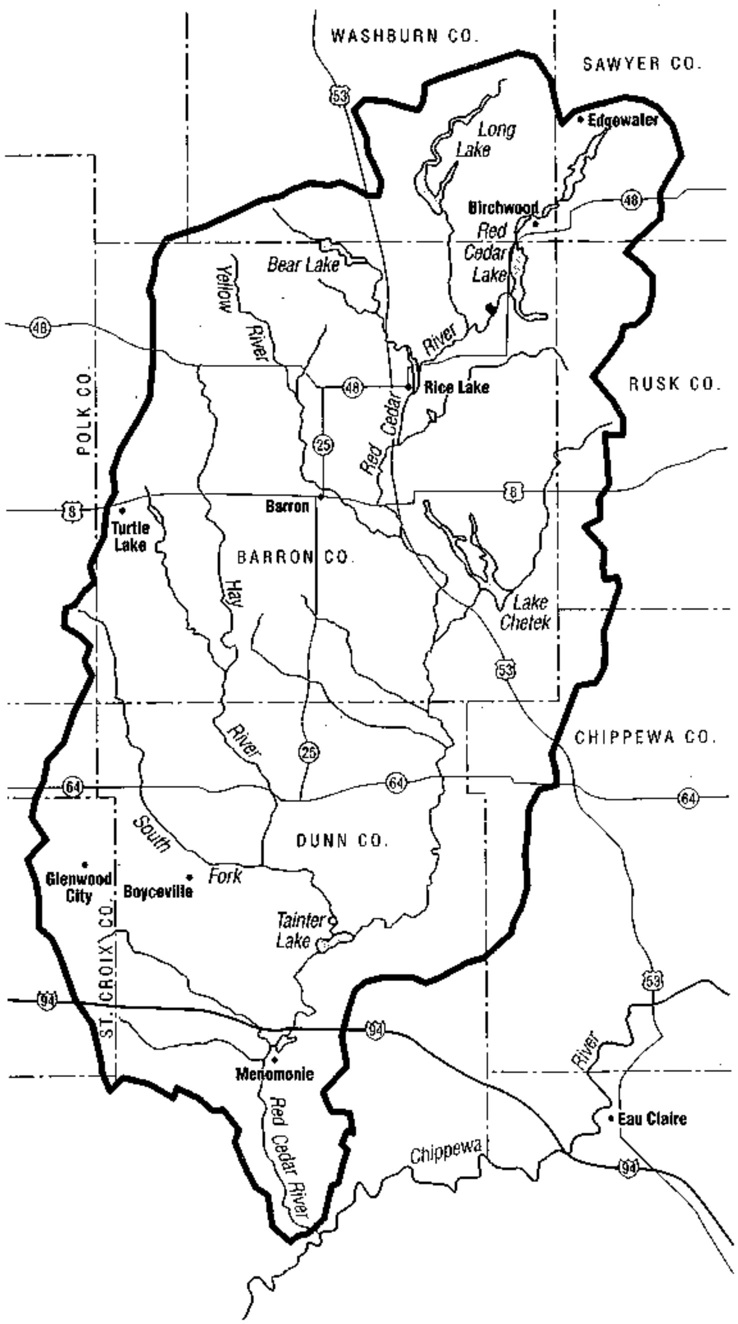
Phosphorous Content of Water and Suspended Sediment in the Red Cedar River Basin



Completed January, 1999

Prepared by: Paul LaLiberte and Erik Kampa
Wisconsin Department of Natural Resources
West Central Region

PROJECT DESCRIPTION

Over the past several years, the Red Cedar River Basin has been monitored as part of a USEPA 104(B)(3) grant for pilot watershed projects. Past grant-related activities have included extensive background monitoring of the Red Cedar River and its main tributaries (1995) and monitoring several flowages in the system in conjunction with a user-perception survey (1996).

Water quality in the Red Cedar River Basin is impaired by excessive loadings of sediment and nutrients arising from point and nonpoint sources of pollution. During 1996, the suspended solids and phosphorous loadings from all sources of pollution within the basin were estimated. A process based computer model, Simulator for Water Resources in Rural Basins - Water Quality (SWRRBwq), was used to estimate sediment and phosphorous contributions from various agricultural, forested, and urban land uses for the seven watersheds in the Red Cedar River Basin. The phosphorous loads were also estimated from point sources and barnyards using Wisconsin Pollution Discharge Elimination system permits and Priority Watershed Project data, respectively. Finally, the sediment and phosphorous loading from all watersheds were routed to Tainter Lake to determine the relative contribution of various pollutant sources and watersheds in the Basin. However, the modeled loads did not agree well with loads monitored in 1989-90. In an effort to reconcile the discrepancies, additional monitoring was planned for 1997 with the following major goals:

- to augment data collected in 1990 to calibrate the SWRRB model
    - document the dissolved phosphorous(DP) / total phosphorous(TP) ratio
    - document the phosphorous content of suspended solids
    - gather data during an additional snowmelt period at two stations
- to evaluate new sampling methods

METHODS

The data collection objectives for augmenting existing data for SWRRB calibration included collecting event and base flows at six sites in the basin. To allow comparison with data collected by the United States Geological Survey (USGS) in 1990, two mainstem sites **(Hay River at Wheeler and Red Cedar River at Colfax)** were selected. Additional study sites were identified using the following selection criteria:

- Agricultural area with high soil loss predicted by SWRRB.
- No point sources to bias base flow samples.
- Headwater areas with uniform conditions (no upstream watershed with better land use).
- Preferably located in South Fork Hay or Yellow River Watersheds so that Priority Watershed land use inventories could be considered.
- Include one reference site.

After consulting with Land Conservation staff and DNR fish managers, the following sites were selected (Figure 1):

Connors Creek, So. Fk. Hay River Watershed - 9 square mile watershed with high erosion potential as predicted by WNHSLE and by SWRRB, steep stream gradient,

