Chapter 6 Sediment and Nutrient Modeling

Sediment and Phosphorus

By Jim Klang– MPCA

Kevin Kuehner– BNC Water Board

Introduction

The watershed restoration management process has traditionally attempted to gather water quality and quantity information to compare with land use information for selection of restoration efforts. Many tools are utilized to help assist watershed managers characterize the pollution problems and determine strategies which would best remediate the water quality concerns. Some of the tools utilized include the use of a water quality monitoring network, watershed inventories such as the (Tailored Integrated Surface Water Assessment), and Geographic Information System (GIS) database technologies. All of these tools help to gain further understanding of possible Best Management Practices (BMPs), and an understanding of the social, political and economic endorsements or limits that exist. Furthermore, analysis models, communication tools, educational materials, and financial incentives are employed to ease the transition and provide risk management for selecting changes.

Described in this chapter are two models or tools that were utilized by project staff to aid in the success of a watershed restoration management process in the Seven Mile Creek watershed. The first model describes a new methodology developed by Jim Klang and Kevin Kuehner for modeling sediment and phosphorus sources. This is a very new method and has not been adequately peer reviewed due to application deadline concerns. It is felt this model could be used by many other clean water partnerships at the minor shed level. The write-up describing the process is at times broad and is no way designed to be a detailed methodology; rather it is designed to indicate the general process of conducting the analysis. A more complete report on the approach, methods, and results of the modeling efforts will be available sometime this fall or winter. Through other funding sources, the ADAPT model will be run on Seven Mile Creek watershed as part of a USDA paired watershed study. This could provide a unique opportunity to see how the two sediment and phosphorus approaches compare and contrast and further the understanding of water quality at a watershed scale.

The second analysis tool described below was used for nitrogen analysis. To better understand nitrogen sources and outputs within the watershed, nitrogen mass balance was conducted. Estimating N budgets for soil-crop systems is a theoretically sound and time-honored approach that has been used for more than 100 years. Like sediment and phosphorus modeling, nitrogen budgets are based on the concept of conservation of mass that simply states that the inputs into a particular ecosystem less the N outputs must be equal to the change of N stored within the ecosystem.

The following is an example of how Seven Mile Creek watershed managers attempted to answer water quality questions using an innovative, simplified, and cost effective modeling approach.

The GIS-based methodology described was developed to advance the understanding of land use impacts in an affordable and practical way within Seven Mile Creek. Keeping in mind the relationship between resources (i.e. staff and financial capital) and accuracy is often linear, this model and information protocol are intended to improve the effectiveness of targeted investment dollars and staff time while achieving a higher quality output for land use assessments. This process has been tested in Seven Mile Creek watershed (a relatively homogenous agricultural watershed) with good success, and may be applied to other similar watersheds with slight changes to the methodology.

This methodology provides land use analysis by a logic process that combines ground-truthed watershed inventories with information from GIS coverages to explain sub watersheds and/or source types and loadings. The fore mentioned information is combined with current Minnesota research and principles of more complex models. The data is organized, calculated and analyzed in an Excel spreadsheet. Besides the benefits of the end results, the information gathering process develops a local and tailored understanding of the unique watershed and ultimately a more affordable process.

As hinted to above, this methodology's accuracy improves with more investment like any other analysis tool. Likewise, if extreme weather events dominate the watershed data, the annual average estimations of RUSLE[1] (the primary sheet erosion estimator) will be less applicable. Therefore, when this methodology is used for targeting implementation program dollars, care should be given to compare only relative size of source contributions and not to take the resulting number as absolute. Once BMP programs have been selected and a watershed manager is evaluating a particular site within a project, this same methodology can assist with determining reductions in watershed loading again by using relative size of contributions and not ignoring the averaging that takes place when estimating delivery ratios.

Advantages of the Model

- Helps identify the significance of bank erosion contributions to watersheds.
- Ideal for Clean Water Partnership Phase I watershed projects.
- Relatively cheap and cost effective. In the MN River Basin, most watershed managers already have access to GIS layers, tillage transect surveys, and other tools needed for the analysis. It is estimated that the entire process was completed at a cost of $10,500 (2 people @ 15 hours a week for three months or approximately 400 hours @ 25$/hour). Other costs: $500 (travel, soil tests, etc.).
- Ease of use. Utilizes a widely used and accepted soil erosion prediction tool (RUSLE).

- Results correlate with university research conclusions.

- Multi-faceted and holistic approach. Integrates current and localized research literature, field surveys, water quality data (loading estimates), and GIS into one tool for refining watershed management decisions. Information can be plugged into spreadsheet.

- Water quality and education promotion. Help watershed managers convey water quality data into an easy to understand format. Allows for discussion points at public meetings. Helps landowners understand the importance of the implementation plan and potential positive outcomes.

- Allows manager to target BMPs and set realistic goals.

- Allows watershed manager to get into the watershed through inventories thereby connecting the person with the data.

Model Disadvantages

- Works best on smaller scale where staff have the time and resources to inventory. Larger watersheds could be assessed.

- The minor watersheds must be homogenous in nature.

- Moderate margin of error. Model is not meant to quantify but to describe sources and their relative impact on the watershed.

- Model has spring runoff limitations. RUSLE is used mainly as a summertime erosion runoff model and therefore does not work well when there are heavy spring snowmelt conditions.

- Must have at least one or two year's worth of water quality of data before analysis can be run.

- Sources of pollution coming from cities or bank erosion may skew the sediment and phosphorus mass balance.

