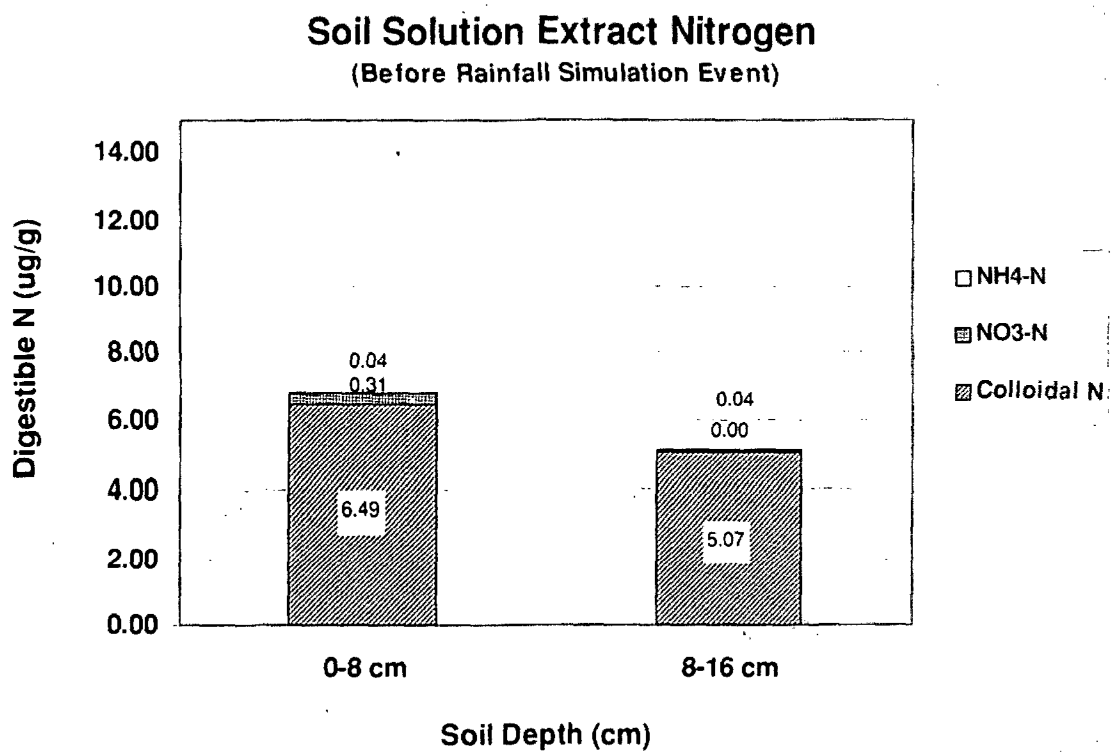


Figure 4-7— Water extractable inorganic and colloidal nitrogen from soil before artificial rainfall (from Rhea et al. 1996).

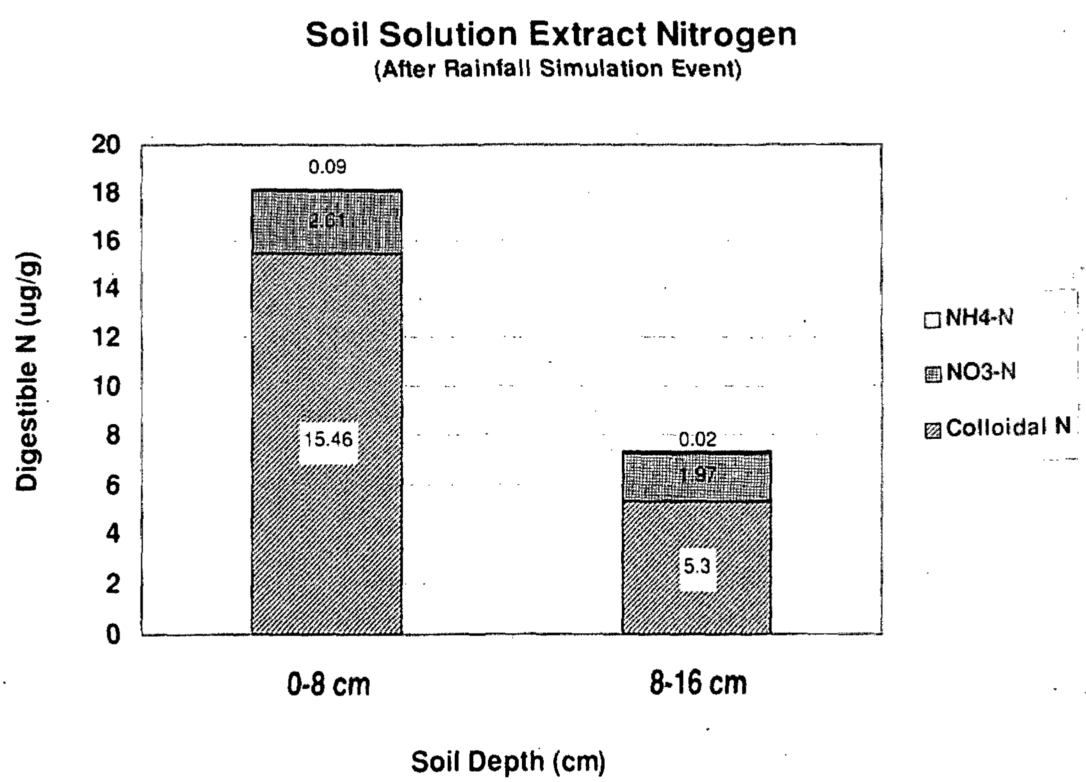
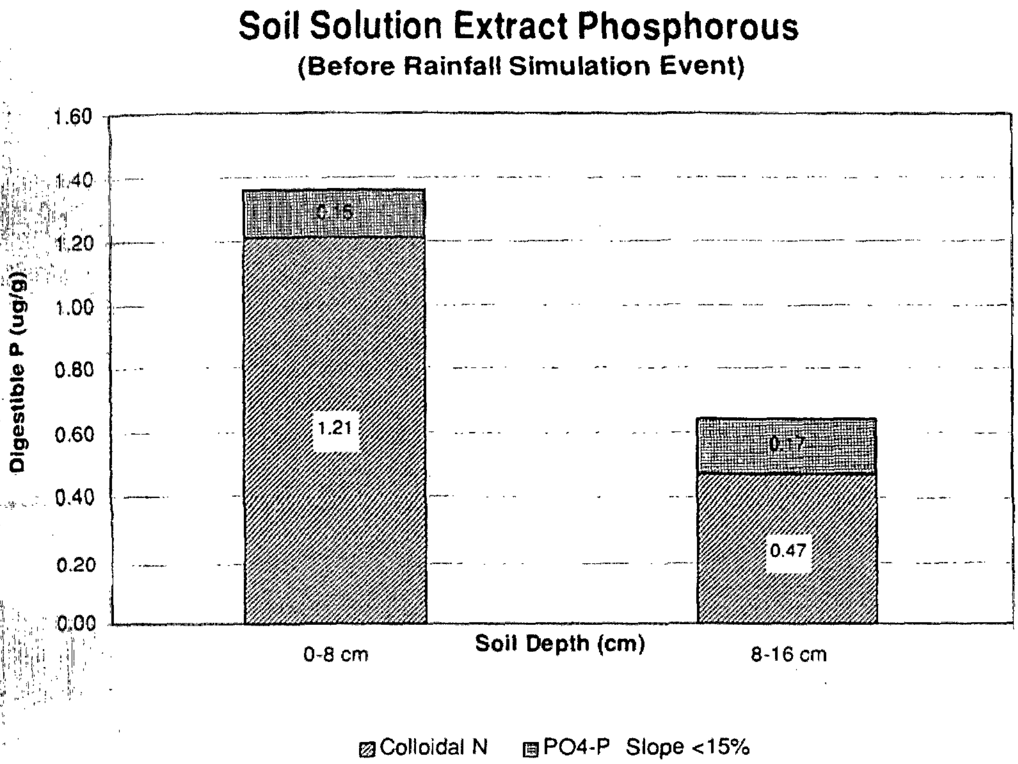