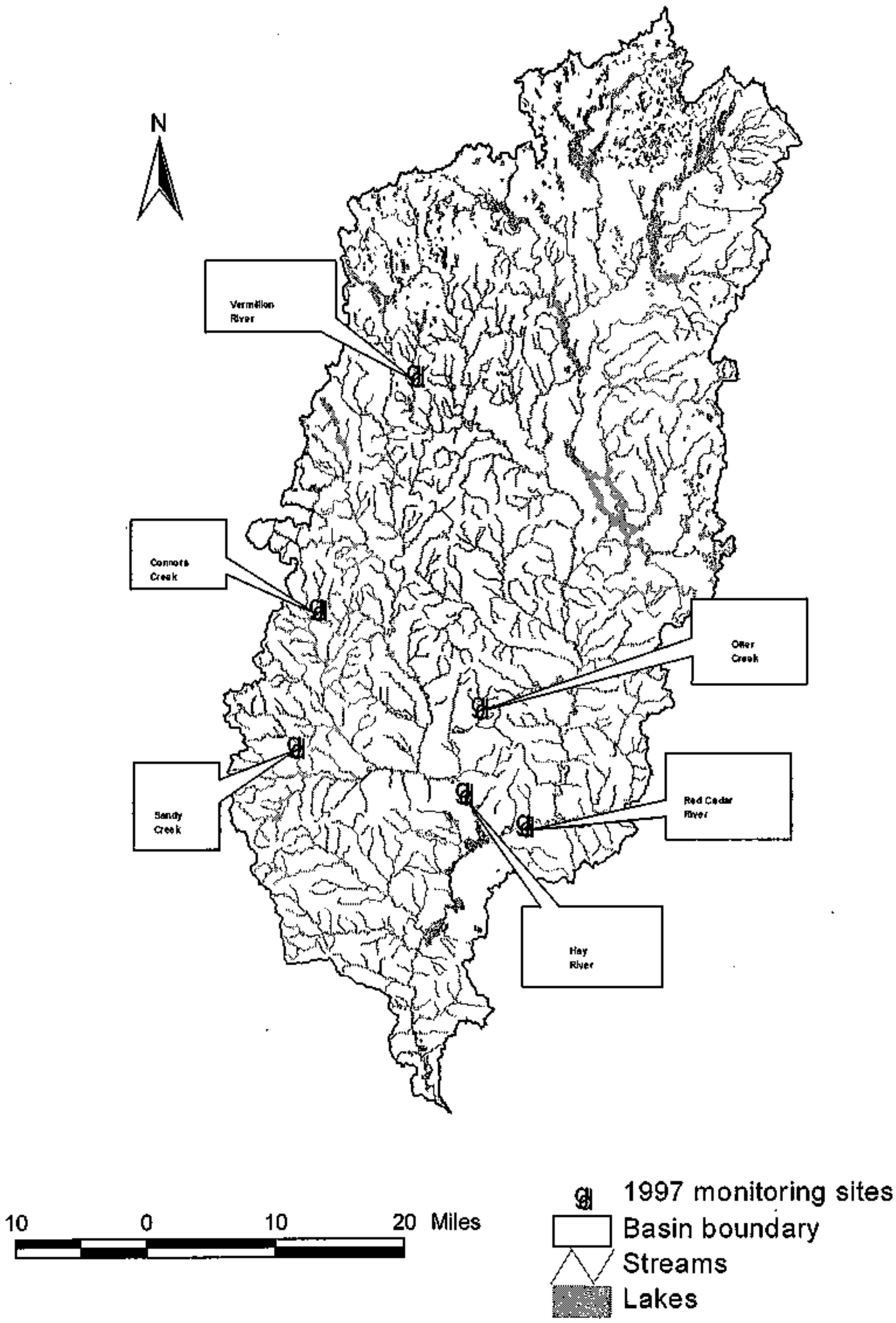


Figure 1. Monitoring sites in the Red Cedar River Basin, 1997

Class II trout streams, moderately high turkey manure application rates, and moderate to high densities of dairy operations.

Upper Vermillion River, Yellow River Watershed - 11 square mile watershed with high erosion potential, low stream gradient, forage fish streams, moderately high turkey manure application rates, and moderate to high densities of dairy operations. The stream also has a significant amount of riparian wetlands.

Otter Creek, Hay River Watershed - The upper ten square miles of this watershed is primarily forested and it contains a high quality trout fishery. Very little agriculture is present.

Sandy Creek, So. Fk. Hay River Watershed - 18 square mile agricultural watershed with low erosion potential, low stream gradient, Class I-II trout streams and no turkey manure application in 1996. This stream presents a unique opportunity to study system with this combination of attributes.

Water samples

Analysis included total and dissolved phosphorus and suspended solids. Flow was collected only at existing USGS gauges. An attempt was made to sample 5 events at all sites, including some samples before and some after vegetative cover was established on cropland. Four base flow samples were collected at each site.

Depth integrated sampling methods were used at the two mainstem sites. This duplicates the procedure used during previous work at these sites in 1990 and allows comparison of the total phosphorus results from the two studies. Events were grab sampled daily during the rising limb of the hydrograph for runoff events. Events were defined as an increase in flow at the USGS gauge on the Hay River in Wheeler of at least 10% in a 24 hour period. This assessment was done daily by accessing the USGS web site. Professional judgment was used to determine the frequency of sampling during the falling limb of the hydrograph. Larger events were sampled less frequently than smaller events. Sampling began at these sites during snowmelt in March 1997 and extended through August 1997.

Events in the four smaller watersheds were sampled using stage activated samplers (Appendix A) attended by a local cooperator. Two sample devices were located at each site at slightly different elevations. This will result in one or two samples per event collected on the rising limb of the hydrograph. Sampling in the four smaller watersheds began in April after snowmelt. Appendix B is an example instruction sheet for field personnel servicing stage activated samplers.

Stream temperature, dissolved oxygen and pH were measured each time manual grab sampling occurred. Meter calibration and sampling followed the procedures in *WI DNR Field Procedures Manual, Sections 2101 & 2001*. These parameters were not evaluated on water samples from the stage activated samplers.

Manual water grab samples were preserved and handled in accordance with the *Handling and Preservation Handbook* of the Environmental Sciences Section of the

Wisconsin State Lab of Hygiene (SLOH), in sample bottles provided by SLOH. Samples were stored on ice beginning at the time of collection. Samples were shipped as soon as possible to ensure no more than 48 hours of elapsed time from sampling to analysis during weekday sampling and no more than 72 hours elapsed time for weekend sampling.

Samples from stage activated samplers were handled in accordance with the procedures outlined in Appendix B. All samples were shipped on ice to SLOH via US Postal Service with postage sufficient to ensure a transport time of no more than 24 hours. If a sample was judged to have sat in the sampler more than 48 hours prior to being retrieved, it was not analyzed. This should ensure that no sample had an elapsed holding time of more than 72 hours.

The average ratio of dissolved to total phosphorus at the two mainstem stations were used for model adjustment. The significance of differences between sites were assessed using the Mann-Whitney Rank Sum Test. The average ratios from the smaller watershed stations were used to subjectively assess variability of the ratio within the basin.

A measure of the phosphorus content of suspended solids was performed using the water sample data and the following equation:

$$\text{P concentration of suspended solids (ppm)} = \frac{\text{mg/L total P - mg/L dissolved P}}{\text{mg/L suspended solids}} \times 1\text{X}10^{6}$$

Past experience with this technique has indicated that it provides inconsistent results when the standard SLOH procedure for suspended solids analysis is used and the results are below 10-15 mg/L. Therefore, the equation was applied to samples with SS levels above 15 mg/L. A modification to the standard SLOH suspended solids technique was utilized in this study to get lower detection levels (down to 0.7 mg/L). The modification consisted of filtering 600 ml of sample instead of the standard 200 ml. The data was further evaluated to see if this lower detection level allows application of the equation to samples with SS levels below 15 mg/L.

The resultant estimates of the phosphorus concentration of suspended solids in the basin listed above were used to adjust the SWRRB model as necessary.

Sediment samples

Sediment traps were used to obtain a long term composite sample of suspended sediments moving through select watersheds. These samplers were deployed at the same sites where chemistry grab samples are taken. Appendix C illustrates the operation and design of the sediment traps. Two sets of triplicate traps (six traps total) were deployed at each site to allow for statistical evaluation of the analytical results. The traps were maintained in accordance with the instructions in Appendix D. Sediment samples were placed in new, labeled Zip-Lock plastic bags and kept frozen until all samples were collected.

Sediment volume was insufficient to analyze each sample separately. Many samples were composited by combining the contents obtained from each individual trap regardless of date. The goal was to determine the average total phosphorus content measured by each trap. The ability of replicate traps to discriminate phosphorous content was evaluated by calculating the coefficient of variation. Any significant differences were to be assessed using T-tests if the data was normally distributed or with Mann-Whitney Rank Sum tests if it was not.

A third evaluation of the phosphorus content of basin suspended solids was the comparison of total phosphorus determined by rigorous digestion (SLOH technique) and mild extraction (UW-EXT technique) on the trap contents. The SLOH technique is commonly used in water quality studies while the UW-EXT technique is commonly used to assess agricultural soils in Wisconsin. These methods were compared to better understand the integration of land use data with pollutant transport within the SWRRB model. While the primary data source for model calibration was the SLOH data, it is anticipated that the paired sampling may help explain why initial model load projections were different from monitored loads.

The physical parameters, organic content, total volatile solids, particle size and bulk density were regressed against phosphorus concentration to look for significant relationships and to normalize the phosphorus concentration for each watershed when comparing them to each other.

Several tests were employed to evaluate the reliability of current, and new, sampling methods. The effect of holding time on dissolved phosphorous tests was examined by comparing several different combinations of time-interval storage at room temperature and cooling. These results were compared by calculating a standard deviation for all samples.

The effectiveness of the stage activated samplers was evaluated. The problems noted and suggestions for improving sampler design are discussed under the results section.