Inputs

- GIS databases (i.e. soils and land use)

- Tile intake survey

- Non-complying septics inventory

- Conservation tillage survey (for C factor adjustments)

- Stream bank erosion survey on targeted areas

- **C**hemicals, **R**unoff, and **E**rosion from **A**gricultural **M**anagement **S**ystems (CREAMS), phosphorus enrichment algorithm

- **R**evised **U**niversal **S**oil **L**oss **E**quation (RUSLE), rainfall soil erosion prediction model

Outputs

- Relative contributions of pollutants and their respective surface water loading pathways

Approach and methods

Water quality loads from the FLUX program were used to balance sediment values derived from the RUSLE program. Excel spreadsheets were used to evaluate the data. The monitoring and FLUX model runs are enhanced by a Geographic Information System (GIS) spatial analysis database. The GIS tool allowed averaging/estimating of small diverse soil erosion contributions to be combined with information and inventoried larger "point source" type loadings. The results are a holistic look at the watershed. The principles are to use current literature for sediment erosion, nutrient enrichment and delivery ratios, and inventories of bank erosion, septic tanks (and conditions) to source partition the non-point source loads for better understanding of how to target the BMPs in the implementation phase.

An acknowledgement that differences exist even in research due to climate changes, soil types, slopes, geomorphology of the watershed and cropping techniques is paramount. To overcome these dynamic changes and differences, from site to site, a few key assumptions are made:

- Seven Mile watershed, subdivided into three watersheds, has zones in each subwatershed with like characteristics.

- Since a water quality monitoring year is based on six months (April-Sept.) and RUSLE (tons of soil loss/acre/year) is based on a 30-year annual average, RUSLE needs to be normalized for the monitoring year. To normalize, we took the watershed runoff value for 2000 growing season and divided it by the 30-year average runoff value for this area, which is published by the MDNR. Another way to normalize for differences in time scale is to divide watershed monitoring year precipitation by 30-year average precipitation levels found at St. Peter.

- A "Delivery Ratio" will be defined as not just the ratio of sediment delivered as compared to the sediment eroded, but also includes a correction factor for other assumptions on normalizing yearly rainfall averages and variations in rainfall intensity.

- To proceed carefully–the modeler must make judgments in the first watershed and check/confirm them in the second watershed prior to proceeding on with the assumed "Delivery Ratios."

- For phosphorus projections, it was assumed that non-complying septics are connected to tile lines and a high-end value was used for total phosphorus concentrations.

This model combines soil and land use information with the **R**evised **U**niversal **S**oil **L**oss **E**quation (RUSLE) developed by the USDA-NRCS, and the **C**hemicals, **R**unoff, and **E**rosion from **A**gricultural **M**anagement **S**ystems (CREAMS) sediment-attached phosphorus algorithms to balance soil and nutrient loading from the FLUX pollutant loads. 2000 pollutant loads were used in the analysis. By comparing the FLUX results as the mass of sediment or phosphorus that must be balanced, the RUSLE results are first adjusted from a long-term annual average to better reflect the precipitation that occurred in the monitoring period. (In this particular analysis we took the runoff value from the watershed in 2000 and divided that by the 30-year average runoff value for the area.) Then zones with like runoff characteristics are used in GIS to select the right delivery ratios. In this watershed, the zones are riparian (first 100 feet along ditches and streams), intakes (the depressional areas served by subsurface tile intakes) and the remainder is left in a zone called upland. The zones were delineated with ArcView GIS.

Delivery zones used in sediment modeling:

1. Riparian corridor (100 feet buffer on ditches)
2. Open tile intake basins
3. Upland
4. Bank erosion (subtraction of 1-3 from entire RUSLE value)

Delivery zones used in phosphorus modeling:

1. Riparian corridor (100 feet buffer on ditches)
2. Open tile intake basins
3. Upland
4. Non-complying septics
5. Bank erosion

To determine the riparian zone, the GIS system mapped out the 100 feet perpendicular to the watercourse. For the intake zone, a surface tile intake representative survey was performed in spring prior to crops coming up to determine the number and the size of the area surveyed. This survey was then extrapolated up to represent each specific subwatershed density and the GIS soil map allowed selection of probable soils for intakes to be placed. The remainder of soils in the upland zone was those soils not previously selected by the first two zones.

Using University of Minnesota research to select delivery ratios from 0-20 percent for upland areas outside of a quarter mile, 10 to 40 percent for surface tile intakes, and 50 to 100 percent for soils along watercourses, the first watershed was balanced. The results were then applied to subwatershed 2[1], which contained six tenths of a mile ditch with extreme bank erosion. Using an inventory process to set the minimum range for the bank erosion in subwatershed 2, the determined delivery ratios for subwatershed 1 were applied. (Note: the GIS model would have been improved if the monitoring placement had excluded the bank erosion source that was found at the mouth. This "point source" type load can be solved for if isolated in a paired watershed effort.) After a few feedback loops, the selected delivery ratios to use are:

Riparian zone: 95% delivery ratio

Intake zone: 25% delivery ratio

Upland: 7.5% delivery ratio

This balance is used for sediment and phosphorus projections given in figures 33 and 34.

Through subtraction, bank erosion sources are estimated from each of the three minor watersheds. It was found that bank erosion was very low in the upper two watersheds due to the high concentration of ditch systems. An exception to this was within the lower un-channelized area of watershed 2. Within this area, the bank erosion survey indicated large areas of extensive incising, degradation, slumping, and general bank instability (photo 12, chapter 5). It is estimated that within this quarter of a mile section of riparian corridor in watershed 2, about 50% of the sediment load was attributed to bank erosion. It is estimated that approximately 50% of the sediment load is coming from bank erosion within the entire watershed as well.

Phosphorus

The phosphorus projections operate on a similar principle but take into account nutrient enrichment processes as eroded material advances toward a watercourse. As sediment and attached phosphorus moves through its various pathways to a watercourse, the heavier sands drop out and the lighter clays and silts continue on. These lighter clays and silts are in effect increasing the concentration of phosphorus since these soil particles contain more phosphorus by weight. Therefore, CREAMS provides a projection tool that uses the erosion rate, phosphorus content of the parent soil, and an algorithm to project how much phosphorus is delivered in the sediment attached form from sheet erosion predicted by RUSLE. Bank erosion or gully erosion does not use this process and assumes the phosphorus eroded by channelized water delivers the whole amount in this watershed.