Figure 4-8— Water extractable inorganic and colloidal nitrogen from soil after artificial rainfall (from Rhea et al. 1996).



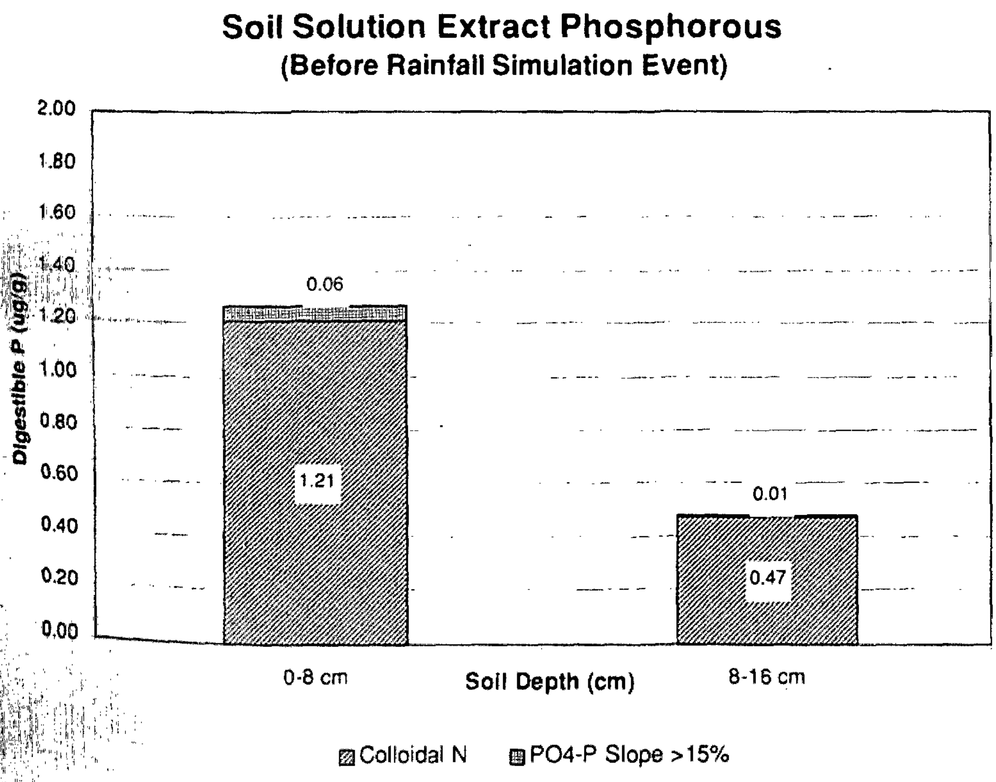


Figure 4.9—Water extractable inorganic and colloidal phosphorus from soil before and after artificial rainfall (from Rhea et al. 1996).

