ASSESSING ENVIRONMENTAL EQUIVALENTS FOR WATER QUALITY TRADING

by

MING-CHIEH LEE

B.S., National Taiwan University, Taiwan, 1995

M.S., National Taiwan University, Taiwan, 1997

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Biological and Agricultural Engineering

College of Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2009

Abstract

Water quality trading (WQT) is a market-based approach to improve water quality. It is an innovative, voluntary program that connects point source (PS) dischargers who need to reduce their pollutant loads with land managers who could offset those loads with nonpoint source (NPS) reductions to economically achieve water quality improvements in a watershed. The potential issues impeding WQT are its inability to address trading risks and quantify the uncertainty of potential load reduction in trades between PS and NPS. Recent research has also shown that trading information level and transaction costs cause problems in implementing WQT. Therefore, the goals of this study were to quantify the uncertainties of pollutant load reduction and delivery effect for potential trades, to estimate their spatiotemporal variations, and to provide information for stakeholders to reduce intangible costs of WQT. This study simulated agricultural cropland with more than 225 alternative land management practices to identify trends among these scenarios. Both total nitrogen and total phosphorus loads were modeled with SWAT and EUTROMOD for 36 years to analyze the potential load reduction, in-field uncertainty ratio, in-stream delivery ratio, and overall trading ratio (TR) in Lower Kansas watershed, Kansas. The analyses of site-specific effects in both geospatial and temporal aspects were also applied on subbasin level. The variant loading patterns and time distributions of each subbasin showed strong site-specific phenomena. The ANOVA of in-field nutrient load showed significant differences among the design criteria of scenarios. The results also showed a significant delivery and lake effects within the subbasins. The overall TR ranged from 1 to 2.2 or more in different scenarios. The advanced cluster analysis presented a potential method to eliminate the problems involved in fixed TRs while keeping the method simpler than finer-resolution floating TR system. Based on WQT geospatial data model, a three-tier GIS-based web interface Water Quality Trading Information Platform System (WQTIPS) was then developed for WQT information and assessment. A case study demonstrated WQTIPS can provide systematic, spatially information for stakeholders to assess the potential environmental benefit changes from the land management shifts using a simple interface. This study demonstrated that it is possible to automate water-quality trades, use watershed models to minimize trading risk and maximize water-quality benefits, and prioritize among possible trades both spatially and by BMP.

ASSESSING ENVIRONMENTAL EQUIVALENTS FOR WATER QUALITY TRADING

by

MING-CHIEH LEE

B.S., National Taiwan University, Taiwan, 1995

M.S., National Taiwan University, Taiwan, 1997

A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Biological and Agricultural Engineering
College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2009

Approved by:

Major Professor
Kyle R. Douglas-Mankin

Abstract

Water quality trading (WQT) is a market-based approach to improve water quality. It is an innovative, voluntary program that connects point source (PS) dischargers who need to reduce their pollutant loads with land managers who could offset those loads with nonpoint source (NPS) reductions to economically achieve water quality improvements in a watershed. The potential issues impeding WQT are its inability to address trading risks and quantify the uncertainty of potential load reduction in trades between PS and NPS. Recent research has also shown that trading information level and transaction costs cause problems in implementing WQT. Therefore, the goals of this study were to quantify the uncertainties of pollutant load reduction and delivery effect for potential trades, to estimate their spatiotemporal variations, and to provide information for stakeholders to reduce intangible costs of WQT. This study simulated agricultural cropland with more than 225 alternative land management practices to identify trends among these scenarios. Both total nitrogen and total phosphorus loads were modeled with SWAT and EUTROMOD for 36 years to analyze the potential load reduction, in-field uncertainty ratio, in-stream delivery ratio, and overall trading ratio (TR) in Lower Kansas watershed, Kansas. The analyses of site-specific effects in both geospatial and temporal aspects were also applied on subbasin level. The variant loading patterns and time distributions of each subbasin showed strong site-specific phenomena. The ANOVA of in-field nutrient load showed significant differences among the design criteria of scenarios. The results also showed a significant delivery and lake effects within the subbasins. The overall TR ranged from 1 to 2.2 or more in different scenarios. The advanced cluster analysis presented a potential method to eliminate the problems involved in fixed TRs while keeping the method simpler than finer-resolution floating TR system. Based on WQT geospatial data model, a three-tier GIS-based web interface Water Quality Trading Information Platform System (WQTIPS) was then developed for WQT information and assessment. A case study demonstrated WQTIPS can provide systematic, spatially information for stakeholders to assess the potential environmental benefit changes from the land management shifts using a simple interface. This study demonstrated that it is possible to automate water-quality trades, use watershed models to minimize trading risk and maximize water-quality benefits, and prioritize among possible trades both spatially and by BMP.

Table of Contents

List of Figures

List of Tables

Acknowledgements

I would especially like to thank my advisor, Dr. Kyle Douglas-Mankin, for his help and guidance throughout my graduate career. My thanks also goes to my advisory committee- Drs. Stacy Hutchinson, Shawn Hutchinson and Jeffrey Peterson- for their continued substantial support and guidance and the time they spent reading and correcting this dissertation. This work would not have been possible without the help of Drs. Amir Pouyan Nejadhashemi, Chun-Yen C. Cochrane, Pushpa Tuppad, and Mr. Craig Smith- thank you for your insights and expertise on watershed model, water quality trading program and statistics analysis. Finally, I am extremely gratefully to my wife, Dr. Mei-Hui Wang, my daughter, Michelle W. Lee, and my family for their incredible understanding and patience. Your constant optimism kept me going.

Chapter 1 Introduction

1.1 Research Question

Despite the continuous improvement in knowledge of how best to reduce pollution from our environment, the logistics of achieving this goal are extremely complex. In 1972, the Clear Water Act (CWA) was set-up by Congress as a primary federal law in the United States to govern surface water pollution in our daily life. Although the CWA has mandated regulations to deal with point source (PS) pollution, such as wastewater treatment facility, it has had little impact on non-point source (NPS) pollution. Analysis of US Environmental Protection Agency (EPA) data found that since 2003, hundreds of municipal sewer authorities have been fined for violations, including spills, which compromise local drinking water quality and kill aquatic animals and plants (USEPA, 2008). However, financial issues often restrain upgrades of facilities needed to reduce PS pollution.