---

[1] **For simplification, minor-watershed 062, 066, and 063 are called watershed 1, 2 and 3 respectfully.**

Using the sediment budget, CREAMS algorithm, and the estimate of septic tank discharges in the watershed (table 32) a phosphorus mass budget was put together for subwatersheds 1 and 2. The remaining phosphorus is assumed to be the soluble fraction from agricultural land use. Phosphorus from bank erosion was determined by sampling soils from bank erosion sites and analyzing the total phosphorus content. Results of the soil survey indicated roughly 1.0 lb. of phosphorus per ton of soil and 1.25 pounds/ton of soil in the upper A horizon of the soil profile.

Problems associated with the mass balance assumption for watershed 3

Sediment

Subwatershed 3 is at the mouth of the creek with a fall of 210 feet down through Jordan sandstone features. This geomorphology posed an interesting problem as there is a small loss of water (losing reach) in the channel as it travels from the mouth of watershed 1 and 2 to the monitoring station in subwatershed 3. By checking the hydrograph flows in subwatershed 3 against the hydrograph flows added up in subwaterhsed 1 and 2, it was found that for periods of time, on the tail of the hydrograph during storm events and also during base flow periods, watershed 3 yielded less than 1 and 2. At first glance this is a major concern for sediment, phosphorus and nitrogen projections However, through the following discussions it becomes clear that the overall projection for sediment and phosphorus is likely affected less than 5% by this feature.

In the year 2000 data, the acre-inches of runoff for watershed 1 was 3.84 acre-inches, watershed 2 was 3.62 acre inches, and the total for the entire watershed was 3.53 acre-inches. When using the total acreage for each subwatershed and comparing the acre-inches of runoff for the total acreage of the entire watershed, one finds subwatershed 3 yielded only 2.66 acre-inches of runoff. These figures at first glance seem to reflect the total loss occurring in subwatershed 3, but on closer look 50 to 60 percent of the subwatershed 3 land use is in forest cover. Forest cover yields less runoff then other land uses, so not all of the decrease in the above numbers is attributable to surface water infiltration. If a water budget is calculated with:

3.84 acre-inches across 9956 acres in watershed 1,

3.62 acre-inches across 9120 acres in watershed 2, and

3.53 acre-inches across 4475 acres in watershed 3 (an overly large projected lost flow, hence a conservative estimator for determining error);

then the projected runoff unaccounted for is approximately 3900 acre-inches. This amount at a flow combined with the station's weighted average concentration of 191 mg/l yields approximately 85 tons of underestimated sediment. This value of underestimated projected sediment is less than five-percent of the total watershed yield as determined by Flux.

A significant portion of the sediment load unaccounted for is still carried out of the watershed at different times. The physical processes of riverine systems allow scour and redeposition to occur as needed by the energy present at any one time. With less flow/energy, a riverine system allows sediment to be redeposited to balance the sediment transport capacity. The sediment is stored in the channel bed for: a) long periods, or b) carried out of the watershed at base flow periods (low sediment yields), or c) snow melt periods when erosion on the land may be minimal but flow energy in the channel is high (high sediment yields). Bed load, another transport mechanism has the ability to transport large quantities of sediment and nutrient yields. In addition to water column load there is bed load yield during high flow-high energy periods that can transport small and large bed material in great volumes as bed load. This process carries the sediment through two methods. The first method is as smaller materials as large as small boulders or larger cobblestones bouncing on the bottom. The second is capable of transporting extremely large rocks that end up floating along on a greater mass of moving bed material. When the bed becomes saturated with fast moving water, it is possible to begin acting like a slurry; the whole section of bed material "slips" and moves all at once in a loosely connected mass floating the larger materials out of the watershed on a bed of moving "marbles."

Since no visual aggradation zones existed in the 2000 monitoring period, it can be concluded that not all of the underestimated sediment was left in the subwatershed 3, but in fact much of it was carried out in one of the above described processes.

Nutrients

Related predictions of nitrogen and phosphorus should also be discussed. As discussed above, sediment and therefore sediment attached nutrient projects are minimally affected by the lost flows in subwatershed 3. The primary phosphorus tools used for the nutrient balance used sediment-attached phosphorus loading and solved for soluble fractions. It is commonly agreed in literature that the largest fraction of phosphorus in water quality runoff is the sediment-attached fraction in an annual balance. Literature does demonstrate that the soluble fraction dominates during snowmelt periods, however the year 2000 monitoring period did not capture snowmelt runoff. The soluble fraction during the growing season will be interacting with soils as the surface water infiltrates and the exchange will probably be highly affective at sequestering that small fraction.

Nitrogen poses bigger questions regarding unaccounted water, although it is a small percent of the monitored flow. Nitrogen, predominately nitrates, travel in soluble fractions that do not have the affinity for soil adsorption that phosphorus does. This pollutant follows the water pathway more closely temporally and spatially. In the 2001 dry periods, Seven Mile Creek was observed to dry up at the head area of the County Park, and downstream flow would again appear approaching the monitoring station at watershed 3. An outstanding question about the water pathway is if the water emerging in the springs is the same as the water infiltrating into the shallow alluvial material or if it is older water that traveled through a deeper groundwater system and does not necessarily have the same nitrate loading. More information is needed to confirm this station's results. However, whether the nitrate from the upper watershed emerges again in the channel, recharges deeper ground water aquifers, or emerges closer to or in the Minnesota River, it remains a pollutant of concern that can be reduced.

What the analysis tells us

- General direction of what BMPs to use
- Where to locate BMPs
- Where to cost-effectively implement cost-share dollars

The accuracy of the resulting percentages is not precise to the decimal points given in the spreadsheet. What is important is the relative differences between sources.