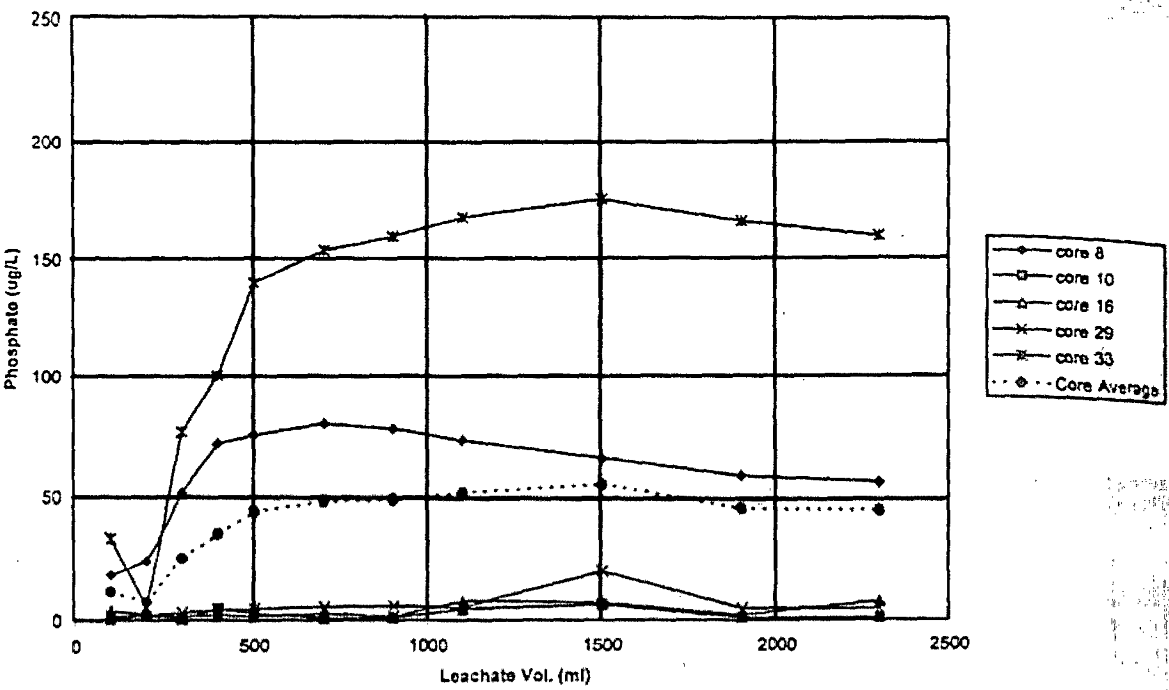


Figure 4-10— Phosphorus release during leaching of undisturbed soil cores from upland forested sites (UPFOR) (from Harlow 1998).

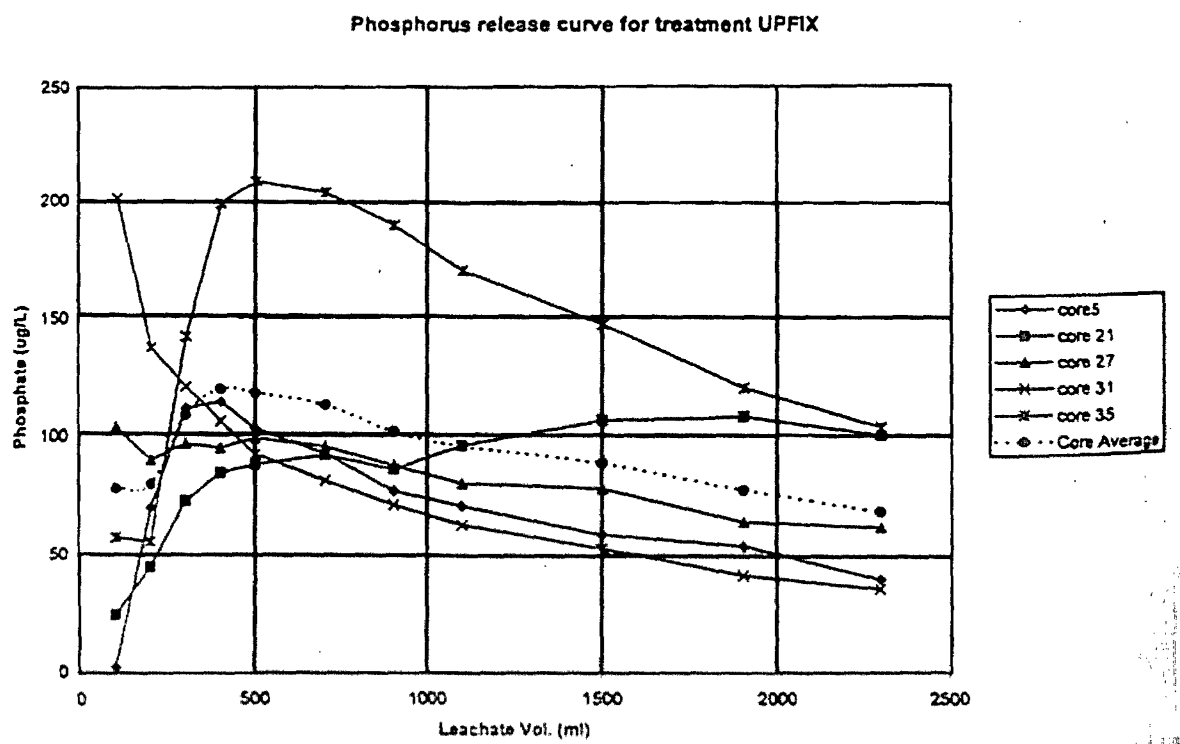


Figure 4-11— Phosphorus release during leaching of undisturbed soil cores from upland sites with nitrogen fixing vegetation (UPFIX) (from Harlow 1998).

Comparison to Background Concentrations and Water Quality Standards

Table 4-3 provides the average annual flow-weighted total-P concentrations for the nine LTIMP streams. Accompanying these concentrations are the numeric water quality standards and objectives established by California and Nevada. For California, each creek is identical with a desired concentration of 15 µg/L. This concentration was exceeded in each of the ten years from WY 1987 to WY 1996. For most of the LTIMP creeks, it was exceeded by a factor of two to four times; however, in Ward and Blackwood Creeks during WY 1995 and WY 1996, the 15 µg/L was exceeded by four- to eight-fold. Only General Creek approximated the water quality objective with average annual TP in the range of 17 to 31 µg/L. This observation supports the use of General Creek as an indicator of "control" conditions. The California objectives are particularly stringent, they are aimed at restoring historical or better water quality. The Nevada value of 50 µg/L is based on data collected during the more recent period WY 1988 to WY 1995 and consequently reflects more current rather than historical conditions. Even so, Incline Creek always exceeded this value, while Glenbrook Creek does so about half the time. With a range of 21 to 42 µg/L, TP in Logan House Creek was relatively low, again reflecting its undeveloped nature.

In their analysis of land use and water quality in streams tributary to Lake Tahoe, Byron and Goldman (1989) used the y-intercept from plots of disturbed, low, and high hazard land versus TP as representative of control conditions, i.e., those with little or no human disturbance. At the time of their analysis adequate data was only available for streams on the north, west, and south sides of the lake; monitoring of the eastside creeks was not yet fully underway. They found that the predicted TP concentration without disturbance was in the neighborhood of 12 to 15 µg/L, which supports the California water quality objective of 15 µg/L (representing historical conditions).