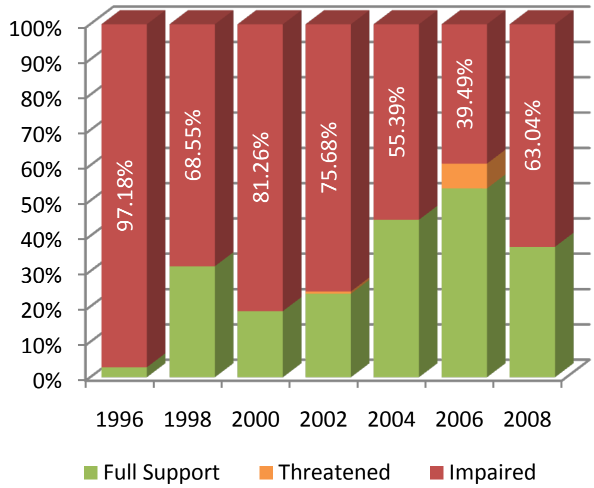
NPS pollution, including phosphorus and nitrogen, is the primary cause for excessive growth of algae in The Gulf of Mexico hypoxic zone (Burkart and James, 1999; Osterman et al., 2006; Dale et al., 2007). Hypoxia or oxygen depletion is a phenomenon that occurs in aquatic environments when dissolved oxygen (DO) levels in the water fall below a point (DO levels less than 30% of saturation or 2 parts per million (ppm)) that detrimentally affects aquatic organisms living in the bottom strata of the ocean (Osterman et al., 2006). A seasonal Dead Zone forms and causes red tides in the northern Gulf of Mexico, from the mouth of the Mississippi River to beyond the Texas border. The hypoxia was first recorded in the early 1970s (Rabalais et al., 2001). It originally occurred every two to three years, but now occurs every spring bringing nutrient rich waters that form a layer of fresh water above the existing salt water (Rabalais et al., 2001). Concentrations of nitrate and phosphate in the lower Mississippi have increased proportionately to levels of use of fertilizers by agriculture since the 1960s (Burkart and James, 1999; Dale et al., 2007). Excessive amounts of nutrients lead to eutrophication, the takeover of nutrient-rich surface water by phytoplankton or other plants. In addition to NPS nutrients, inadequately treated or untreated sewage and other urban pollution also contribute to eutrophication and hypoxia. If nutrient pollution is not greatly reduced, fish and shellfish may someday be irreversibly impacted.

It would be a very complex process to define policies and programs needed to sustain sufficient water quality and restore the “natural condition” of those waters that are impaired. In the traditional approaches of pollution reduction, many states have applied additional regulation to wastewater treatment facilities to conform to EPA’s policies. For NPS, they have used education, incentives, and technical assistance to encourage better management practices. While these traditional approaches have made progress in the resolution of water quality issues, they still have not achieved the TMDLs or the water quality goals. Innovative policy solutions are needed to eliminate the remaining gap.

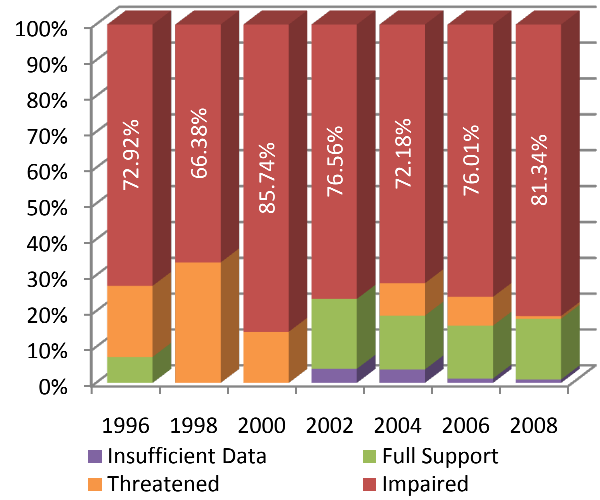
1.1.1 Water Quality Status in Kansas

Kansas landuse is primarily agricultural, with approximately 90% of land use in farms, and the average farm size being 297 ha (733 ac) (NASS, 2004). Nearly 98% of the potential water supply of Kansas comes from precipitation on the land surface. Approximately 58% of the total land area in Kansas is used for row crop agriculture (NASS, 2004). Row crop agriculture contributes a significant amount of sediment, pesticides and nutrients into the State's surface waterbodies (USEPA, 2008). Hundreds of miles of Kansas stream and river corridors, as well as lakes and reservoirs, are in a degraded condition. Figure 1-1 (a) and (b) illustrate the change in status of stream mileages and lake acreages from 1996 to 2008 throughout Kansas. The data were collected from 1996 to 2008 Kansas Water Quality Assessment (305(b) Report), which is the biennial assessment report of the State's surface water quality as required by 33 USC 466 et seq., the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (KDHE, 1996; KDHE, 1998; KDHE, 2000; KDHE, 2002; KDHE, 2004a; KDHE, 2006; KDHE, 2008). The stream water quality impairment percentage decreased from 1996 to 2006. However in 2008, stream water quality worsened again. Similarly, lake water quality slightly improved from 1996 to 2006, but declined in 2008. Data obtained during these reports indicated that around 40% of the Kansas State's designated stream mileage and 20% of the lake acreage fully supported all Clean Water Act section 101(a) uses, whereas 60% of stream and 80% of lake were impaired for one or more uses.

Many factors can degrade the condition of a stream corridor, including lack of riparian vegetation, development and increased runoff within the watershed, and farming up to the edge of the stream. Figure 1-2 illustrates the nutrients are the major causes and agricultural activities are the major sources of water quality impairment in the streams of Kansas (KDHE, 2008). The NPS abatement needs for agricultural land are extremely diverse.