Discussion

Results of the sediment and phosphorus modeling can be seen in figures 33 and 34. In terms of sediment, bank erosion is a very large pathway for sediment within the watershed. As mentioned earlier, most of the bank erosion is occurring within watershed 3 and the lower portion of watershed 2. It is presumed that the major driving force behind the bank erosion is derived from accelerated drainage and climatic changes within the watershed. A combination of more rainfall coupled with more subsurface and surface drainage networks, leads to more frequent, flashier discharges. Higher discharges lead to more bank full or stream forming discharges. The stream therefore needs to adjust to the increase in energy and instability within the stream channel. This adjustment can be witnessed in the lower reaches of watershed 2 and the entire area of watershed 3. Stream incising or entrenchment, scour, bank slumping and stream bank failure are commonplace within these areas of the watershed. From an implementation management perspective, fixing these problem areas may not be cost-effective. A more pro-active and indirect way to help decrease the acceleration of bank erosion within the watershed is to use water storage techniques such as wetland restorations, off-channel storage areas, restoration of floodplain through the use of rock cross-vane structures, and no-net increases in public tile or surface water drainage. If funded, a proposal through the McKnight foundation would help fund this effort within the watershed.

The second dominant source of soil erosion within the watershed is upland sources (cultivated areas). As mentioned, a majority of the soils within this watershed are meeting tolerable soil loss ranges. However, over the long-term these areas do contribute a significant source of soil to Seven Mile. The main reason stems from the fact that the upland zone dominates the overall area of the watershed. It is felt that the most cost effective way to manage this sediment pathway is through the targeting of cultivated areas, which are losing greater than 5 tons per acre per year. To further increase targeting, areas that are greater than 5 t/a/yr and within 300 feet of a waterway could be targeted for specialized soil saving measures. Conservation tillage, waterways, and warm season grass buffer strips would be utilized in these areas to reduce the effect of these “hot spots.” Through GIS analysis it is found that most of these hot spots occur near the upland and dendritic drainage interface of watershed 3.

(figure 32) Buffer strips and/or conservation tillage would be most effective within these areas. In addition, no or minimum spring tillage of soybean stubble would be encouraged for further soil saving measures.

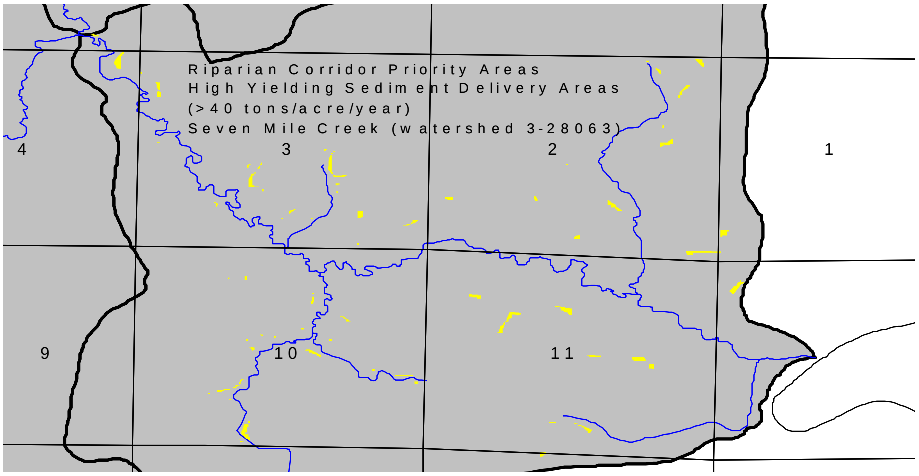


Figure 32. Areas shown in yellow (about 15 acres) are priority areas within the lower reach of watershed 3 for sediment reduction BMPs as indicated by RUSLE modeling.

The last two zones, riparian corridor and open intakes are the smallest overall contributors of sediment within the basin. Grass buffer strips and gravel inlets would be the most effective BMP to help slow the sediment delivery to Seven Mile Creek.

As for phosphorus, the most dominant pathway within the watershed is the upland delivery zone. Because over 95% of the upland zone is in a corn and soybean crop rotation, nutrient management will be the key best management practice strategy. Soil phosphorus testing, and manure crediting will be key features of the implementation plan to reduce the overall phosphorus load. In addition, waterways and buffer strips in critical areas will be encouraged to slow down the overall phosphorus transport mechanisms. Average soil test values for the watershed are estimated to be 22 ppm Bray and 29 ppm Olsen[2]. These soil tests are interpreted as very high for plant available phosphorus. However, with key nutrient management changes, these soil tests and overall potential loss into the surface waters could be reduced in 5-10 years.

Through a combination of careful targeting of open intakes, nutrient management, and general septic upgrades it is estimated that approximately 25-40% of the long-term phosphorus load could be reduced.