The variability of the sediment traps was also evaluated. This was accomplished by comparing the variability between samples placed in close proximity (assumed to be replicates) and the variability between separate sites.

RESULTS AND DISCUSSION

Dissolved phosphorous holding time

One ongoing QA/QC concern has been the effect of various holding times on dissolved phosphorous data. For example, some samples are collected, iced, shipped immediately, and processed within 24 hours. Other samples may be iced for 24 hours, shipped, and processed within 48 hours. To quantify the effect of different holding times on dissolved phosphorous results, replicate samples were collected with eight different holding time regimes (Appendix E). The dissolved phosphorous results are presented in Table 1.

The standard deviation (0.0064) indicates little variability among the treatment groups. The mean was 0.074 with a 95% confidence interval of 0.0696 to 0.0784. Based on the results of this comparison, various holding times do not have a large enough effect on dissolved phosphorous to bias the results. Therefore, samples which were collected and immediately shipped are comparable to results from samples which were stored on ice (i.e. over the weekend) or even stored at room temperature prior to shipping.

Table 1. Dissolved phosphorous results using different holding time regimes.

Treatment	Dissolved Phosphorous (ug/l)
A	0.076
B	0.075
C	0.059
D	0.075
E	0.075
F	0.075
G	0.076
H	0.081
Mean	0.074
standard deviation	0.0064

Effect of reduced suspended solids detection limits

A problem which commonly occurs when developing a suspended solids to total phosphorous relationship is the amount of "noise" that occurs at suspended solid levels below 15 mg/l. It has been difficult to detect significant relationships at low levels due to high variability among total phosphorius values. The SLOH agreed to modify analytical techniques to lower suspended solid detection limits. The performance of lower detection limits can be seen in plots of total phosphorous versus suspended solids on the Red Cedar River and Hay River (Figures 2, 3, and 4, Appendix F).

The Red Cedar River plot (Figure 2) indicates fairly constant variance over the entire range of suspended solid values (R-squared = 0.74). Increases in the amount of

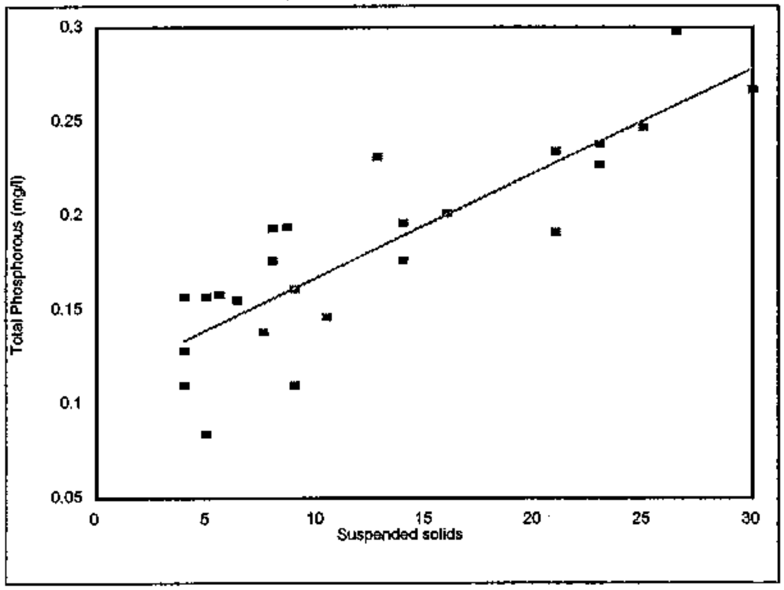


Figure 2. Red Cedar River - Total phosphorous versus suspended solids

suspended solids reaching the river should result in a linear increase in the amount of total phosphorous delivery.

The relationship between total phosphorous and suspended solids in the Hay River does not appear to be linear (Figure 3, R-squared = 0.66). There appears to be a "plateau" in phosphorous levels above 100 mg/l suspended solids. If this plateau indeed exists, it is not evident from Red Cedar River data; because, suspended solid levels did not exceed 30 mg/l during the study. If the high suspended solid values are removed from the Hay River data (Figure 4, R-squared = 0.83), a linear relationship can be detected.

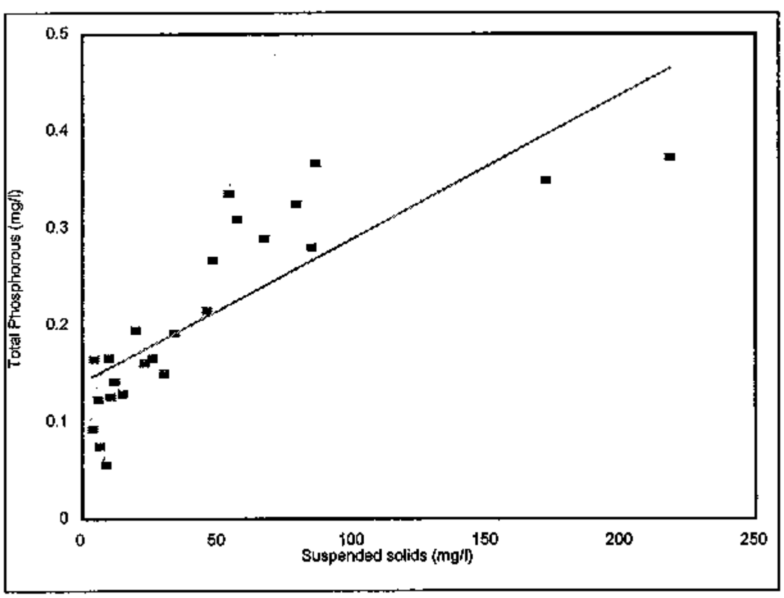


Figure 3. Hay River - Total phosphorous versus suspended solids

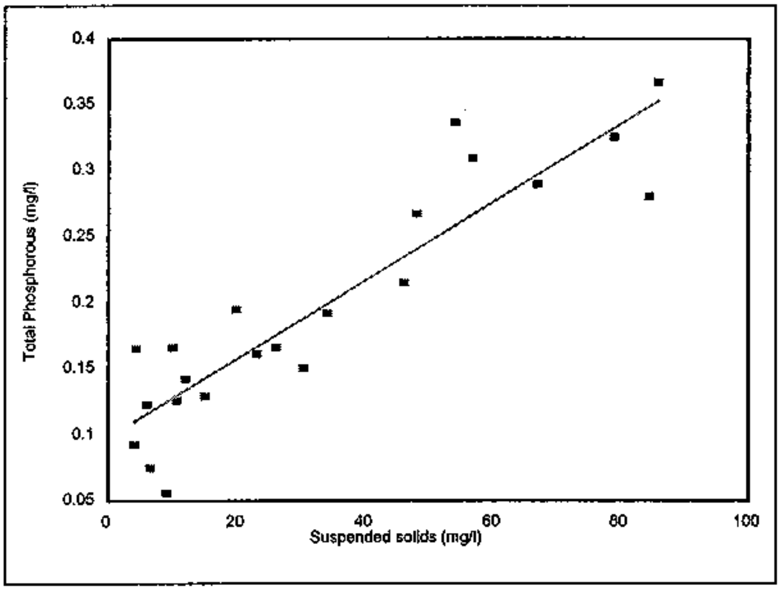


Figure 4. Hay River - Total phosphorous versus suspended solids (excluding ss above 100 mg/l)

Additionally, the reduced detection limits lead to improved relationships between suspended solids and total phosphorous (at suspended solid levels less than 15 mg/l). The total phosphorous variability appears to be fairly constant over the entire range of values, both on the Red Cedar River and the edited Hay River data.

Sediment traps as indicators of sedimentation rates

Based on the variability among replicates, the sediment traps deployed during this study were ineffective at detecting sedimentation rates. The within replicate coefficient of variation (CV) ranged from 0.117 to 1.539, with a mean CV of 0.552 (Appendix G). Since the variability between replicates was excessively high, no attempt was made to compare sedimentation rates between sites.