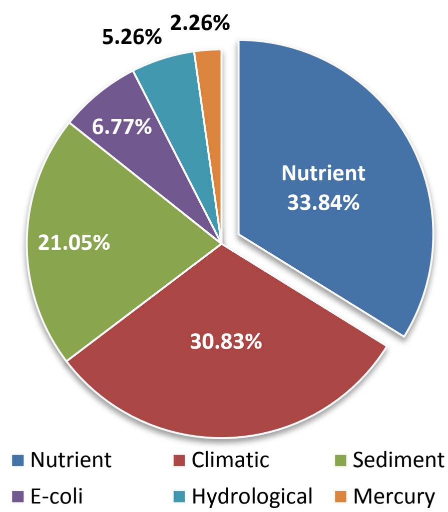


(a) Stream Mileage

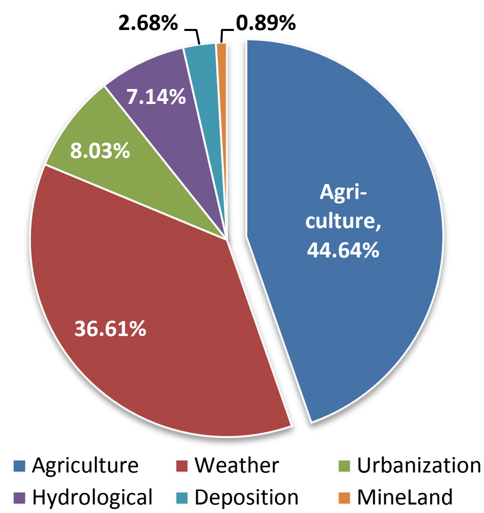


(b) Lake Acreage

Figure 1-1 Summary of Water Quality Status for Kansas Waterbody (1996-2008)



(a) Major Causes of Impaired Stream



(b) Major Sources of Impaired Stream

Figure 1-2 Major Causes and Sources of Water Quality Impairments for Kansas Stream

As Figure 1-2 illustrates, urbanization, hydrological effect, and natural deposition were responsible for less than 20% of the sources of impaired stream, while agricultural producers accounted for another 45%. Among the major causes of impaired streams, nutrient, sediment and seasonal weather issues dominate. Research conducted by Kansas Department of Health and Environment (KDHE) in 2004 also pointed out the important role of nutrient loads. The KDHE indicated that annual nutrient loads exported across Kansas border to Gulf of Mexico are estimated at about 46,266 Mg (51,000 tons) of total nitrogen (TN) and 6,985 Mg (7,700 tons) of total phosphorus (TP) (KDHE, 2004b). The contributions of PS for each nutrient were 18% of TN and 25% of TP; NPS was responsible for the remainder (KDHE, 2004b). Reduction of pollutants from NPS is critical to reducing impairments to the water quality.

Moreover, Kansas streams are required to meet EPA's ecoregional criteria which range from 0.56 to 2.18 mg/L for TN and from 0.020 to 0.067 mg/L for TP (USEPA, 2000a; USEPA, 2000b). However, the best performance expected for wastewater treatment plants utilizing secondary treatment methods is around 3.0 mg/L TN and 0.3 mg/L TP (KDHE, 2004b). Hence, the current treatment technology and equipment of wastewater treatment plants cannot produce effluents that meet EPA's regulation without in-stream dilution. Further improvements in treatment technologies and facilities are typically beyond the financial and technical capabilities of the many small towns throughout Kansas.

1.1.2 Cost of Clean Water

In 1998, impaired water made up about one-third of the length/area of all assessed waterbodies in the U.S. (USEPA, 2001). A report from EPA estimated at least 3.2 billion m^3 (850 billion gallons) of storm water mixed with raw sewage pour into streams every year from aged combined sewer systems, and an additional 11 to 38 million m^3 (3 to 10 billion gallons) of raw sewage accidentally spill every year from sewage-only systems (USEPA, 2008). Lack of finances is one of the major causes of this problem. The nationwide pressure is increasing for water utilities to upgrade aging and deteriorating infrastructures, improve security, serve a growing population, and meet new water quality regulatory requirements (GAO, 2008). The Government Accountability Office (GAO) estimated in 2008 that investments for upgrading aging and deteriorating water infrastructures lie in the range of $485 billion to nearly $1.2 trillion over the next 20 years (GAO, 2008). The 2004 Clean Watersheds Needs Survey also projected infrastructure-related investments for publicly owned wastewater systems of $202.5 billion through 2024 (USEPA, 2008; GAO, 2008).

Many water and wastewater utilities have had difficulty raising funds to repair, replace, or upgrade aging facilities in order to comply with regulatory requirements. GAO reported in 2002 that about one-third of the utilities had deferred maintenance due to insufficient funds, and had 20% or more of their pipelines nearing the end of their useful life (GAO, 2002). EPA also reported the total wastewater treatment and NPS pollution prevention needs for the Nation as $201.7 billion in 2004 dollars, of which $38.3 billion is NPS needs documented by 41 States and the District of Columbia (USEPA, 2008). Best management practices (BMPs) and water quality protection measures can help improve the quality of runoff from agricultural land. The Kansas State Conservation Commission (SCC) tracks land treatment costs and estimates the average cost to treat an acre of land to be $125. However, during 2006 and

2007, Kansas provided around $55 million per year in financial aid for wastewater treatment facility upgrades and expansions, but only $3.5 million per year for NPS pollution abatement.

Due to the insufficient funds and inability of both PSs and NPSs to alleviate their pollution, many watersheds could not reach the water quality standards as required by CWA (USEPA, 2008). As a result, TMDLs standards have been created to address impaired water pollution in States' waterways. TMDLs consider the total maximum capacity of streams or lakes to receive effluents while also meeting its designated use(s). It assesses all of the sources contributing to that pollution from both PSs and NPSs. Then, it sets water quality goals for the use of that stream, and estimates the reduction requirement of PSs and NPSs for achieving those goals. According to EPA's report of 2001, the national cost of implementing pollution control measures to develop and implement TMDLs were estimated to range from $0.9 billion per year to $4.3 billion per year depending on efficiency of TMDLs (USEPA, 2001). The average annual cost of developing TMDLs is estimated to be $63 million to $69 million per year for the next 15 years, nationwide. Furthermore, the cost of water quality monitoring to support the development of TMDLs is expected to be approximately $17 million per year (USEPA, 2001).