Table 4-3—Mean annual total phosphorus (P) concentrations (µg/L) in each of the monitored streams in the Tahoe basin. Values were obtained by dividing total P load by annual discharge. Each year 30-50 samples are taken for chemical analysis from each stream as part of the Lake Tahoe Interagency Monitoring Program (LTIMP). A Water Year (WY) extends from October 1 to September 30. LTIMP streams include TC = Trout Creek, UT = Upper Truckee River, GC = General Creek, BC = Blackwood Creek, WC = Ward Creek, TH = Third Creek, IN = Incline Creek, GB = Glenbrook Creek and LH = Logan House Creek. Combined these account for approximately % of the annual inflow to Lake Tahoe, ND denotes that data is not available.

Station/WY	87	88	89	90	91	92	93	94	95	96	Nevada[1]	California[2]
TC	ND	ND	42	42	32	34	44	36	58	49		15
UT	48	40	43	32	37	23	40	28	53	44		15
GC	24	23	18	21	21	17	23	17	28	31		15
BC	43	33	35	34	51	31	57	27	71	126		15
WC	33	31	33	34	35	33	55	39	67	101		15
TH	ND	11	160	75	241	119	164	100	345	60	50	
IN	ND	ND	98	81	74	68	81	76	131	67	50	
GB	ND	ND	70	42	48	33	ND	60	78	74	50	
LH	ND	ND	32	34	26	21	28	20	42	30	50	

Requirements to Maintain Existing Higher Quality (RMHQs) are based on the 95th percentile using the WY 1988-1995 data set.
numerical objectives based on 90th percentile values for historical (often pre-1975) water quality.

Directly differentiating between the natural and the human impact contribution to P delivery is difficult because there is no adequate database for predevelopment water quality conditions in the LTIMP watersheds. However, as noted above, the General Creek watershed can be considered as relatively undeveloped because it is in a state park. If one characterizes P transport in General Creek and applies these relationships to a more developed watershed nearby, one can get a glimpse as to what P transport would be like if that nearby watershed were not subject to human disturbance. This technique enables a preliminary differentiation between natural and human-influenced P delivery. Of the monitored watersheds adjacent to General Creek, Ward Creek is the best candidate for comparison. Housing subdivisions and roads are the major human influences in Ward Valley. General and Ward Creeks have approximately the same precipitation amounts, vegetation types, and basin area; however, they are not identical with respect to all aspects of geomorphology. For example, the General Creek watershed consists primarily of a granitic geology, whereas the Ward Creek watershed contains significant portions of volcanic material. In addition, channel morphologies in the lower reaches of the main stems are different (Norman 1999).

In his analysis of this situation, Hatch et al. (1997) presented a simplistic "model" of TP loading in which annual areal TP load is significantly related to annual discharge for General Creek. This model is intended only for problem-solving purposes. Assuming that current hydraulic discharge in Ward Creek would be characteristic of undeveloped conditions, the discharge for Ward Creek was substituted into the equation generated from the General Creek model. The results of this extrapolation indicated that Ward Creek areal TP loading would be much lower during high precipitation and discharge years (Figure 4-12) if the watershed had no development. Ward Creek's actual measured load exceeded the predicted load during above-average precipitation years, suggesting that Ward Creek responds to the effects of human development primarily during high-discharge years. The model estimated that human development increased areal TP loading over background levels by 73 percent in WY 1983, by 39 percent in WY 1984, by 74 percent in WY 1986, by 33 percent in WY 1993, by 58 percent in WY 1995, and by 144 percent in WY 1996. That actual measured loading from Ward Creek was similar to predicted loading based on the General Creek model during low precipitation/low flow years but was greater during high precipitation/high flow years supports the observation mode by Hatch (1997) that TP loads did not increase greatly with precipitation levels until a certain threshold level of precipitation was reached.

Nitrate Transport

Coats and Goldman (1993) published a study on nitrate transport in subalpine streams in the Tahoe basin. LTIMP data from Ward Creek, Blackwood Creek, General Creek, the Upper Truckee River, Third Creek, and Snow Creek were used to develop a linear model relating nitrate-N concentration to two discharge variables. The data set comprised >3,100 mean daily discharge and nitrate concentration values representing 45 watershed years. The goal was to compare the relative contribution to nitrate concentration of two dominant water types: short flow-path water, which occurs during storms and snowmelt, and long flow-path water, or base flow.

The first variable was a reciprocal function of discharge, derived from a mixing model for both water types in an open system. The second variable used either cumulative water discharge or cumulative nitrate load for the water year. Stepwise linear regression was used to fit model parameters to the data. Both independent variables made a highly significant contribution to explaining the concentration variance. Values of R^2 ranged from 0.22 to 0.45. For one catchment, the model was fitted to data for eight separate water years; it explained up to 80 percent of the variance in nitrate concentration. The results of this study indicated the Coats and Goldman model can be used to distinguish anthropogenic nitrate sources from the ion pulse associated with early snowmelt and can be developed into predictive models for estimating total N load.