Relationship between sediment phosphorous content and other sediment characteristics

One study objective was to determine which sediment physical characteristic would be the most predictive of sediment phosphorous content. Additionally, differences between phosphorous analysis techniques were examined. Samples were split and sent to both the SLOH for regular phosphorous digestion and the University of Wisconsin Soil and Plant Analysis lab for Bray digestion.

There were significant differences between the two methods of phosphorous analysis (Appendix H). There was virtually no correlation (Pearson Product Moment Correlation = 0.05935) between results from the two labs. A paired, two-tailed t-test, assuming unequal variances, indicated that there were statistically significant differences between the methods ($P(t<=T) = 0.00278$). In order to compare results with previously collected data, the SLOH regular digestion method was chosen for additional analysis.

Sediment physical parameters were examined to determine which would yield the best relationship with total sediment phosphorous (correlation matrix, Appendix H). All sediment particle types (% sand, % silt, % clay, % silt + clay) were examined. Only one of the sediment particle type parameters, sand, showed a strong relationship and was used to avoid multi-colinearity problems. (I.E. A high percent of sand would likely be negatively correlated with percent clay or silt.) Initial analysis indicated that percent organic matter showed a strong positive correlation with sediment phosphorous. Percent sand showed a strong negative correlation with sediment phosphorous.

The evidence for a relationship between organic matter and sediment phosphorous was not as strong when sites were analyzed individually. While the positive correlation still existed on the Red Cedar River and Otter Creek, Hay River showed a negative correlation between the two parameters. Further examination of this relationship was suspended since the data did not indicate that it was universal for all sites.

The relationship between percent sand and sediment phosphorous was also problematic when examined visually (Figure 5). The variability between sites and between dates at the same site (e.g. the Red Cedar River) is too large to make generalizations about the relationship between percent sand and sediment phosphorous.

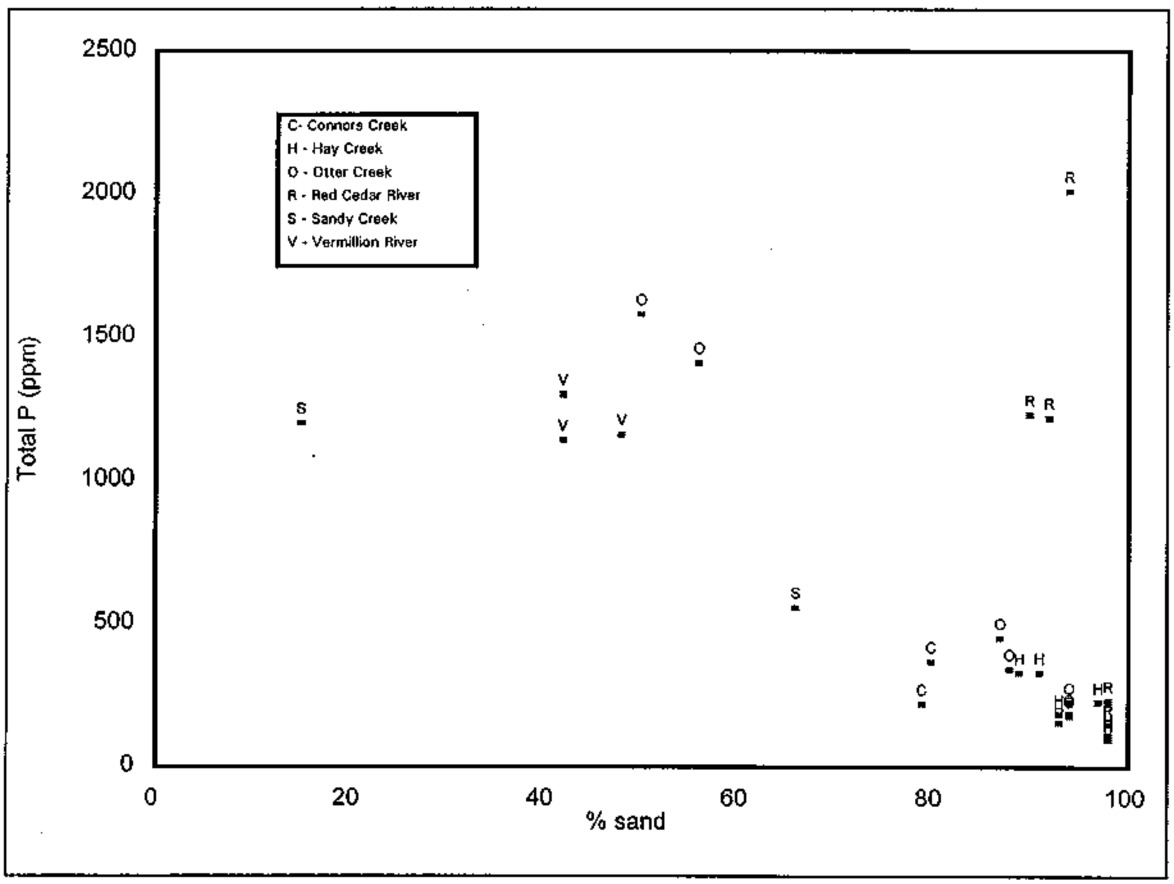


Figure 5. Red Cedar River Basin - Sediment phosphorous versus percent sand

Another problem evident in Figure 5 is the relatively narrow range of sandcontent which was sampled by the sediment traps. The percent sand data collected by sediment samplers at virtually all sites exist in a narrow range. The only exception is the Sandy Creek site. Data over a much broader spectrum of conditions are necessary to adequately assess any relationships between percent sand and sediment phosphorous.

With the exception of Sandy Creek, the replicate sediment traps produced similar values for % sand, the physical parameter best correlated with sediment phosphorous content. However, the variability of sediment phosphorous concentration among replicates was unacceptably high. Also, the samplers collected too much sand to be useful as a tool for estimating the phosphorous content of stream suspended sediment.

Based on data collection and analysis in this study, event water samplers are recommended (as opposed to sediment samplers) to provide estimates of phosphorous being carried by (adsorbed to) the suspended solids.

Comparison of Red Cedar Basin phosphorous levels to other basins

The phosphorous content of particulate material in water samples collected in the Red Cedar River Basin during 1997 were compared to data collected by USGS and WDNR from other rivers in the state (see equation, page 5). In addition to comparing the particulate phosphorous concentrations, the suspended solids to total phosphorous ratios were calculated (Table 2, Appendix I).

Table 2. Comparison of particulate phosphorous concentration to the suspended solids/ total phosphorous ratio.

Location	No. samples	PP content (ug/g)	PP rank	% DP	SS : TP	SS : TP rank
RED CEDAR BASIN SITES						
Red Cedar River @ Colfax	8	5318	1	49	97	1
Connors Creek	6	3502	2	37	229	3
Hay River @ Wheeler	16	3075	3	40	233	4
Sandy Creek	6	2707	4	26	729	12
Otter Creek	7	2441	5	37	271	5
REFERENCE SITES						
Red River @ Morgan	18	1453	6	37	833	14
Bad River @ Odanah	48	1052	7	23	766	13
Rush and Trimbelle Rivers	6	1041	8	56	483	9
Brewery Creek	15	1020	9	43	571	11
Yahara River @ Winsor	82	931	10	42	517	10
Garfoot Creek	14	823	11	50	428	7
Kickapoo River @ Steuben	126	728	12	32	458	8
Oconto River @ Gillett	16	489	13	25	366	6
Black River @ Neillsville	53	261	14	18	123	2

The particulate phosphorous content data clearly indicate that the suspended solids in water samples from the Red Cedar River drainage have a much higher phosphorous content than what is usually encountered around the state (2-5 times the statewide average, depending on the site). Essentially, this means that sediment particles transported into the system from upland soils contain an extremely high level of phosphorous.

While this analysis indicates an extremely phosphorous-enriched suspended sediment load enters the Red Cedar River Basin, it also provides evidence that controlling a ton of upland soil loss may reduce the phosphorous loads 3 to 6 times more in this basin versus elsewhere.