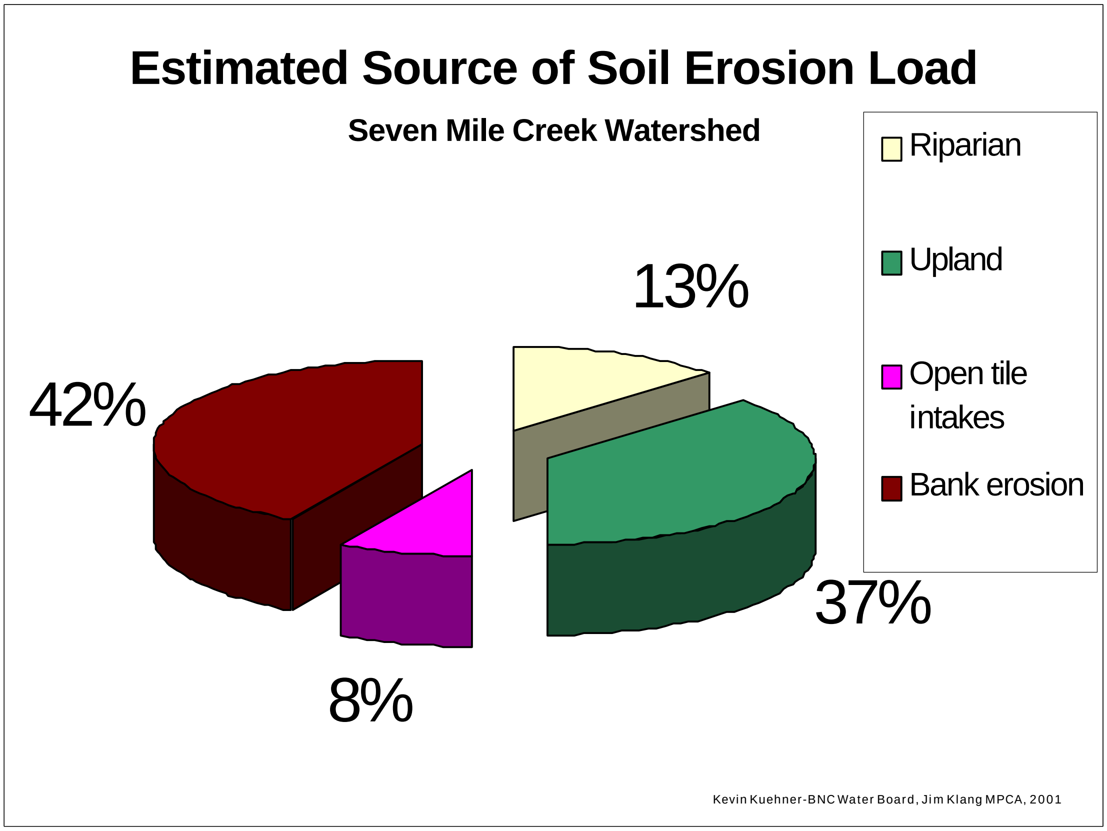
---

[2] **Average of Clients within Seven Mile Creek Watershed, Blue Earth Agronomics ,2001.**

Table 32. Phosphorus contributions from septics.

Watershed	# of ISTS 1	# of people/ ISTS 2	# of people/ 2	Gallons per person 3	High TP Concentrations(mg/l) 4	# of days monitored 5	Phosphorus contribution from septics (lbs.) =2*3*5/1000000*8.34/4
WS 1	39	2.5	98	45	30	239	262
WS 2	28	2.5	70	45	30	239	188
WS 3	29	2.5	73	45	30	239	195

Results



Kevin Kuehner-BNC Water Board, Jim Klang MPCA, 2001

Figure 33. Sources of sediment in Seven Mile Creek watershed.

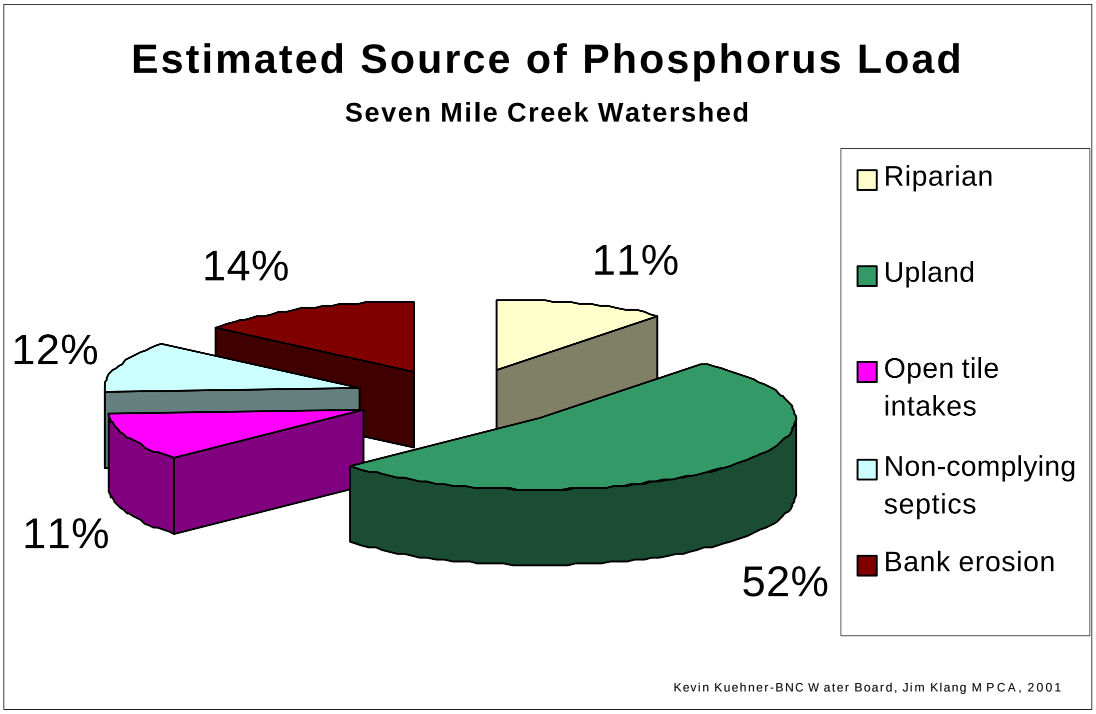


Figure 34. Sources of Phosphorus in Seven Mile Creek watershed.

Nitrogen Mass Balance Methods and Approach

Nitrogen is a large source of pollution within Seven Mile Creek. Knowing the inputs and outputs is very important in terms of setting realistic water quality goals and implementation strategies for the watershed. To better understand the fate of nitrogen on a watershed scale, a mass balance approach was used. The main objective of this very basic approach was to develop a N-screening tool that would quickly estimate watershed scale N sources. It should be noted that a large number of assumptions had to be made when conducting the N-mass balance. Wherever possible, the most recent and local data was used. However, it should be noted that because of the many complexities involved with the nitrogen cycle at the field and watershed scale, the N mass balance work does contain a significant margin of error. The fate of nitrogen in a natural environment is very complex and therefore the intent of this exercise is not meant to quantify, rather this exercise is meant for educational purposes. Local data and expertise from extension agents and soil scientists were used as much as possible to help assist in the development of N inputs and outputs of the watershed system. It is hoped the mass balance process and understanding of nitrogen fluxes in an agricultural setting can be refined through the use of the ADAPT model which will be performed through the paired watershed study and information gathered at Red Top Farm research fields.