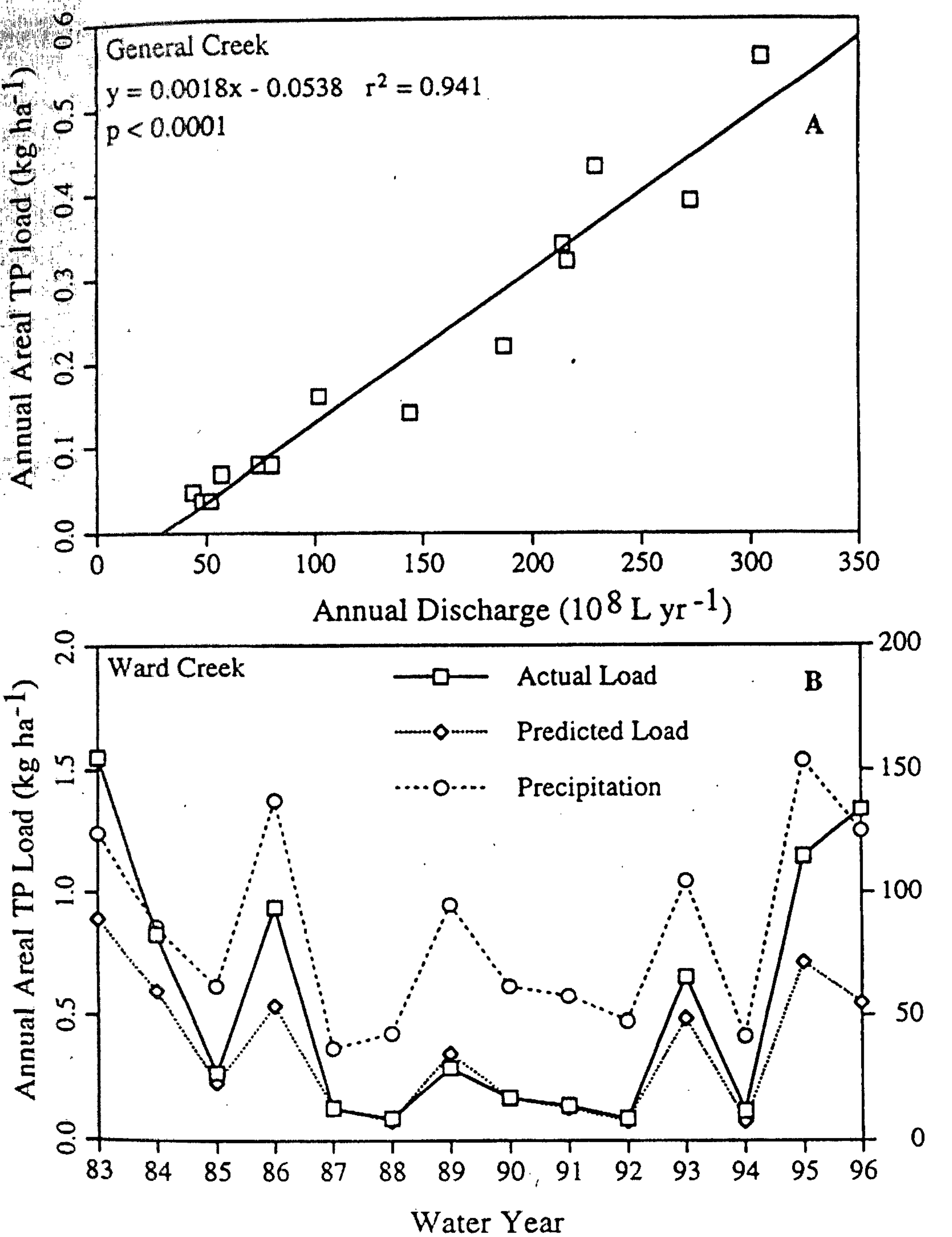


Figure 4-12— Discharge versus areal TP load relationship for General Creek used to predict areal load from Ward Creek under similar land use conditions. This undisturbed value is compared to actual measured loading from Ward Creek under current conditions of development in the watershed (from Hatch 1997).

APPENDIX C

ACCOUNTS OF FOCAL AQUATIC ECOSYSTEMS AND ECOLOGICALLY SIGNIFICANT AREAS

Matthew D. Schlesinger and Erik M. Holst, editors

Focal Aquatic Ecosystem: Upper Truckee River

By Erik M. Holst

General

From its headwaters at approximately 2,804 m (9,200 ft), near Red Lake Peak, the Upper Truckee River flows north for a distance of 34.6 km (21.5 mi) into Lake Tahoe (CDFG 1987). Within the 146.6 km^2 (56.6 mi^2) drainage, 24 tributaries flow into the Upper Truckee River (CDFG 1987). The Upper Truckee River and the tributaries which make up the Upper Truckee River Watershed comprise the largest contribution to the waters of Lake Tahoe (CWQCB 1999).

Using Moyle's (1996) aquatic habitat classification, the Upper Truckee River can be divided into two aquatic habitat types: alpine streams and mainstem rivers and their larger tributaries. (See Issue 5, Chapter 5 for further discussion of this classification.) Mainstem rivers and their larger tributaries are widespread and of special concern in the Great Basin Province. That is, they are "declining in abundance and quality but many examples still exist" (Moyle 1996, p. 946). However, as noted in Issue 5, Chapter 5, only mainstem rivers received the highest concern rating of "imperiled" in the Lake Tahoe Basin; the lower reaches of the Upper Truckee River comprise the only representative of a mainstem river in the basin.

History

Between 1852 and 1857 emigrants moved thousands of sheep and cattle through the Lake Tahoe basin on their way to the gold fields of California (Supernowicz 1999). Transient grazing patterns persisted until the later part of the 1850s at which time more defined, less transient, patterns of grazing evolved along with human settlement patterns (Supernowicz pers. comm.). By the late nineteenth century in the Lake Valley area of the Upper Truckee River watershed, harvested land was being grazed by dairy cattle, and indiscriminate, unregulated sheep grazing was occurring in those areas not suitable for cattle (see Chapter 2; Supernowicz pers. comm.). During this same period, land use activities in the headwaters of the Upper Truckee River were primarily limited to grazing; no commercial logging occurred. By the 1910s, the development of a seasonal grazing allotment system throughout the watershed dedicated land to specific uses and limitations. The allotment system attempted to reduce the previous levels of resource damage and essentially eliminated indiscriminate sheep grazing (Supernowicz pers. comm.). However, four decades later the California Department of Fish and Game noted the Upper Truckee River was experiencing erosion problems due to past cattle grazing (CDFG 1957).

Commercial logging first occurred in the Lake Valley portions of the Upper Truckee River watershed in the 1860s (Supernowicz pers. comm.). Harvest data from 1887 to 1890 in T.12N., R.18E. indicate a stand composition of Jeffrey pine (*Pinus jeffreyi*), sugar pine (*Pinus lambertiana*), and incense cedar (*Calocedrus* decrurrens) with an average diameter of 67 cm (26.4 in) (see Chapter 2). By 1897 the aforementioned township, and Lake Valley in general, was almost entirely cut over (see Chapter 2; Supernowicz pers. comm.). In 1936, parcels of this township were acquired by the USDA Forest Service from the Carson and Tahoe Timber and Flume Company; this acquisition included both harvested and unharvested lands. The harvested areas included stands or portions of stands that were clearcut as early as 1860, along with other areas that were selectively logged in the 1900s (USDA 1935). Most of the timber harvest occurred on flatter ground, and stands within the same land survey section in which clearcuts occurred were noted to contain trees between 75 and 300 years of age (USDA 1935). The acquisition included two main areas of 'virgin timber.' The 227 ha (560 ac) tract of late seral timber adjacent to the sawmill operated by C. G. Celio and Sons was described as having Jeffrey pine averaging 122 cm (48 in) in diameter at breast height in some areas (USDA 1935). All age classes were represented in this stand with 95 percent of the volume being classified as 'mature and overmature'; the species characteristics for the entire 227 ha (560 ac) tract are described in Table C-1.