Comparisons between particulate phosphorous rankings and suspended solid to total phosphorous rankings also strongly support the need to collect dissolved phosphorous data. Dissolved phosphorous samples are sometimes excluded from a study to reduce monitoring costs. If such data is unavailable, it is impossible to fraction particulate phosphorous from total phosphorous. In such cases, the suspended solid to total phosphorous ratio is often used in lieu of particulate phosphorous data. The results of this study indicate that making the assumption that the ratio (SS:TP)provides a good index for gauging the amount of phosphorous transported into the system via solids is misleading.

For the Red Cedar Basin streams, most rankings did not change significantly. However, Sandy Creek dropped from number 4 to number 12 by changing methods. (Other examples of large ranking changes statewide include the Red River atMorgan,Bad River at Odanah, Oconto River at Gillett, and Black River at Neillsville.) Estimates of the amount of phosphorous associated with suspended solids entering the system in Sandy Creek would be underestimated using the SS:TP ratio.

Another common practice is using a statewide particulate phosphorous average to adjust soil movement models. The range of particulate phosphorous values in Table 2 illustrate the danger of using an average. If an average value of 1000 ug/g were selected as a hypothetical average, real values could be five times greater or less than the estimate (5000 or 200).

In order to provide a realistic estimate of particulate phosphorous for soil movement models, event data should be collected, including dissolved phosphorous. The stage-activated samplers were designed to do this in a cost effective manner. Their use is encouraged. These samplers could be deployed to sample high flow conditions when there are significant amounts of suspended solids moving through the system rather than base-flow conditions.

Since the study was concluded, the sampler design has been modified to make them even easier to use. Revised design and operation literature is available on request.

1990 SS:TP ratios

To provide a comparison to current data and to provide an index of annual variability, SS:TP ratios were calculated from 1990 data (Schreiber, 1992). The ratio in the Red Cedar River at Colfax was 99 in 1990 and 148 at the Hay River at Wheeler. The Red Cedar River still would be ranked as number 1. The Hay River would move up from number 4 to number 2. Overall, it appears that there is some variability from year to year. However, it also appears that a single year of data would be adequate to describe a watershed as having high, medium, or low sediment phosphorous levels.

References

LaLiberte, P. Red Cedar River Watershed strategy implementation: quality assurance project plan. Wis. Dept. Nat. Res.

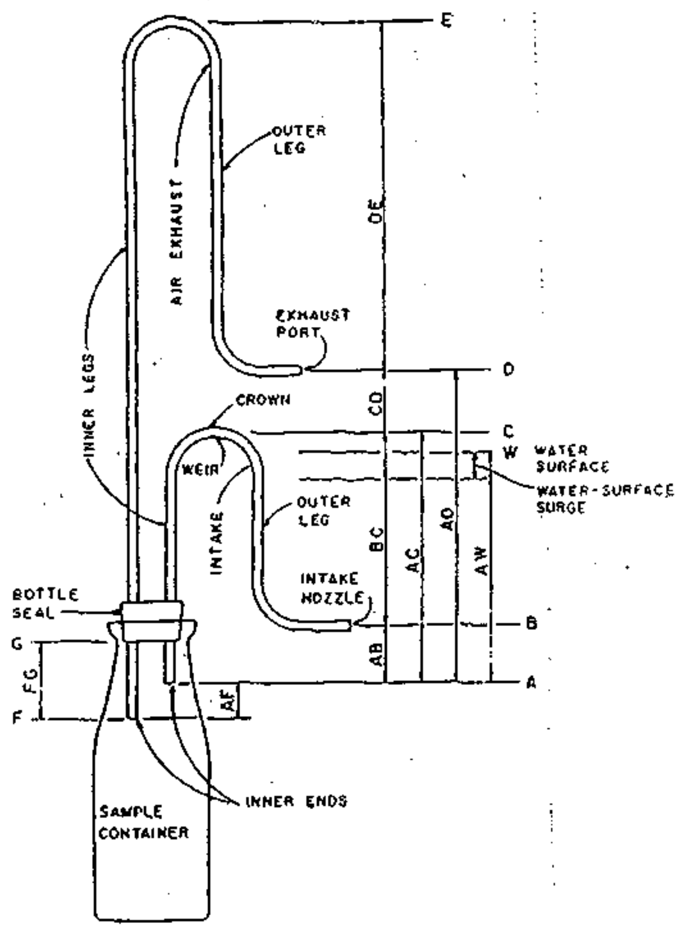
Schreiber, K. 1992. Red Cedar River / Tainter Lake phosphorous assessment. Wis. Dept. Nat. Res.

State Lab of Hygiene. 1981. Handling and preservation handbook. Environmental Sciences section.

Wis. DNR. 1983. Field procedures manual for water quality and compliance monitoring.

Appendix A.

Diagram of stage activated sampler



Appendix B.

WATER SAMPLING INSTRUCTIONS - STAGE ACTUATED SAMPLER

1. LABEL SMALL, MEDIUM AND LARGE BOTTLE*

2. REPLACE FULL BOTTLE(S) WITH EMPTY ONE**

3. AGITATE THE SAMPLE AND POUR SOME INTO THE SMALL AND MEDIUM BOTTLES SO THEY ARE HALF FULL

4. ACIDIFY MEDIUM BOTTLE WITH ONE ACID AMPULE AND LABEL

5. PUT ON ICE FOR TRANSPORT

6. IMMEDIATELY PRIOR TO SHIPPING, ADD NEW ICE PACKS (ABOUT EQUAL VOLUME TO SAMPLE)

7. INCLUDE LAB SLIP IN A BAGGIE

   FILL IN: FIELD NUMBER*
   COLLECTED BY
   PHONE
   GRAB DATE
   BEGIN TIME

8. MAIL FOR DELIVERY NEXT DAY

* FIELD NUMBERS:

SANDY CREEK LOWER SAMPLER = SC-1L
SANDY CREEK UPPER SAMPLER = SC-1U
CONNORS CREEK LOWER SAMPLER = CC-1L
CONNORS CREEK UPPER SAMPLER = CC-1U
OTTER CREEK LOWER SAMPLER = OC-1L
OTTER CREEK UPPER SAMPLER = OC-1U
VERMILION RIVER LOWER SAMPLER = VR-1L
VERMILION RIVER UPPER SAMPLER = VR-1U

** The goal of this water sampling effort is to catch a snowmelt sample plus four different runoff events. Snowmelt was grab sampled previously. To spread out the event sampling, do not replace a filled event sampler immediately. Wait to reset the sampler so that at least 2 weeks elapses between samples. For example;

If the lower sampler only fills (small event) , remove it for two weeks. Leave the upper sampler in place. If a second event occurs within two weeks, it will have to be larger than the first event to fill the upper sampler. This constitutes a different kind of event (same time of year only bigger).

If both samplers fill, (large event) remove both samplers for 2 weeks to allow watershed conditions to change.