Inputs to the N-Mass Balance

- 1996 St. Peter Wellhead Protection Farm Nutrient/Pesticide Management Assessment Program (FANMAP) survey by Minnesota Department of Agriculture.
- Nicollet County Feedlot Permits
- Nicollet County Soil Survey
- N Balance publications and technical journals
- Local soil scientists and agronomists
- UM Extension Publication of Livestock nutrient manure levels
- UM Extension Publication of Crop Nutrient Removal
- National Atmospheric Deposition Program web site-Lamberton Site

The nitrogen mass balance approach taken in this analysis uses digital databases, GIS, and published research values. The data sets were combined to calculate six general categories of nitrogen sources and five general losses. The difference between the two indicates the long-term potentially leachable nitrogen sources in the watershed.

The basic methodology and sources for the calculations can be found in table 33.

Table 33. Nitrogen mass balance for Seven Mile Creek.

Seven Mile Creek Watershed
Eastern Nicollet County, Minnesota

Watershed area is 23,551 acres, 86% cultivated land use, 20,181 crop acres

Assumed, 100% corn/soybean rotation (10,091acres beans, 10,091 acres corn), 150 bu/acre avg. corn yield, 45 bu/acre avg. soybean yield, pH >7 with high CEC, sub-humid climate

Average Organic Matter content is 5%, average bulk density is 1.42 (g/cm3) cultivated land soils(top 9)=Canisteo-Glencoe Complex(15.5%),Cordova Clay Loam (14%),
Canisteo Clay Loam (13%), Webster Clay Loam (9.7%), Le Sueur Clay Loam (8%), Nicollet Clay Loam (6%), Harps Clay loam (5%), Klossner Muck (4%),
Glencoe Silty Clay Loam (4%)

Source (entire ws)	***lb. of N/acre***	U of M	Randall	***Calculation notes with referances***
Nitrogen Inputs				
Fertilizer on Corn acres	66			154 lbs./acre applied on corn ground Based on 1996 survey of 22 producers in the St. Peter Drinking Water Area over entire ws=154lbs.acre*10091=777 tons/23551=66lbs./acre Supply Management Area FANMAP Survey, 1996 Meisinger and Randall, Table 5-2 assumes no N on soybeans
Manure	10.1	39	28	=827dairy@1000lbs*140lbs N/yr =280 beef@750lbs*90lbs N/year =5754 swine@150lbs*25lbs N/year 6127 spreading acres, animal units=# of animals that could be permitted. whole ws=39lbs/acre*6127=119 tons/23551=10.1lbs/acre Meisinger and Randal, 5-3.1 and 5-3.2 Max capac.,PCA Permits, Nicollet County Env. Services, 2000 Assume 30% loss due to storage, scraping, etc. U of M Extension Publications With NP dairy=70lbs.acre or about 30 lbs more N
Symbiotic N2 Fixation	32			**N removed=3.3lbs N/acre*50bu/acre*10,091 acres of beans in ws N removed (833 tons) *55%(table)=N2 Fixation from soybeans =375 tons fixed from soybeans, whole ws=32lbs./acre Meisinger and Randal, Table 5-4 and 5-5
Manageable Totals		**108.1**		
Irrigation	0			No irrigation in watershed
Precipitation	8.4			Lamberton 2000 data NADP web site
Dry Deposit	8.4			assumed equal to ppt Meisinger and Randal
Crop seed	0			assumed negligible
Nonsym. Fixation	0			assumed neglible
Mineralization	106			Mineralizable N=1000*bulk density of specific soil *Organic matter content of soil (%) *volume of 30cm thick soil in 1 ha (constant=3000m3) *elemental N fraction of soil organic matter (constant 3%) *annual mineralizable portion of soil organic N (constant 2%)=106.5 Burkart and James, p 854 and GIS database Randall assumes 10-20lbs. Per % of OM=15*5=75 lbs N/acre
Ammonia Redeposition	2.5			75% of manure and fertilizer ammonia loss =1.8+1.5+3.3*.75%=2.5
Total Input	233.4	183.4		

Nitrogen Outputs

Crops	142		=150 bu/acre*.83=Corn Used high end of table Meisinger and Randal, Table 5-4 Crop nutrient Removal, 1986 =45 bu/acre*3.5=Beans Meisinger and Randall, Table 5-4 Crop nutrient Removal, 1986 Average watershed uptake=158+125/2=142
Fertilizer Ammonia Loss	1.8	5	Anhydrous=66 lbs/acre N*3% lost=2 lbs/acre, whole ws=.42lbs/acre UAN=66 lbs/acre *10% lost=6.6 lbs/acre, = whole ws 1.4lbs/acre =anhyd+UAN=1.8 assumed subhumid, pH>7 with CEC soils, moderate tillage Meisinger and Randall, Table 5-3.2.1
Manure Ammonia Loss	1.5		assumed half manure solid other liquid, with short term fate, broadcast no incorp. 5 lbs/acre*.15=.75 5 lbs/acre*.15=.75 =1.5 lbs N lost Meisiger and Randall, 5-6.2
Denitrification	20.6		Assume somewhat poorly drained soils=20% Obtained by multiplying total inorganic N imputs (fert +rainfall) by est. % denitirification loss and net manure input by twice estimated loss =66+17=83*20%=16.6 =10.1(manure)*40%=4, 34.2+14.2=20.6 Meisinger and Randall, Table 5-7
Erosion Runoff	10		=avg RUSLE value*%OM*2 1* 5% *2 Meisinger and Randall, pg 111
Misc gaseous ammonia	0		Negligible
Total	175.9		
Long Term Potentially Leachable Nitrogen (LPLN)	57.5		

Interpretation	High

LPLN is in High category

If producers are applying 34 lbs/acre acre(154-120) over UM Recs (120 lbs./acre)
This equates to $7.50/acre loss or $75,000 for watershed corn acres

Referances

1996 St Peter Wellhead Protection MDA FANMAP survey

Estimating Nitrogen Budgets for Soil-Crop Systems, Meisinger and Randall.