By 1996 the stand composition in this area had shifted to Jeffrey pine, lodgepole, white fir, and incense cedar with average diameters of 35.5 to 40.5 cm (14 to 16 in) with the largest diameter being about 76 cm (30 in) (see Chapter 2). (For further discussion of historical land uses, see Chapter 2.)

In general, land use along the Upper Truckee River in the Lake Valley area from the 1850s to the 1920s/1930s was expansive and intensive in nature insofar as logging, ranching, and grazing created openings and meadows where they had not previously existed (Supernowicz pers. comm.). However, after the 1920s/1930s land use patterns changed, and vegetation began to encroach into the openings created during the Comstock Era (Supernowicz pers. comm.). In addition, during the Comstock Era and shortly thereafter, impoundments were placed along the Upper Truckee River and its tributaries to provide water for domestic and/or agricultural use (Supernowicz pers. comm.). Sanders, in his 1932 'Field Correspondence' to Chief Macaulay of the California Department of Natural Resources, Division of Fish and Game, notes the existence of dams along the Upper Truckee River that were used to irrigate cattle pastures in the summer months; during the fall, winter, and spring, gates on these dams were opened to facilitate fish passage (CDFG 1932). Celio (1930) notes the existence of a fish trap built by the Fish Commission on the Upper Truckee. Effects of these impoundments and fish traps on water flows and the aquatic biota are unknown. However, it should be noted that during this same time period, the Mt. Ralston Fish Planting Club was introducing exotic species such as water lilies, water hyacinth, and parrot feather into numerous high elevation lakes (Pierce 1932). They also introduced *Gammarus* (a fresh water shrimp) in shallow lakes and streams in the Lake Tahoe basin area (Pierce 1932). Similarly, during the late 1920s, private individuals were stocking sections of the Upper Truckee River with brook trout (*Salvelinus fontinalis*) supplied by the Fish Commission[1] (Celio 1930). At the urging of the Mt. Ralston Fish Planting Club, the California Division of Fish and Game (which was to become the California Department of Fish and Game) closed the Upper Truckee to fishing in the late 1920s for a period of two to three years (Supernowicz pers. comm., Celio 1930). This closure precipitated a disagreement during the late 1920s and early 1930s between the fish planting club, the California Division of Fish and Game, and private interests in the basin. Neither the extent nor the effect of such introductions and closures is well documented (Supernowicz pers. comm.).

Ecology

The California Department of Fish and Game evaluates water management strategies and manages fish resources in the Upper Truckee River based, in part, on instream fish flow requirements (CDFG 1987). Based on channel morphology, substrate, water flows, and habitat type, the Department has divided the entire 34.6 km (21.5 mi) Upper Truckee River into five segments (Table C-2) (CDFG 1987).

Native fish species presently occurring in the Upper Truckee River include Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*),

[1]The California Fish and Game Commission and the California Department of Fish and Game are different entities; the California Fish and Game Commission has been in existence since 1870 (CDFG 1999a). Ms. Celio's letter does not clarify the agency affiliation of the 'Fish Commission.'

Table C-1—Timber species characteristics and estimated volume for a timber stand within lands acquired from Carson and Tahoe Timber and Flume Company (USDA 1936).

		DBH				
		Av.		Max.		Estimated Percent cut
Common Name	Scientific Name	cm	(in)	cm	(in)	by Species
Jeffrey pine	*Pinus jeffreyi*	76	(30)	127	(50)	66.2
Sugar pine	*Pinus lambertiana*	107	(42)	152	(60)	12.3
White fir	*Abies concolor*	91	(36)	137	(54)	11.3
Red fir	*Abies magnifica*	66	(26)	76	(30)	6.6
Incense cedar	*Calocedrus decurrens*	99	(39)	152	(60)	3.6

Table C-2—Segment lengths and substrate characteristics of the Upper Truckee River as delineated by the California Department of Fish and Game (CDFG 1987).

Segment	Length		Location	Characteristics
1	10.5 km	(6.5 mi)	Lake Tahoe to Angora Creek	silt, sand and mud substrate
2	3.2 km	(2.0 mi)	Angora Creek to Echo Creek	cobble and gravel riffles; sandy pools
3	4.5 km	(2.8 mi)	Echo Creek to Benwood Creek	silt, sand, gravel, and boulder
4	1.8 km	(1.1 mi)	Benwood Creek to the end of Christmas Valley (base of Hawley Grade)	low gradient of approximately 0.7 percent
5	14.6 km	(9.1 mi)	Benwood Creek to the headwaters near Red Lake Peak	5 to 6 percent gradient with interspersed flat meadows

Lahontan redside (*Richardsonius egregius*), Paiute sculpin (*Cottus beldingii*), and Tahoe sucker (*Catostomus tahoensis*) (CDFG 1987). Introduced species include brook trout (*Salvelinus fontinalis*), brown bullhead (*Ameiurus nebulosus*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*).

Rainbow trout and Paiute sculpin occur throughout most of the drainage. With the exception of Lahontan cutthroat trout which are stocked in the Upper Truckee River's headwaters, the remaining species generally occur in the lower gradient reaches downstream of the base of Hawley Grade (Segment 4) (CDFG 1987). Spawning and rearing of lake run rainbow trout, brown trout, Lahontan redside, and Tahoe sucker also occur in the lower gradient reaches downstream of the base of Hawley Grade (CDFG 1987). Table C-3 notes the California Department of Fish and Game optimum flow regimes for each of the segments of the Upper Truckee River; these regimes were determined independently for each segment (CDFG 1987).