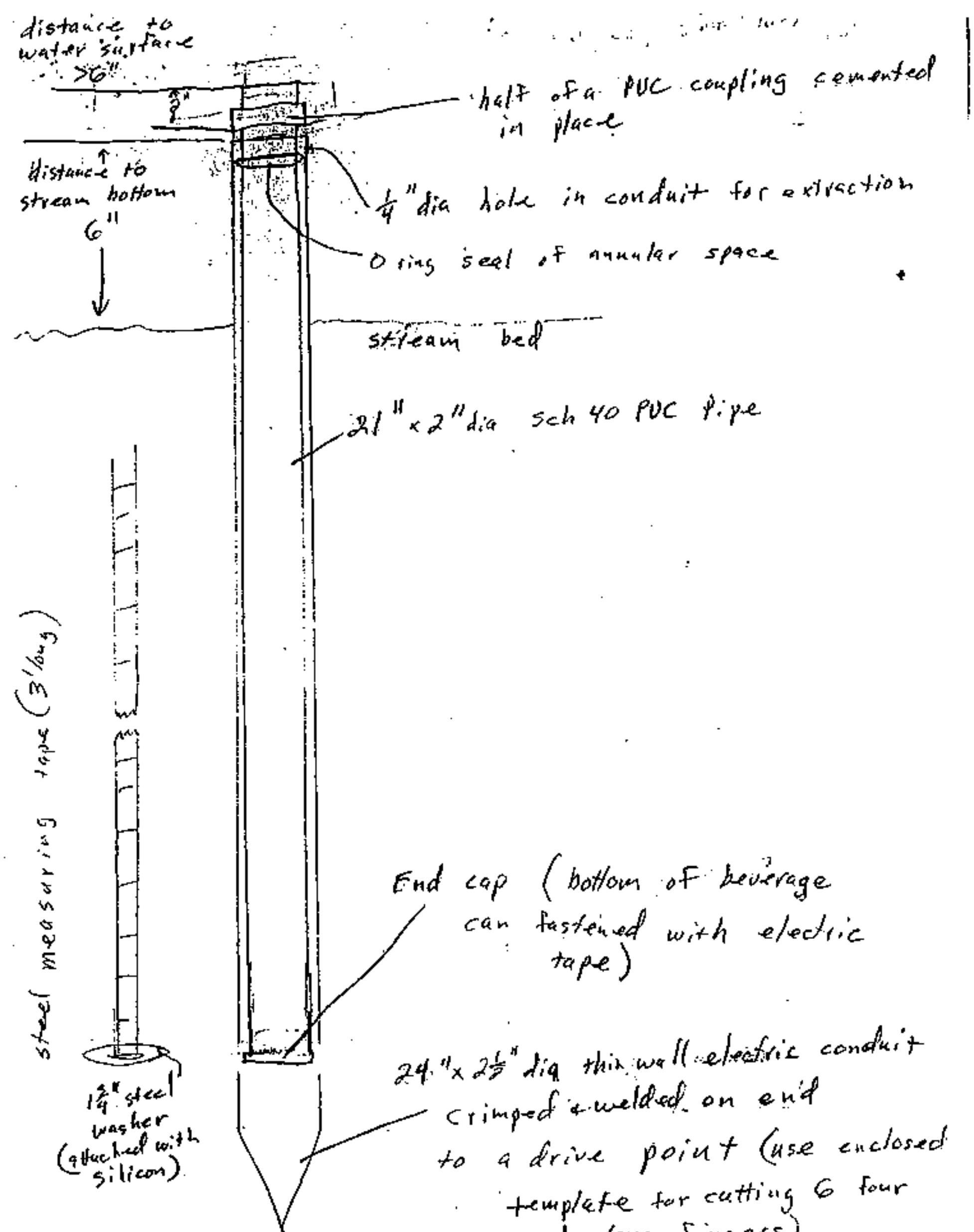
QUESTIONS?

CALL PAUL LA LIBERTE 715-839-3724
KEN SCHREIBER 715-839-3798
ERIK KAMPA 715-836-6573

SAMPLE.INS

Appendix C.

Diagram of sediment trap



Appendix D.

SEDIMENT TRAP MONITORING

June 5, 1997

As part of monitoring in the Red Cedar River Basin in 1997, sediment trap monitoring is being planned. The goals of the effort would be to:

1. Determine the phosphorus content of suspended sediment being transported through watersheds.

2. Test a new trap design and deployment method for estimating gross sedimentation and TSS concentration in shallow streams.

Six test sites will be chosen. The sites would encompass a range of expected sedimentation rates. Each site will include two sets of three traps located in the same reach. While each trap will meet the enclosed minimum deployment conditions, an effort will be made to deploy each set of three at different depths or orientations to assess the sensitivity of the device to localized effects. For example, at three sites, one set of three replicate traps could be deployed at a depth of 1' and another set at 2.5'. At the other three sites, two sets of replicate could be placed at the same depth but at different locations in a pool. The gross sedimentation rate of each trap will be monitored individually.

All the sediments trapped over a 3-5 month period at each site will be composited into a single sample for analysis (one sample for each of the six watersheds). The sediment will be analyzed for total phosphorus, Bray phosphorus (an agricultural technique), particle size, bulk density (gm/cm^3) and organic content (loss on Ignition). The replicate traps will not be analyzed individually due to budget constraints.

The six sites will also have water samples collected 12-30 times during the growing season with the intent of obtaining 4 base flow samples and 5 event samples. The water samples will be analyzed for suspended solids and dissolved and total phosphorus. Two sites in large watersheds will be sampled using manual grab samples off a bridge. Four sites in small watersheds (10 sq mi) will be sampled using two stage activated samplers (bottle on a stick) at two different elevations.

SEDIMENT TRAP DEPLOYMENT SPECIFICATIONS FOR SMALL STREAMS

The trap needs to be placed in a run or pool with 12-18" water depth at the lowest expected flow. The exception to this will be at sites where the effect of depth is an experimental variable. The PVC liner orifice should always be located at least 6" above the steam bottom. All traps should be initially set out so that the orifice is 8" off the bottom initially. If, at any time during trap deployment, the stream bottom rises to within six inches of the trap opening, it should be relocated to achieve a eight inch height. The trap must be emptied often enough to ensure the height of the trapped sediment does not get within six inches of the orifice.

The steel casing should be driven into the stream bottom to the appropriate depth. Don't pound directly on the casing, or the resultant damage will prevent the PVC liner from properly seating. Some sort of steel drive cap is recommended. For stream bottoms containing gravel, a pilot hole should be made with a steel pry bar before attempting to drive the casing. Driving the bar in and rotating it will usually loosen the gravel sufficiently. A pilot hole will not be needed in sand bottom streams. If trap stability is a problem in very soft bottoms, the casing can be made longer and driven in deeper.

The preferred length for the PVC liner is 18 inches (an 8/1 aspect ratio when empty and 3/1 when filled within 6" of the top). This requires that the 24 inch steel casing be driven about 18 inches into the stream bottom. If this is not possible (eg encounter bedrock) the casing can be driven shorter distances and cut off so that it terminates 8 inches above the stream bottom. If this is done, the PVC liner will also have to be shortened by the same length. These modifications can be done in the field with a hacksaw. The PVC edges should be rounded with a knife blade after cutting. Shorter trap heights will necessitate more frequent visits to service the trap to ensure that it does not fill with sediment. In most streams, an 18 inch trap should be sufficient to last six months without being serviced. However, monthly visits for the first three months are recommended initially until an understanding of the stream's gross sedimentation rate is obtained. Visits should also be made after very large runoff events to see if the trap survived or is near filled.

SERVICING THE SEDIMENT TRAP

Approach the trap from downstream. Remove any accumulated debris and perform the following:

GROSS SEDIMENTATION RATE: Allow a 3' steel measuring tape with a 1 1/4" steel washer attached to fall, by gravity, until it stops. Record the distance between the top of the trapped sediment and the top of the PVC liner to the nearest 1/16 inch. Subtract this value from the internal height of the PVC liner to get the depth of sediment trapped. Be sure to record the date, the height of trapped sediment, the height of the trap orifice over the stream bottom and depth of the water on an appropriate field sheet. Make note of any unusual circumstances (e.g. a fish in the liner or trap filed to within 6 inches of the orifice). If you are not sure that there is sufficient volume remaining in the trap to catch all events that will occur before the trap is next checked, remove the PVC liner, dump the contents, flush it out and replace it. If the contents are to be retained for chemical analysis, see the following.

SEDIMENT CHEMICAL ANALYSIS: If chemical analysis is to be done, lift the PVC liner from the steel casing and carefully decant off all but 3-4 inches of water. Temporarily cap the liner and agitate the contents to loosen the sediment and pour it off into a specially cleaned container. If significant sediment remains in the liner, add an additional 1-2 inches of stream water and repeat until all the sediment is transferred. Replace the PVC liner and put the sample container on ice.