1991Managing Nitrogen fo Groundwater quality and farm profitability, Soil Science Society of America, Madison, WI

Agricultural-Nitrogen Contributions to Hypoxia in the Gulf of Mexico, Journal of Environmental Quality, Burkart and James. 1999

1996 Nicollet County Soil Survey

BNC Water Quality Board GIS database

National Athomospheric Deposition Program, http://nadp.sws.uiuc.edu/nadpdata/state.asp?state=MN

Crop Nurtrient Removal, S.R. Alsdrich et al, 1986, Minnesota Extension Service Publication

Gary Hachfeld, Nicollet County Extension Service

Gyles Randall, Univeristy of MN Research Outreach, Waseca

Kimm Crawford, Olmsted County Soil and Water Conservation District Supervisor

Results

According to the nitrogen mass balance analysis for the watershed, mineralization (natural process of nitrogen converting organic matter within the soil to No_3-N within the soil by bacteria) is considered the largest overall source of nitrogen within the watershed, followed by inorganic fertilizers, which are spread on cornfields, soybean nitrogen fixation, precipitation, manure, and ammonia redeposition.

The watershed contains inherently high sources of nitrogen due to the high organic matter content of the clay loam soils. To illustrate why mineralization could be the largest overall source of nitrogen within the watershed consider the following:

On average every percentage point of soil organic matter contains 1,000 pounds of N. Assume that soil organic matter mineralizes at a rate of about 2.5% per year (depends on weather). In Seven Mile Creek watershed the average soil organic matter content on cultivated land is 5.5% O.M. That is 5,500 pounds of N, mineralizing 2.5% X 5,500 = 137.5 pounds of N per acre per year made available from soil organic material. This further demonstrates that mineralization can be a significant form of plant available nitrogen within the watershed. Furthermore, any additional nitrogen beyond 120 lbs./N per acre (UM Corn Fertilizer Recommendation for this area) can increase the long-term potentially leachable nitrogen.

The largest removal of nitrogen was in the form of crop uptake and removal, followed by denitrification, erosion, and fertilizer and manure ammonia losses during application and storage.

A general feature common to many agricultural watershed N budgets is that the largest No3-N losses are associated with areas that receive excess N inputs. That is, sites where manure or fertilizer inputs greatly exceed crop N removals. Within Seven Mile, it was found the nitrogen sources (233 lbs.) minus the nitrogen losses (176 lbs.) equals around 60 pounds of long term potentially leachable nitrogen. The nitrate concentrations in Seven Mile Creek correlate very well with the mass balance data. For 2000 and 2001 the average nitrate loss from the watershed was estimated at 27 pounds per acre per. This is roughly half of what was modeled. Considering the complexity and fate of nitrogen in the landscape, this is a fairly important tool for small watershed projects to utilize, especially when local data exists.

Results from a 1998 MN Dept. of Ag. survey[2] reported on average, approximately 54 pounds/acre of N was being applied above UM recommendations on corn following soybean rotations in the wellhead protection area. Assuming producers are over applying N by just 34 lbs./acre for additional insurance purposes, 170 tons of N would have the potential of being leached away through the soil and into the tile lines, drainage ditches, and eventually Seven Mile from corn fields within the watershed. If the current rate was cut back from 150 lbs./acre to 120 lbs./acre, the 22 producers could save $750,000 or an average $7.50/acre/year on their corn ground (assuming $0.22/lb for N).

In conclusion inorganic fertilizers are the largest manageable source of nitrogen within the watershed. It is assumed that producers and fertilizer dealers are continually underestimating the nitrogen credits associated with legumes and manure inputs or are simply applying insurance nitrogen and therefore are applying fertilizer at rates of

30-50 lbs. over what is needed by the corn plants for the purpose of maximizing yield (University of MN Extension Service recommendations). As the water quality monitoring indicates, this is ultimately showing up in the form of at least 15-40 pounds per acre nitrate loss from the watershed.

Field scale N-rate demonstrations have shown within the wellhead protection area of St. Peter that 90 pounds/acre might be more than adequate if considering net profits (figure 41). Intensive economic and agronomic analyses have been conducted through the University of MN, BNC Water Board and agronomic consulting firms using field-scale demonstrations Producers may not be comfortable applying 90 pounds of N per acre to soybean stubble for corn production, but research is showing that applying more than 120 pounds might cut into farm profits and water quality for Seven Mile Creek. An N-rate in between might provide the best yield and profit scenario for individual farmers. It is proposed in the implementation plan that further N-rate and profitability demonstrations be conducted within the watershed through the Center for Agricultural Partnerships Mid-Western Water Quality Project and Phase II of a Clean Water Partnership. In addition to nutrient management education, the use of wetlands, tile outlet to wetlands, and restoration of active floodplains will play key roles in reducing overall nitrate loads.