Adult Lahontan cutthroat of the Heenan Lake strain were introduced annually in Taylor Creek and the Upper Truckee River from 1956 through 1964. However, it is believed that competition from, and to a lesser extent predation by brook trout and other non-native species prevented the establishment of a self-sustaining cutthroat population (Elliott pers. comm.). After the removal of brook trout in 1989, the California Department of Fish and Game restored Lahontan cutthroat trout to 6.4 km (4 mi) of the Upper Truckee River and its tributaries, upstream (south) of the confluence of

Table C-3—California Department of Fish and Game optimum flow regimes for each of the segments of the Upper Truckee River (CDFG 1987).

Segment	Optimization strategy
1	Optimize flows for brown trout spawning and incubation habitat from October 1 to March 31; optimize for rainbow trout spawning and incubation habitat April 1 to July 15; and, optimize for brown trout rearing habitat July 16 to October 1.
2	Optimize flows for lake run rainbow habitat from April 1 and July 15; optimize for rainbow trout rearing habitat July 16 to September 30; and, optimize for brown trout spawning and rainbow trout rearing habitat October 1 to March 30.
3	Optimize flows for rainbow trout spawning and incubation habitat from April 1 to July 15; optimize for rainbow trout rearing habitat from July 16 to September 30; and, optimize for brown trout spawning and rainbow trout rearing habitat October 1 to March 30.
4	Optimize flows for lake run rainbow trout habitat‡.
5	The California Department of Fish and Game noted no specific flow objective for Segment 5 in their "Stream Evaluation Report 87-1" (CDFG 1987); however, the California Heritage Trout Program notes that Lahontan cutthroat trout have been restored to the Upper Truckee River, including tributaries, upstream of the confluence with Showers Creek (CDFG 1999b).

‡ Segment 4 requires maintenance of natural flow conditions all year long.

Showers Creek (CDFG 1987). Since 1989 annual removal efforts have continued and will continue as long as this effort indicates brook trout are present in this portion of the Upper Truckee River (Reiner pers. comm).

Grass Lake Natural Research Area and Osgood Swamp are two *Sphagnum* bogs located with in the Upper Truckee River watershed. For further discussion on these areas, see the account for bogs and fens in this appendix.

Effects of Human Activities

Aquatic communities of the Lake Tahoe basin have undergone a significant transformation since the arrival of Euro-American settlers. Grazing, logging, and development have affected virtually all aquatic ecosystems in the basin, and the stocking of exotic fish in waters in the Lake Tahoe basin (including naturally fishless lakes and drainages) has changed the character of the basin's fishery. Similarly, the Upper Truckee River has undergone notable change during this time period. Construction of the Tahoe Keys subdivision displaced Rowland's Marsh at the river's mouth, and the lower reaches of the Upper Truckee River were channelized and hydrologically modified by the construction of the South Lake Tahoe Airport (CDFG 1963, CWQCB 1999). Additionally, lower portions of the Upper Truckee River watershed have been adversely affected by the urbanization of Tahoe Valley. Activities such as the construction of housing developments, the construction and maintenance of two golf courses and Highway 50 have altered landscape features, changed surface run-off patterns, contributed to degraded water quality and introduced exotic plant species.

Effects from recreational activities to the Upper Truckee River watershed are somewhat difficult to quantify. Some lands in the drainage have been, and are being adversely affected to varying degrees by a variety of uses including dispersed motorized and nonmotorized recreation (USDA 1988). Additionally, concentrated recreation may trample vegetation, adversely affect streambank stability, and degrade water quality. In the past there was expressed concern regarding public access to certain portions of the river. However, recent land acquisitions such as the December 1998 purchase of Sunset Ranch by the California Tahoe Conservancy, will provide for future access (O'Daly pers. comm.). Specific impacts to aquatic and terrestrial components of the watershed from such stream-oriented recreation are difficult to predict, but could be expected to correlate roughly with the degree of development of recreational facilities.

Increasing human population levels in the basin also create other problems. To avoid eutrophication of Lake Tahoe, sewage is currently pumped out of the basin. Treated sewage has spilled several times in recent years along the Luther Pass pipeline that generally runs parallel to the Upper Truckee River, and on November 7, 1996 a spill of 5,000 gallons of treated wastewater went directly into the Upper Truckee (NDWP 1997). In an aquatic environment, wastewater spills have the potential to introduce viral and/or parasitic pathogens, raise bacteria levels, reduce dissolved oxygen, increase suspended solids, and/or stimulate algal blooms (EPA 1996, USGS 1997, USGS 1999). However, wastewater treated at the South Tahoe Public Utility District (STPUD) facility receives secondary treatment[2] and is pressure filtered before transport (Solbrig pers. comm.). Thus, the STPUD treatment facility is considered 'filter secondary' or 'advanced secondary' (Johnson pers. comm). Because such secondary wastewater treatment removes dissolved organic matter, is chlorinated, but does not appreciably reduce nitrates or phosphates, any impacts to the aquatic environment from wastewater spills would be expected to be related to ammonia (20 mg/l) and various chlorine compounds (3 mg/l), as opposed to pathogens (Johnson pers. comm, Solbrig pers. comm.). Given the degree of treatment and considering dilution rates, impacts from small wastewater spills from the STPUD sewage transport line would be expected to be minimal. (To reduce the potential for wastewater spills, the South Tahoe Public Utility District is actively replacing older segments of the sewage transport line [O'Daly pers. comm.].)

Conservation

For approximately the last 15 years, the water quality of tributaries to Lake Tahoe has been monitored to varying degrees by the following agencies and groups: Environmental Protection Agency, Joint Studies Group, Lahontan Region Water Quality Control Board, University of Nevada Reno, Nevada Division of Environmental Protection, Tahoe Research Group, USDA Forest Service, and US Geological Survey (TRPA 1996). Currently such monitoring is carried out by the latter 4 agencies and groups (TRPA 1996). Continuous monitoring data for an array of water quality components are lacking (e.g., pH, turbidity, fecal coliform bacteria). However, data compiled by Tahoe Regional Planning Agency indicate that the Upper Truckee River has exceeded the State of California's acceptable total nitrogen and biologically available iron levels for water years 1989 through 1993 and 1995; California total phosphorus concentrations were exceeded in water years 1981 through 1995 (TRPA 1996).