CASING REMOVAL SUGGESTIONS

Usually, a vigorous circular motion in combination with twisting is sufficient for removal. For particularly difficult extractions, use a long steel bar or pipe with a cable and hook to lift it out with a lever action. A hole in the casing is provided for this purpose. Sometimes vibrating the casing by pounding on the side is useful.

CAUTION

If you leave the casing in place without a PVC liner, it will eventually fill up with sediment and make it impossible to replace the liner. The casing alone is not an adequate sediment trap since it cannot be adequately serviced. If you leave the casing in place, leave the liner as well or cap it.

Do not enter the stream until storm waters have receded to the point where the stream can be safely entered with waders.

The placement of this device requires a state permit unless it is part of a state or federally sponsored project.

The bed of a stream is owned by the person owning the riparian property. Always obtain permission from the property owner before placing any devices.

trap.mem

Appendix E.
Dissolved Phosphorous QA Study

Sample	Treatment	DP
A	room temp (48 hours), ice (24 hours)	0.076
B	room temp (24 hours), ice (48 hours)	0.075
C	ice (24 hours)	0.059
D	ice (48 hours)	0.075
E	room temp (24 hours), ice (24 hours)	0.075
F	ice (72 hours)	0.075
G	room temp (24 hours)	0.076
H	ice (24 hours), with field filter	0.081

Summary Statistics

Mean	0.074
Standard Error	0.0023
Median	0.075
Mode	0.075
Standard Deviation	0.0064
Variance	4.09E-05
Kurtosis	5.998
Skewness	-2.197
Range	0.022
Minimum	0.059
Maximum	0.081
Sum	0.592
Count	8
Confidence Level(0.950000	0.0044

Appendix F.

Regression Analysis: Total Phosphorous (y) vs. Suspended solids (x)

Regression Output:		Red Cedar
Constant		0.111511
Std Err of Y Est		0.027218
R Squared		0.738838
No. of Observations		25
Degrees of Freedom		23
X Coefficient(s)	0.00556	
Std Err of Coef.	0.000689	

Regression Output:		Hay River
Constant		0.14099
Std Err of Y Est		0.058254
R Squared		0.657128
No. of Observations		24
Degrees of Freedom		22
X Coefficient(s)	0.001484	
Std Err of Coef.	0.000229	

Regression Output 2		excluding ss > 100
Constant		0.098265
Std Err of Y Est		0.037782
R Squared		0.830016
No. of Observations		22
Degrees of Freedom		20
X Coefficient(s)	0.002958	
Std Err of Coef.	0.000299	

Appendix G.
Sediment Trap Data, in inches

Red Cedar River @ 22 mile, Ford Park							n	mean	s	CV
Date	1A	1B	1C	2A	2B	2C				
4/24/97	installed	-------	-------	-------	-------	-------				
7/1/97	18.875	18.75	7.625	2.75			4	12.00	8.114	0.676
7/15/97	3.00	13.00	2.00				3	6.00	6.083	1.014
8/7/97	3.25	7.875	2.5	0.875	0.50	1.00	6	2.67	2.763	
9/11/97	4.00	4.25	4.75	2.00	2.00		5	3.40	1.306	0.384
11/7/97	18.125	19.00	13.5	6.75	5.25	5.75	5	13.68	6.305	0.461
7/15 -11/7	25.375	31.125	20.75	9.625	7.75	6.75				
Totals	47.25	62.875	30.375	12.375	7.75	6.75				

Hay River @ Wheeler gauging station							n	mean	s	CV
Date	1A	1B	1C	2A	2B	2C				
4/24/97	installed	-------	-------	-------	-------	-------				
7/1/97	19.75	19.00	19.75	10.25	13.75	2.75	6	14.21	6.805	0.479
7/15/97	18.25	19.00		18.75		5.00	4	15.25	6.840	0.449
8/7/97	19.875	19.25		20.375	20.375		4	19.97	0.534	
9/11/97				18.5	18.125	7.875	3	14.83	6.029	0.406
4/24 -7/15	38.00	38.00	19.75	29.00	13.75	7.75				
Totals	57.875	57.25	NA	67.875	52.25	15.625				

Otter Creek @ Clover Swamp Drive							n	mean	s	CV
Date	1A	1B	1C	2A	2B	2C				
4/16/97	installed	-------	-------	-------	-------	-------				
5/19/97	3.25	4.125	1.00	6.25	5.00	4.00	6	3.94	1.767	0.449
7/1/97	7.75	4.75	7.75	18.25	18.125	19.75	6	12.73	6.665	0.524
9/3/97	5.75	6.875	19.875		18.00	12.875	5	12.68	6.361	0.502
9/11/97	0	0	0.125			0.75	4	0.22	0.359	
4/16 - 7/1	11.00	8.875	8.75	24.5	23.125	23.75				
Totals	16.75	15.75	28.75	NA	NA	37.375				

Connor's Creek							n	mean	s	CV
Date	1A	1B	1C	2A	2B	2C				
4/16/97	installed	-------	-------	-------	-------	-------				
5/19/97	0.25	0.25	0	0.25	0.25	0	6	0.17	0.129	
7/1/97	0.125	0.187	0	0.125	0.125	0.25	6	0.14	0.083	
9/3/97	3.25	2.812	3.687	3.00	2.75	3.437	6	3.16	0.368	0.117
10/11/97	1.25	0.4375	0.3125	0	0.25	0.5	6	0.46	0.425	
Totals	4.875	3.6865	3.9995	3.375	3.375	4.187				

Sandy Creek							n	mean	s	CV
Date	1A	1B	1C	2A	2B	2C				
4/16/97	installed	-------	-------	-------	-------	-------				
5/19/97	2.25	1.00	1.50	0.25	0.875	0.50	6	1.06	0.723	0.681
7/1/97	2.00	1.75	1.25	0.75	1.375	1.00	6	1.35	0.464	0.342
9/3/97	3.75	2.25	2.25	2.25	2.125	2.25	6	2.48	0.625	0.252
11/10/97	3.25		2.0625	1.625	0.75	2.00	5	1.94	0.901	0.465
Totals	11.25	5.00	7.06	4.88	5.13	5.75				

Vermillion River

Date	1A	1B	1C	2A	2B	2C				
4/15/97	installed	------------	------------	------------	------------	------------				
5/16/97	1.8125	0.8125	1.4375	1.375	1.6875	2.4375	6	1.59	0.539	0.338
6/25/97	5.75	15.5	0.5	0.6875	1	0.125	6	3.93	6.042	1.539
7/21/97	3.125	5	1.625		0.125	0.125	5	2.00	2.088	1.044
10/13/97	9.25	15.125	12.25	6.375	6.875	7.125	6	9.50	3.509	0.369
10/31/97		0.25	0.25	0.25	0.25	0.25	5	0.25	0.000	
Totals	19.94	36.69	16.06	8.69	9.94	10.06				

max	1.539
min	0.117
mean	0.552

Appendix H.