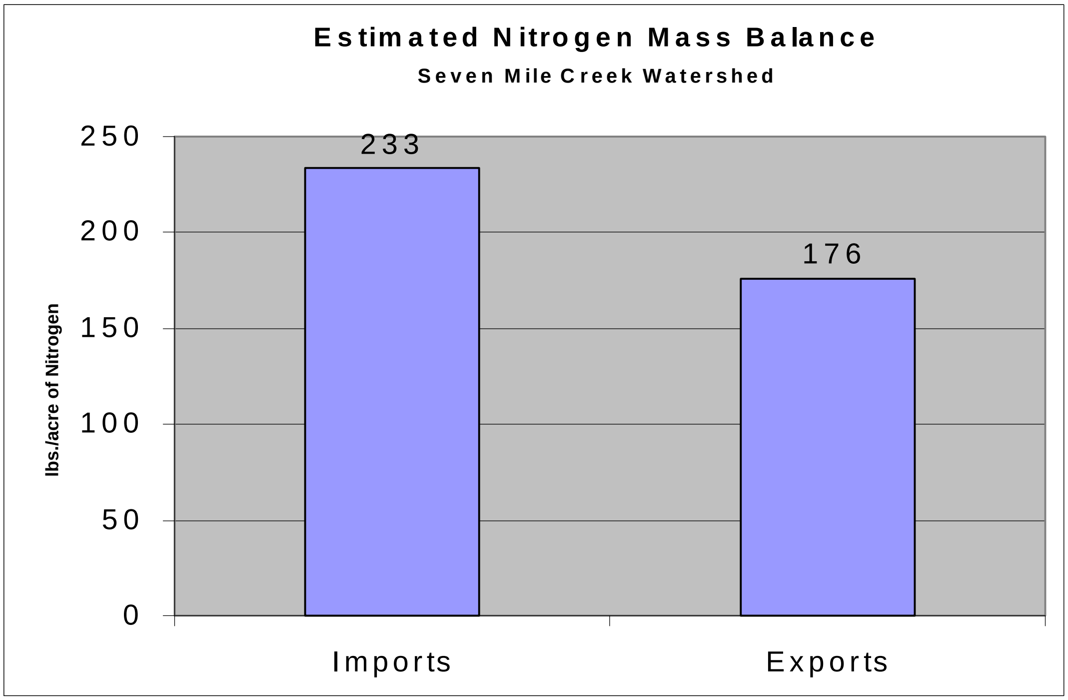


Figure 35. Nitrogen mass balance estimate for Seven Mile Creek.

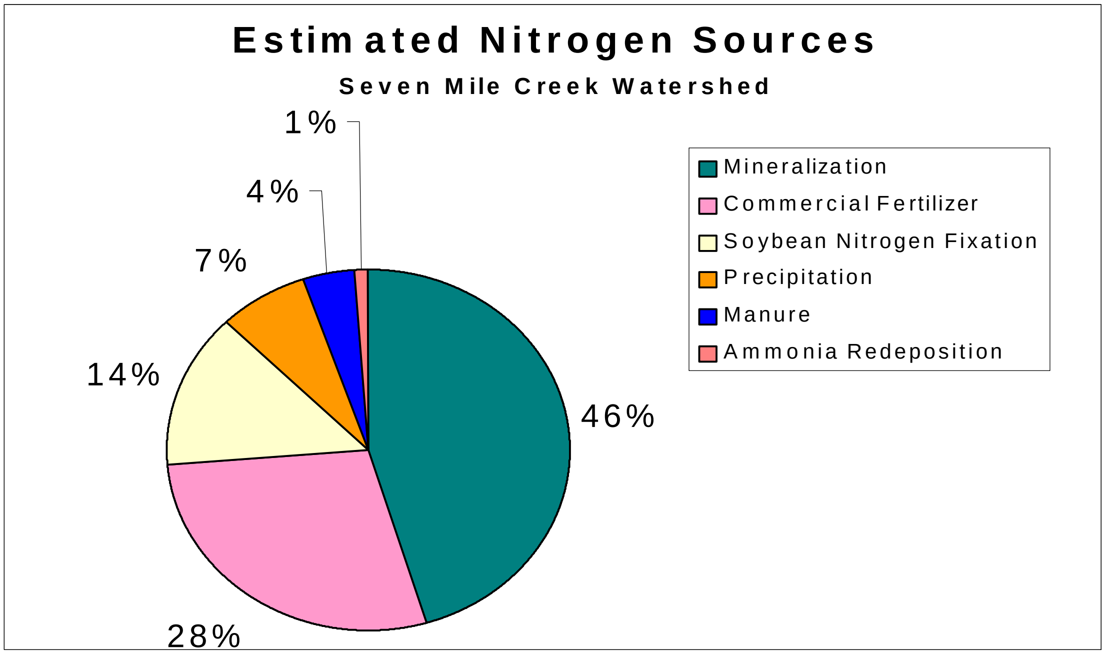


Figure 36. Estimated Nitrogen sources for Seven Mile Creek watershed.

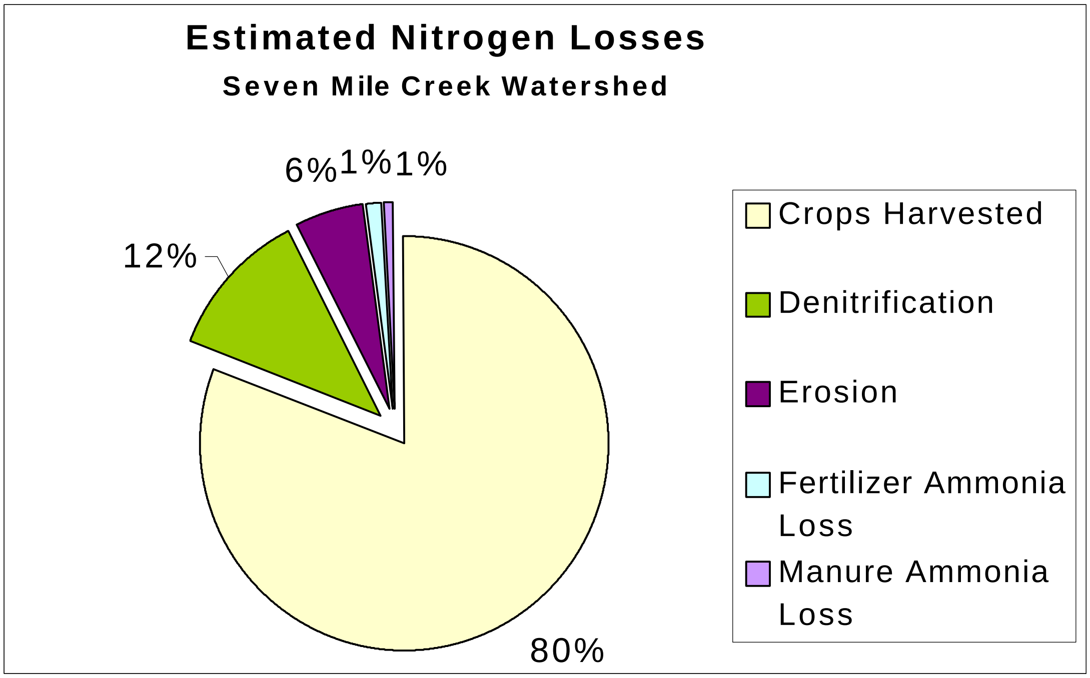


Figure 37. Estimated Nitrogen losses from Seven Mile Creek watershed.