Policies and programs are needed that sustain sufficient water quality and restore the "natural condition" of those waters that are impaired, but many difficulties must be overcome in the process. In the traditional approaches of pollution reduction, many states applied additional regulation to wastewater treatment plants to conform to EPA's policies. For NPSs, they use education, incentives, and technical assistance to encourage BMPs. Although TMDLs distribute the burden of meeting water quality requirements across all polluters, PSs still struggle in upgrading their equipment and facilities to meet their regulatory requirements. In contrast, NPSs still rely on the voluntary agricultural producers to participate the pollution abatement program. Even though TMDLs provide a way to re-allocate responsibilities of addressing the water quality goals of CWA, innovative policy solutions are needed to solve the funding crisis and eliminate resistance to addressing water quality concerns. One such solution receiving considerable attention recently has been water quality trading (WQT) (Leatherman et al., 2004).

1.1.3 Water Quality Trading

WQT is a market-based approach to improve water quality. It is an innovative, voluntary tool that connects industrial and municipal facilities, or PSs, with agricultural producers, NPSs, to economically achieve water quality improvements in the watershed. Assuming all sources are accountable for a certain minimal level of pollution prevention and that no water quality degradation is permitted, the trading program would allow the pollution source with a high reduction cost to purchase the same or a greater level of equivalent pollutant reduction from others with lower costs. The source with high costs achieves a targeted level of pollution reduction at less overall costs, while the source with low costs sells environmental equivalents or "credits" in the process of reducing pollution. This trading process allows for a mutually beneficial situation for both the seller and buyer.

The basic idea behind WQT is to create a "market" in which all the sources of pollution are jointly charged with the task of meeting a water quality goal. However, achieving that goal is determined by the participants in the market. In this market, a series of rules are required in order to guide the market operation, provide incentives to the trader to participate, and also have a pollution load reduction from each participant. Participants are free to find the least-cost method both to achieve their financial goal and water quality mandate of current law. It is a flexible and cost-effective approach for maintaining, restoring, or enhancing water quality.

Nelson and Keeler (2005) reported that existing WQT programs have had unexpectedly low trading volumes. The availability of a sufficient number of potential trading partners is important to the success of a WQT market. Motivation of trading market is based on a large number of pollution sources willing to trade and the costs of pollution reduction is expected to be highly variable. The size of trading market must be large enough to supply the environmental credits adequate to meet the load reductions sought by buyers (Rowles, 2005). It might fail if the participants are too small or too few (Letson et al., 1993, Crutchfield et al., 1994).

For example, the total cost for a farmer to use some sort of BMPs, an alternative land operational procedure or installing certain structural remedies, may be less than the total costs of reducing the same amount of pollutants by installing complex industrial pollution control technologies and equipments. Other factors, such as the method for pricing credits, the trading ratio, the applicable market structure, and the information disclosed, also affect stakeholders' willingness to participate in a trading program. Hoag and Hughes-Popp (1997) suggested that improving trading processes and methods of simulating trading results are the keys for successful trading programs.

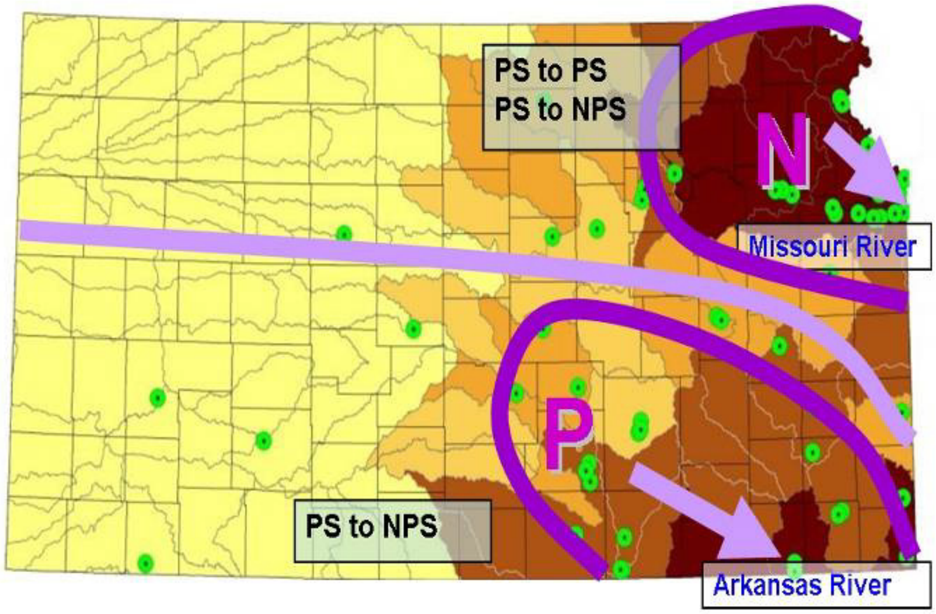
1.1.4 Potential Water Quality Trading Program Area

WQT is based on a watershed region that encompasses more than just a single nutrient source point location. For pollutants like nutrients, the equivalent water quality improvement in the watershed can often be achieved at lower overall cost since trades among participants can be arranged that do not cause an immediate problem for a local watershed area, and so its environmental risk compared with other pollutants is low (KDHE, 2004b). EPA only suggests four types of suitable pollutant to trade: nitrogen, phosphorus, sediment, and temperature (USEPA, 2004). This does not mean only these four types of pollutant can be traded; rather, it indicates that other pollutants, such as heavy metals or bacteria, will require more studies to ensure the trading activities do not increase risk of new water quality issues at other locations in a watershed (USEPA, 2004).

Kansas does not currently have a formal WQT policy. Kansas Department of Health and Environment (KDHE) cooperated with Kansas State University's Office of Local Government to study potential areas that have sufficient demand for a formal trading program (KDHE, 2004). As discussed in prior studies, the TN and TP are the nutrient issues of Kansas surface water resources (KDHE, 2004b). TN has been implicated as the primary cause of hypoxia in the Gulf of Mexico (KDHE, 2004b). Water leaving Kansas eventually finds its way to the Gulf via the Missouri and Arkansas River drainage basins. Therefore, a fraction of TN and TP leaving Kansas eventually winds up in the Gulf (KDHE, 2004b). Kansas point sources contribute a relatively large percentage of TN to the Gulf due to their proximity to large streams directly connected to the Gulf (KDHE, 2004b).