Red Cedar River Sediment Trap Data

Sediment Sample Analysis

	Sample #	BRAY P (ppm)	SLOH P(ppm)	BULK DENSITY gdry/ccwet	VOL SOL %	OM %	SAND %	SILT %	CLAY %	S+C %
Otter	MELT	89	450	0.12	2	2.0	87	8	5	13
	1A		1580	0.404	15.7		50	43	7	50
	1B	65	1410	0.378	14.7	10.3	56	39	5	44
	1C	160	184	1.316	1.6	1.1	94	3	3	6
	2A	100	177	1.422	1.9	1.2	94	3	3	6
	2B	125	225	1.283	2	1.5	94	3	3	6
	2C	125	342	1.305	4	2.8	88	7	5	12
Hay	1A	49	113	1.441	0.7	0.4	98	1	1	2
	1B	40	95	1.418	0.5	0.4	98	1	1	2
	1C	34	225	1.437	0.7	0.2	97	1	2	3
	2A	65	154	1.327	1.3	0.9	93	3	4	7
	2B	66	183	1.469	1.7	7.0	93	3	4	7
	2C	73	329	1.395	2.4	1.2	89	6	5	11
	2C	68	329	1.395	2.4	1.2	89	7	4	11
	2C	66	329	1.395	2.4	1.2	91	5	4	9
CONNORS	MELT	59	220	0.995	2	2.3	79	16	5	21
		26	368	1.044	3	2.7	80	18	2	20
VERMILLION	A	72		0.255	73.3	17.7	42	54	4	58
	B	72		0.247	71.9	17.5	48	49	3	52
	C	58		0.259	70.5	20	42	56	2	58
SANDY	MELT	55	1200	0.187	14	1.9	15	60	25	85
		62	558	0.558	8.8	4.4	66	32	2	34
RED CEDAR	1A	82	148	1.442	1	1.1	98	1	1	2
	1B	72	230	1.242	0.9	0.6	98	1	1	2
	1C	105	2010	0.034	20.7	4.0	94	4	2	6
	2A	98		0.06	2802	3.4	92	6	2	8
	2C	88		0.047	26.9	5.0	90	8	2	10

Correlation Matrix	BRAYP	SLOHP	BDENS	TVS	OM	SAND	SILT	CLAY	S+C
BRAYP	1								
SLOHP	0.059352	1							
BDENS	-0.04484	-0.83167	1						
TVS	0.148448	0.983112	-0.31400104	1					
OM	-0.09628	0.544908	-0.55895417	0.006	1				
SAND	0.241758	-0.59517	0.61437076	0.081	-0.7	1			
SILT	-0.25567	0.623708	-0.63456627	-0.072	0.77	-0.98	1		
CLAY	-0.0765	0.37936	-0.26383597	-0.087	-0.1	-0.64	0.5	1	
S+C	-0.24176	0.595165	-0.61437076	-0.081	0.67	-1	0.98	0.642	1

Appendix I.
1997 Red Cedar River Basin, Water Quality Data

RED CEDAR RIVER AT COLFAX

DATE		TP	DP	%DP	PP	SS	P UG/G
970324	S	0.16	0.1	63.06	0.06	4	14500
970325	S	0.13	0.08	58.59	0.05	4	13250
970326	S	0.11	0.06	55.45	0.05	4	12250
970327	S	0.16	0.07	43.48	0.09	9	10111
970328	S	0.19	0.08	42.41	0.11	21	5238.1
970329	S	0.23	0.11	47.86	0.12	21	5809.5
970330	S	0.25	0.12	48.18	0.13	25	5120
970331	S	0.23	0.13	55.51	0.1	23	4391.3
970401	S	0.2	0.1	52.04	0.09	14	6714.3
970402	S	0.24	0.12	48.32	0.12	23	5347.8
970404	S	0.18	0.08	43.75	0.1	14	7071.4
970407	S	0.11	0.05	49.09	0.06	9	6222.2
970702	E	0.27	0.15	54.31	0.12	30	4066.7
970703	E	0.3	0.14	47.65	0.16	26.5	5886.8
970708	E	0.2	0.09	46.77	0.11	16	6687.5
970722	E						
970428	B	0.08	0.04	46.43	0.05	5	9000
970522	B	0.14	0.04	31.88	0.09	7.6	12368
970530	B	0.15	0.07	46.58	0.08	10.5	7428.6
970624	B	0.18	0.11	63.64	0.06	8	8000
970630	B	0.19	0.12	60.82	0.08	8.67	8765.9
970701	B	0.19	0.12	64.25	0.07	8	8625
970730	B						
BASEFLOW AVG				52.27			

HAY RIVER AT WHEELER

DATE		TP	DP	%DP	PP	SS	P UG/G
970324	S	0.16	0.04	26.7	0.12	23	5130
970325	S	0.14	0.05	31.7	0.1	12	8083
970326	S	0.12	0.04	32.5	0.08	6	13833
970327	S	0.17	0.04	24.1	0.13	10	12600
970328	S		0.06			118	
970329	S	0.35	0.12	34.1	0.23	172	1337
970330	S	0.37	0.15	40.3	0.22	86	2547
970331	S	0.34	0.17	50.9	0.17	54	3056
970401	S	0.29	0.14	47.4	0.15	67	2269
970402	S	0.33	0.14	41.5	0.19	79	2405
970404	S	0.27	0.14	50.9	0.13	48	2729
970407	S	0.19	0.09	46.9	0.1	34	3000
970702	E	0.37	0.07	19.8	0.3	218	1372
970703	E	0.28	0.09	32.5	0.19	84.5	2237
970708	E	0.22	0.07	31.2	0.15	46	3217
970722	E						
970428	B	0.06	0.02	42.9	0.03	9	3556
970522	B	0.09	0.02	20.4	0.07	4	18500
970530	B	0.08	0.02	28	0.05	6.55	8244
970624	B	0.13	0.06	48.8	0.07	15	4400
970630	B	0.17	0.08	45.8	0.09	26	3462
970701	B	0.17	0.06	35.8	0.11	4.33	24480
970730	B						
				36.9			

OTTER CREEK

DATE		TP	DP	%DP	PP	SS	P UG/G
970402	S	0.08	0.04	49.38	0.04	9.5	4315.8
970501	E	0.1	0.05	50.96	0.05	26	1961.5
970529	E	0.14	0.06	44.68	0.08	39.6	1969.7
970529	E	0.1	0.06	61.54	0.04	26.8	1492.5
970702	E-L	0.45	0.1	21.38	0.35	156	2262.8
970702	E-U	0.58	0.1	16.41	0.48	211	2293.8
970721	E-U	0.27	0.09	33.21	0.18	61.6	2873.4
970721	E-L	0.27	0.08	30.11	0.19	44.4	4234.2
EVENT AVG				36.9			2441.1
970428	B	0.09	0.05	55.43	0.04	5	8200
970522	B	0.18	0.06	34.62	0.12	9	13222
BASEFLOW AVG							

VERMILLION RIVER

DATE		TP	DP	%DP	PP	SS	P UG/G
970403	S	0.28	0.22	80.3	0.06	14	3929
970708	E-L	0.06	0.02	28.1	0.04	4.33	9469
970708	E-U	0.12	0.04	34.5	0.08	7.5	10133
970721	E-U	0.09	0.03	28.7	0.07	2.4	27917
970721	E-L	0.08	0.03	40.7	0.05	5.3	9057
970721	E	0.13	0.05	37	0.08	5	16000
EVENT AVG				33.8			
970522	B	0.1	0.00	1.96	0.1	6.8	14706
970625	B	0.07	0.02	28.2	0.05	6	8500
BASE FLOW AVG				15.1			

CONNORS CREEK

DATE		TP	DP	%DP	PP	SS	P UG/G
970402	S	0.21	0.11	50.47	0.11	36	2916.7
970702	E-L	0.16	0.04	22.56	0.13	55.4	2292.4
970702	E-U	0.18	0.04	24.86	0.13	86	1546.5
970708	E	0.17	0.07	41.52	0.1	26	3846.2
970723	E-U	0.24	0.12	47.95	0.13	21	6047.6
970723	E-L	0.15	0.06	37.25	0.1	22	4363.6
EVENT AVG				34.83			3619.3
970428	B	0.02	0.00	12.5	0.02	4.9	4285.7
970522	B	0.09	0.00	3.297	0.09	2.2	40000
BASEFLOW AVG				7.898			

SANDY CREEK

DATE		TP	DP	%DP	PP	SS	P UG/G
970402	S	0.33	0.24	72.9	0.09	9.5	9474
970702	E	0.39	0.06	15.5	0.33	1150	284.3
970708	E-L	0.11	0.04	35.8	0.07	15.7	4331
970708	E-U	0.16	0.03	20.2	0.13	90	1444
970723	E-U	0.12	0.04	34.1	0.08	17.8	4551
970723	E-L	0.77	0.13	16.9	0.64	278	2302
				24.5			2583
970428	B	0.04	0.01	30.8	0.03	4.9	5510
970522	B	0.12	0.02	18.5	0.1	8	12125
				24.6			