Pursuant to section 303(d) of the Clean Water Act, the Lake Tahoe watershed (ref. no. 16050101), has been listed by the State of California as a Category I (Impaired) Priority Watershed (CWRCB 1998). As such, it is subject to the Total Maximum Daily Load (TMDL) program. In accordance with section 303(d) criteria, TMDL monitoring levels for sediments and nutrients in the Lake Tahoe watershed are being developed by the Lahontan Region of the California Regional Water Quality Control Board. The Upper Truckee River is not noted on the 303(d) list; however, because of its contribution to the surface inflow to Lake Tahoe, restoration measures are needed to improve lake clarity (CWQCB 1999).

Although many of the water quality issues in the Upper Truckee River watershed are being coordinated at state and local levels, the majority of the watershed is presently managed by the USDA Forest Service, and while there is private ownership, both the USDA Forest Service and the State of California manage a significant portion of those lands immediately

[2] Prior to 1989 wastewater from South Lake Tahoe received tertiary treatment and would meet potable drinking water standards (Solbrig pers. comm.).

adjacent to the river. The California Department of Parks and Recreation manages the majority of state lands; however, several state agencies have agency-specific management priorities for the Upper Truckee River. As noted above, the California Department of Fish and Game manages fish resources based on optimum flow regimes. The Watershed Management Initiative of the California Department of Water Resources has directed their efforts in the Upper Truckee River to reduce sedimentation and nutrification, to restore wetland function, and to restore riparian areas and/or river morphology and function (CDWR 1998). The California Regional Water Quality Control Board is responsible for prioritizing activities in individual watersheds. They have established the following objectives: 1) "to enhance water quality in the Upper Truckee watershed of Lake Tahoe, through a concerted effort of implementing watershed projects improvement"; 2) "Use the Upper Truckee River Focused Watershed Group[3] as a clearinghouse for existing information"; 3) "Implement solutions for restoration of watershed function (related to water quality), as well as a reduction of sediment and nutrient inputs"; 4) "Upper Truckee River Focus Watershed Group, in coordination with Tahoe Citizen Environmental Action network, implements a proactive program of community outreach;" and, 5) "Evaluate water quality response to watershed management efforts to develop more effective implementation strategies" (CWQCB 1999, p. 5-6).

Management direction for those federal lands administered by the Lake Tahoe Basin Management Unit (LTBMU) is guided by the Unit's Land and Resource Management Plan (USDA 1988). The majority of the Upper Truckee watershed lands administered by the LTBMU are included in the Tahoe Valley and Meiss Management Areas. The Tahoe Valley Management Area includes the lower gradient reaches of the Upper Truckee River downstream of the base of Hawley Grade; the Meiss Management Area encompasses those reaches of the Upper Truckee from that point south to the headwaters.

Issues and concerns for the two management areas are quite different. In the Tahoe Valley Management Unit, most of the national forest system land is at the urban interface. As such, many of the management issues involve concerns such as dispersed motorized and nonmotorized recreation, stream-oriented recreation, forest health, and risk of fire (USDA 1988). By contrast, the concerns for Meiss Management Area focus on wildlife management issues; the area is closed to all vehicles and grazing is permitted (USDA 1988). Currently Management Standards for the Meiss Grazing Allotment are being analyzed; the environmental analysis will consider water quality tests on the Upper Truckee River that indicate California standards for fecal coliform bacteria levels were exceeded several times in 1999 due to grazing allotment utilization (O'Daly 1999).

The primary resource management emphasis for the Tahoe Valley Management Area is meeting recreational, scenic and special use demands (USDA 1988). The primary resource management emphasis for the Meiss Management Area is to "...provide a variety of unroaded non-motorized recreation experiences and to protect scenic conditions" (USDA 1988, p. IV-140). Management Practices for both areas include 'nonstructural' and 'structural' fish habitat management strategies. However, the 'Standards and Guidelines' differ as noted in Table C-4. Differences in wildlife management habitat strategies are also noted in Table C-4.

Further protection may lie in the future for the Upper Truckee and its watershed. In February of 1999, the LTBMU Forest Supervisor recommended the National Forest portion of the Upper Truckee River, south of Christmas Valley, for Wild River designation under the Wild and Scenic Rivers Act authority. This recommendation has been forwarded to higher Forest Service levels, and planning direction is in place to protect the river corridor from changes that could adversely affect Congressional Wild River designation. (O'Daly pers. comm.)

[3] To coordinate and focus watershed improvement activities, the California Regional Water Quality Control Board, in cooperation with TRPA, established the Upper Truckee River Focused Watershed Group (UTRFWG) in 1995; the Regional Water Quality Control board serves as the group's facilitator (CWQCB 1999). UTRFWG "...is currently collaborating with the U.S. Army Corps of Engineers (Corps) to develop a comprehensive watershed plan..." (Adair pers. comm).

Table C-4—Lake Tahoe Basin Land and Resource Management Plan Practices, Standards and Guidelines for the Meiss and Tahoe Valley Management Areas† (USDA 1988).

Management Area	Practice	Standard and Guideline
Meiss	Nonstructural Wildlife Habitat Management	Protect or improve wildlife in meadow areas
	Nonstructural Fish Habitat Management	Assist the California Department of Fish and Game in the reintroduction of Lahontan cutthroat trout
	Structural Fish Habitat Management	Improve fish habitat in meadow areas.
Tahoe Valley	Structural Wildlife Habitat Management	Waterfowl nesting islands and tubs at Pope Marsh will be maintained. Tubs will be replaced by nesting islands in cooperation with the California Department of Fish and Game
	Nonstructural and Structural Fish Habitat Management	Improve conditions on the Upper Truckee River for migratory and resident trout.

† For a complete list of Practices, Standards and Guidelines for these areas, please consult the LTBMU Land and Resource Management Plan (USDA 1988).

Additionally, an executive order issued by President Clinton recently directed the Forest Service to prepare an Environmental Impact Statement affording roadless areas, including portions of the Upper Truckee watershed, protection from logging, road building, and other activities. This designation would not change the way the area is currently managed, as those activities are already prohibited (O'Daly pers. comm.).

While the aforementioned management directions provide for general conservation and management strategies, consideration should be given to developing a specific management plan for the Upper Truckee River in the context of how the biological integrity of aquatic ecosystems in the basin would be maintained and improved. Due to the diversity of issues and interests, such a plan should include a concerted effort to involve various local, state, and federal agencies, along with residents and special interest groups.

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