According to the research of KDHE (2004b), comparing the total amount of TN and TP discharging from Kansas, they determined which specific areas of Kansas are suitable for a WQT program. The majority of potential TN sources exported to the Gulf of Mexico were located near the largest rivers and streams in the eastern half of Kansas (KDHE, 2004b). TP was the limiting nutrient for most of the eutrophication issues of the lakes and reservoirs in Kansas. The potential TP sources exported to Gulf of Mexico were considered to be located near the southeast of Kansas (KDHE, 2004b).

Figure 1-3 represents the potential study area for a WQT program. According to this map, northeastern Kansas is suitable for TN trade and southeastern Kansas for TP. Due to the location of major wastewater treatment plants in relation to major streams and reservoirs, the trading type for TN could be point source to point source (PS-PS) trade or point source to nonpoint source (PS-NPS) trade in northeastern Kansas. Similarly, the trading type of TP would be point source to nonpoint source (PS-NPS) trade in the southeast (Leatherman et al., 2005).



(Leatherman et al., 2005)

Figure 1-3 Potential Study Area for WQT Program in Kansas

1.2 Research Objective

The design of a WQT program requires sufficient knowledge and understanding of the targeted pollutant and the watershed it affects. The candidate pollutants (e.g., TN or TP) can be produced from either PS or NPS, but the pollution processes can be quite different depending upon its source. Most PS pollutant loads are almost consistent on a day-to-day basis, but NPS loads, the by-product of storm water runoff, are event-based with widely variant pollutant loads. Whereas the improvement of wastewater treatment plant facilities can directly reduce PS pollution, implementing BMPs to decrease potential NPS pollution produces less certain results. Due to these differences in measurement scale, pollutant origins and source locations may cause significant disparity of load reduction, load uncertainty and transport effect for trades between PS and NPS.

Reducing the impediments to WQT is the overall goal of this study. Nutrient loads, particularly TN and TP, are the target pollutants. Spatiotemporal variability and other intangible costs of WQT can be reduced by quantifying uncertainties of pollutant load reduction and delivery effects for potential trades, estimating effects of trades and potential trades, and providing rich WQT information for stakeholders. The possible approaches to quantify uncertainty of nutrient load and delivery effects could be: directly monitoring, applying fixed trading ratio, general discount factor for BMPs, or model simulations (Jones et al., 2005). Direct on-site monitoring would be expensive and might not collect data thoroughly for every location in the watershed. A fixed trading ratio or so called a general discount factor for BMPs cannot provide site-specific, spatiotemporally variant information. As such, application of watershed models is warranted to simulate pollutant load and transport processes from different land management practices and watershed locations. Furthermore, GIS techniques can be used to visualize and analyze the pollutant load uncertainty over the watershed in space and time, and can present rich information to stakeholders. Instead of neglecting load delivery effects, stream network analysis provides a superior method to trace and systematize pollutant transport along the river and to help optimize the selection of potential trading partners. Integrating previous methods and modeling results database with Internet GIS-based applications will provide easy use and access user interface for WQT assessment.

Thus, the first goal for this dissertation was to quantify pollutant load reductions and their spatiotemporal variances to address the difference among field management practice changes. Watershed modeling tools and GIS functions will be used to simulate in-field pollutant load reductions over the watershed space and time scales. Based on model simulations and statistical analyses, site-specific trading ratios were used to address the environmental uncertainty of WQT, both spatially and temporally.

Following the in-field pollutant load estimation, the second goal for this dissertation was to simulate the delivery effects for the pollutant transport along the stream network and incorporate the resulting spatiotemporal effects into the trading system. The pollutants were traced with the routing function of watershed model, lake model and stream network analysis. The delivery ratios for pollutant transported in a single subbasin, as well as the cumulative delivery ratio for pollutant transported to the watershed outlet or specific points, were estimated. Finally, overall trading ratios could be calculated based on the combination of the uncertainty ratio of in-field load reduction and delivery ratio of pollutant load transport.

Transaction costs have significant effects on trading incentives. Market structure selection is the key factor influencing transaction costs. Previous studies show that the central exchange market structure can dramatically reduce transaction cost but has limited flexibility (Woodward and Kaiser, 2002). A different market structure, such as bilateral negotiation, has a higher transaction cost but more flexibility. Regardless of the market structure, information on transactions is not only required by WQT participants for communication purposes, but also needed for the public to supervise the further status of each trade. Thus the third goal of this dissertation was to develop a WQT information platform. A spatial data model and database data structures were used to standardize data input/output and maintenance. Database stored the watershed modeling results and WQT information. A web-based internet GIS map service connected database and WQT information to present the information for client users. A web browser as the client side application was used to provide a low cost and easy access environment for stakeholders.

The hypotheses for each objective are:

1) The tradable pollutant load reduction (or credits) of a trade depends on the pollutant reduction induced by the specific change to land management, location of trading partners and processes that attenuate downstream delivery of pollutants, and the time frame of the trade. A spatiotemporally specific trading ratio can be used to represent the statistical uncertainty (or trading risk) for the trade, where a lower trading ratio means lower risk and a greater advantage to the trade receiver.

2) A site-specific trading ratio that accounts for spatiotemporal variability in pollutant load reductions and delivery will provide more tradable credits per unit cost.

3) A GIS-based web interface, termed the 'Water Quality Trading Information Platform Service' (WQTIPS), could provide systematic structure to allow incorporation of a site-specific trading ratio into a WQT system without increasing system complexity.

1.3 Reference

Burkart, M. R. and D. E. James. 1999. Agricultural-Nitrogen Contributions to Hypoxia in the Gulf of Mexico. *J. Environ. Qual.* 28(3):850-859.

Crutchfield, S. R. and D. Letson. 1994. Feasibility of point-nonpoint source trading for managing agricultural pollutant loadings to coastal waters. *Water Resour. Res.* 30 (10): 2825-2836.

Dale, V., T. Bianchi, A. Blumberg, W. Boynton, D. J. Conley, W. Crumpton, M. David, D. Gilbert, R. W. Howarth, C. Kling, R. Lowrance, K. Mankin, J. L. Meyer, J. Opalauch, H. Paerl, K. Reckhow, J. Sanders, A. N. Sharpley, T. W. Simpson, C. Snyder, D. Wright, H. Stallworth, T. Armitage, D. Wangsness. 2007. *Hypoxia in the Northern Gulf of Mexico: An Update by the EPA Science Advisory Board*. EPA-SAB-08-003. Washington, D.C.: USEPA, Science Advisory Board.

GAO. 2002. Water Infrastructure: Information on Financing, Capital Planning, and Privatization. GAO-02-764. Washington, D.C.: U.S. Government Accountability Office (GAO).

GAO. 2008. Physical Infrastructure, Challenges and Investment Options for the Nation's Infrastructure. GAO-08-763T. Washington, D.C.: U.S. Government Accountability Office (GAO).

Hoag, D. L. and J. S. Hughes-Popp. 1997. Theory and Practice of Pollution Credit Trading. *Rev. Agr. Econ.* 19: 252-262.

Jones, C., L. Bacon, M. S. Kieser, and D. Sheridan. 2005. *Water-Quality Trading a Guide for the Wastewater Community*. Water Environment Federation. New York, NY: McGraw-Hill.

KDHE. 1996. 1996 Kansas Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE), Available at: www.kdheks.gov/befs/305b_1996/part_1.htm. Accessed Dec. 21, 2008.

KDHE. 1998. 1998 Kansas Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

KDHE. 2000. 2000 Kansas Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

KDHE. 2002. 2002 Kansas Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

KDHE. 2004a. 2004 Kansas Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

KDHE. 2004b. *Surface Water Nutrient Reduction Plan*. Topeka, KS: Kansas Department of Health and Environment (KDHE).

KDHE. 2006. 2006 Kansas Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

KDHE. 2008. 2008 Kansas Integrated Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

Leatherman, J., C. Smith, and J. M. Peterson. 2004. An Introduction to Water Quality Trading. In *Proc. Department of Agricultural Economics' Risk & Profit Conference.* Manhattan, KS: Kansas State University.

Leatherman, J., J. M. Peterson, and K. R. Mankin. 2005. Is Water Quality Trading a Policy Option for Kansas? In *Proc. 22nd Annual Water and the Future of Kansas Conference.* Topeka, KS: Kansas State University.

Letson, D., S. R. Crutchfield, and A. Malik. 1993. Point/Nonpoint Source Trading for Controlling Nutrient Loadings to Coastal Waters: A Feasibility Study. Ag. Econ. Report No.674. Washington, D.C.: USDA ERS Research and Technical Division. Available at: www.ers.usda.gov/AboutERS/Sales/index.asp?PDT=2&PID=670. Accessed April 30, 2009.

NASS. 2004. Kansas, State and County Data, Volume 1, Geographic Area Series Part 16, 2002 Census of Agriculture. AC-02-A-16. Washington, D.C.: National Agricultural Statistics Service (NASS), Agricultural Statistics Board, USDA.

Nelson, N. and A. Keeler. 2005. Water Quality Trading in Georgia: Addressing Two Potential Impediments to Success. In *Proc. 2005 Georgia Water Resources Conference*. Kathryn J. Ed. Athens, Georgia: Institute Ecology, University of Georgia. Available at: www.uga.edu/water/GWRC/Papers/NelsonN-GWRCpaper%20April13.pdf. Accessed April 30, 2009.

Osterman, L. E., P. W. Swarzenski, and R. Z. Poore. 2006, Gulf of Mexico Dead Zone—the Last 150 Years: USGS Fact Sheet 2006-3005. Available at: pubs.usgs.gov/fs/2006/3005/. Accessed April 30, 2009.

Rabalais, N. N., R. E. Turner, and W. J. Wiseman Jr. 2001. Hypoxia in the Gulf of Mexico. *J. Environ. Qual.* 30(2):320-329.

Rowles, K. 2005. A Feasibility Analysis of Applying Water Quality Trading in Georgia Watersheds. Water Policy Working Paper 2005-020. Atlanta, GA: Georgia State University, Andrew Young School of Public Policy.

USEPA. 2000a. *Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria - Rivers and Streams in Nutrient Ecoregion IX*. Washington, D.C.: USEPA, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Available at: www.epa.gov/waterscience/criteria/nutrient/ecoregions. Accessed March 31, 2009

USEPA. 2000b. *Ambient Water Quality Criteria Recommendations-Lakes and Reservoirs in Nutrient Ecoregion IX.* EPA-822-B-00-011. Washington, D.C.: USEPA, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Available at: www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes. Accessed April 30, 2009.

USEPA. 2001. The National Cost to Implement Total Maximum Daily Loads (TMDLs): Draft Report. Washington, D.C.: USEPA.

USEPA. 2004. *Water Quality Trading Assessment Handbook*. Washington, D.C.: Office of Water, USEPA.

USEPA. 2008. Clean Watersheds Needs Survey 2004 Report to Congress. Washington, D.C.: USEPA.

Woodward, R. T., and R. A. Kaiser. 2002. Market Structures for U.S. Water Quality Trading. *Rev. Agr. Econ.* 24: 366-383.

Chapter 2 Environmental Equivalents for Water Quality Trading: The Theory and Analysis

Abstract

The design of a water quality trading (WQT) program requires sufficient knowledge and understanding of each targeted pollutant and the watershed it affects. The candidate pollutant (e.g., TN or TP) can be produced from either a point source (PS) or a non-point source (NPS), and the pollutant loading processes can be quite different depending upon its source. Most PS pollutant loads are relatively consistent on a daily basis, but a NPS load, the by-product of storm water run-off, is event-based with widely variant pollutant loads. Whereas the improvement of wastewater treatment plant facilities can directly reduce PS pollution, implementing agricultural best management practices (BMPs) to decrease potential NPS pollution produces less certain results. Due to these differences of measurement scale and pollution origins, the uncertainties for the trades between PS and NPS could be significant. In this research, we first proved the way how NPS and PS can trade their pollutant load to each other. And then, we developed a method to quantify these uncertainties with statistical analysis and a watershed model to estimate the potential deviation of TN and TP load reductions. To test this method, a pilot study was launched for modeling five selected scenarios with SWAT and 36 years historical climate data in Lower Kansas watershed, northeastern Kansas. Within the chosen cases, minimum tillage, surface fertilizer application, and no edge-of-field BMP will produce higher TN loads while a no-till with surface fertilizer application and no edge-of-field BMP might have higher TP loads. For specific cases, the potential pollutant load reductions vary by subbasin. The trading ratios of potential pollutant load reductions also show similar trends, indicating the best alternative scenario might change from one subbasin to another, and scenarios with higher potential load reductions may or may not produce a lower trading-ratio. These analyses show the solid evidence for using a floating trading-ratio system to address current WQT program issues.

2.1 Introduction

In Kansas, the most wide-spread water quality issue is excess nutrients. More than 63% of stream mileage and 81% of lake acreage in Kansas failed to support one or more designated uses (aquatic life support, food procurement and recreation) recognized in Section 101(a) of Clean Water Act (CWA) (KDHE, 2008; KDHE, 2009). As indicated in the Nutrient Reduction Plan, Kansas Department of Health and Environment (KDHE) estimated around 46,266 Mg (51,000 tons) of total nitrogen (TN) and 6,985 Mg (7,700 tons) of total phosphorus (TP) were exported across the Kansas border to Gulf of Mexico annually

(KDHE, 2004). The point source (PS) contribution of nutrient pollutants was estimated at 18% of TN and 25% of TP. In contrast, 82% of TN and 75% of TP were contributed by non-point source (NPS). With the new EPA's Ecoregional Criteria, northeastern Kansas streams and lakes are required to meet the new water quality standard which range from 0.36 to 0.69 mg/L of TN for lake and stream as well as from 20 to 36.56 µg/L of TP for lake/stream (USEPA, 2000a; USEPA, 2000b). However, the potential best performance of wastewater treatment facilities (WWTF) utilizing secondary treatment methods is around 3.0 mg/L for TN and 300 µg/L TP (KDHE, 2004). As a result, with current treatment technology and equipment, effluents from WWTFs are not clean enough to meet EPA's regulation without additional in-stream dilution. In addition, renewing treatment technologies and facilities are typically beyond the financial and technical capabilities of the many small towns throughout Kansas (KDHE, 2004). Furthermore, the traditional voluntary programs to abate NPS pollution have shown little promise of achieving the water quality targets within the desired schedules. Consequently, alternative methods and/or innovated policy solutions are needed to fill these gaps. One such novel idea to solve the watershed water quality problems is water quality trading (WQT) (Leatherman et al., 2005).

Based on the successful experience in using the concept of tradable pollution rights in the context of air since the 1980s, a way to offer firms a more flexible and cost-effective method for reducing emissions through “cap-and-trade” systems was employed as the template for implementing WQT program between pollution sources (Morgan and Wolverton, 2005). WQT is a market-based approach that pulls the trading-market structure into a water quality control program to optimize both economic and environmental benefits. It is a method that connects industrial and municipal wastewater treatment facilities, the PS, with agricultural producers, the NPS, to economically achieve the mandated water quality goals. Assuming all pollution sources are responsible for a certain minimal level of pollution prevention and no water quality degradation is permissible, the trading program would allow a pollution source with a high reduction cost to purchase the same or greater level of equivalent pollutant reduction from other sources with lower costs. The source with high costs achieves a targeted level of pollution reduction at less overall costs, while the source with low costs sells its environmental equivalents or “credits” in the process of reducing pollution. The overall effect is that the watershed benefits from the reduction of total pollutant loads. This trading process instigates a mutually beneficial collaboration between both the seller and buyer which prompts its use.

The biggest issue of WQT is that the actual traded volume might be smaller than anticipated (Nelson and Keeler, 2005). The basic idea behind WQT is to create a “market” in which all the sources of pollution are jointly charged with the task of meeting a water quality goal. In this market, providing incentives for traders to participate while reducing the pollution load from each participant are the ultimate goals. Nelson and Keeler (2005) reported that existing WQT programs have had unexpectedly low trading volumes. An active trading market is based on a large number of stakeholders willing to trade and the costs of pollution reduction having significant disparity. Too few participating trading partners might jeopardize the WQT market (Letson et al., 1993, Crutchfield et al., 1994). Moreover, if the total cost for an agricultural producer to implement alternative land management or to install certain structural remedies could not significantly smaller than the total costs of reducing the same amount of pollutants by installing complex industrial pollution control technologies and equipments, a trade would not occur between agricultural producer and industry. Hoag and Hughes-Popp (1997) pointed out that improving trading processes and methods of simulating trading results are the keys for successful trading programs.

To summarize the discussions in recent WQT studies, there are several obstacles that remain in WQT and may explain the low trading volume. First, the high transaction costs may lower incentives and decrease willingness to trade. Government policies, water quality regulations, market structures, information disclosure, and the specific situation of a given participant will affect the transaction cost (Woodward and Kaiser, 2002).

Second, high trading ratios may decrease the incentive and willingness, thereby hindering trading. Trading ratios often are used as a mechanism to manage uncertainty associated with the effectiveness of NPS pollution controls. A trading ratio greater than 1:1 means reductions from NPS is less certain compared to PS. Morgan and Wolverton (2005) reported the most common trading ratios for WQT programs that trade nutrients between PS and NPS is around 2:1, and in some cases, as high as 10:1. In contrast, PS to PS commonly use a 1:1 trading ratio. These trading ratios, however, largely depend on empirical experience without scientific validation. Furthermore, the equivalency of potential environmental impact of the pollutant load reduction generated between PS and NPS needs to be estimated carefully.

Third, there may be hidden or intangible costs of trading. These costs are due to insufficient information or oversimplified trading processes. Hoag and Hughes-Popp (1997) mentioned that even though the WQT program has been already well developed, PS polluters may hesitate to buy the reductions because of public relations risks - it may be viewed as shirking on environmental responsibility. Inaccuracy of load reduction cost estimation may also occur. In the research of the potential trapping efficiency of vegetative filter strips (VFS), Schauder and Auerswald (1992) suggested the long-term trapping efficiency under agricultural use can be around 55% of the computed annual soil loss of the study area. Japanese scientists Shiono et al. (2004) reported 63% and Blanco-Canqui et al. (2004) showed the effectiveness of VFS is around 92% of sediment. However, Mankin et al. (2006, 2007) indicated the VFS has a potential 66% of TN and TP concentration reductions as well as the grass-shrub riparian buffer system (RBS) has 85% TP load reduction in Kansas. Bhattarai et al. (2008) reviewed at least 21 researches on the performance of VFS in removing sediment, nutrients, and pathogens. The TP reduction efficiencies are ranged from 12 to 90%. These researches show that the same BMP in different geospatial location or under different climatic conditions might produce different reducing efficiencies. Therefore, the geospatial site-specific effects are also a critical issue for pollutant load reduction estimation.

Therefore, while WQT seems to have significant potential to reduce pollutant load from source waters, there remains considerable uncertainty regarding trading processes, market structure, trading ratios, and site-specific phenomena. Understanding and quantifying these hindrances is critical in order to develop feasible WQT programs in Kansas.

The objectives of this study were to review the basic WQT theory and pollution issues, analyze the current water quality program problem, and then develop a potential solution for calculating trading ratio as well as trading effects in a scientifically rigorous manner. A simple case study based on the potential solution method was also assessed in the Lower Kansas watershed, Kansas.

2.2 Materials and Methods

2.2.1 Brief Review of Water Quality Trading

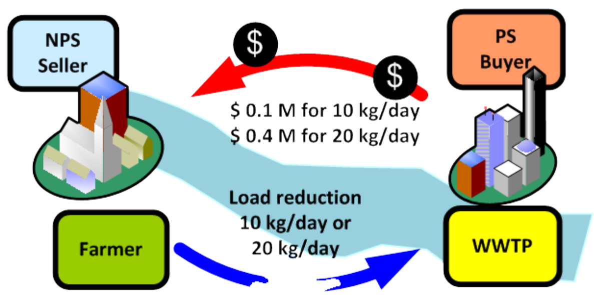
WQT has been promoted for more than a decade. There are at least 40 projects nationwide and another 26 watersheds were proposing projects in 2004 (Environomics, 1999; Breetz et al., 2004). WQT programs intend to create markets where stakeholders, including those responsible for all sources of pollution and those with interest in reducing discharges of pollution, such as environmental organizations or government agencies, can be jointly charged with the task of meeting a water quality goal. Assuming all sources of pollution are accounted for, a certain minimal level of pollution prevention without any water quality degradation can be achieved. The WQT program allows pollution sources with a higher reduction costs to purchase the same or a greater level (e.g., two times) of equivalent pollutant reductions from the others who have lower costs. The sources with higher costs achieve the goal of pollutant load reduction with less overall costs, while the sources with lower cost can sell their own “extra” load reduction or “environmental equivalent credit” via this trading process. Each pollutant trade will reduce the total pollution in the watershed and allow both seller and buyer to gain.

2.2.1.1 *An Example of Trading Work*

The following scenario explains and discusses a typical WQT case between a municipal treatment facility and an agricultural producer. Assume that a new regulation is mandated for a wastewater treatment plant (WWTP) to reduce daily nutrient load by 10 kg from its effluents. The total cost for the WWTP to reach its goal by implementing new facilities or technologies could be as high as $1 million. Upstream, a farmer may be able to reduce his own nutrient load by 10 kg per day for $100,000 or 20 kg per day for $400,000 by implementing alternative management practices. Whereas the total costs between WWTP and farmer are different, WWTP and farmer might be able to make a bargain in which the downstream WWTP can achieve load reductions requirement by purchasing load reduction from the upstream farmer. To eliminate the potential trading risks or uncertainties from agricultural pollutant load reduction, WWTP may be required to buy more reductions (two times, for example) to offset any uncertainty about whether or not the water quality goal can actually be accomplished. Disregarding the farmer’s extra profits and other intangible costs within this trade, the total saving for WWTP would be $0.9 million when buying the load reduction from the farmer, or $0.6 million with two times the load reduction utilizing 2:1 ratio to address the potential trading risk. Within this trade, the overall pollutant load reductions by the WWTP would be expected to meet the new regulation, and both municipal WWTP and agricultural producer will also earn some financial benefits for this trading process.

Figure 2-1 illustrates a trading scenario between the upstream farmer and the downstream municipal WWTP. In this scenario, the ratio of buying pollutant load reduction from the seller to replace buyer's own targets is defined as water quality equivalence ratio, or trading ratio (TR) in this study. In order to guarantee the trade will meet the regulation or expected level of environmental equivalence, this ratio should always be greater than 1. The magnitude of the TR will depend on the alternative land management practices, the spatiotemporal heterogeneity of watershed and other uncertainties within the trade.

Assuming the basic unit for a trading credit is 2 kg nutrient load reduction per day (kg/day), for a 2:1 TR scenario, the WWTP should purchase 10 credits from the farmer to replace its own 10 kg nutrient load reduction required by a new regulation. The price of this trade would depend on the nominal price for each credit and transaction fees within the trading process. The nominal price consists of fixed capital cost and floating profit (USEPA, 2004). Transaction fees originate from information gathering, negotiation, execution, and monitoring needed to implement a trade (USEPA, 2004). For the trading buyers, the money they should pay in order to get the credits would be the total nominal price of credits plus any buyer's transaction fee. In contrast, for the trading sellers, the money they will earn would be the total nominal price of credits minus any seller transaction fees. For the case in Figure 2-1, if the transaction fees for both buyer and seller are $20,000 and seller's profit is 20% of the nominal price, the total amount that buyers should pay is $0.5 million. The result is that the WWTP still saves $0.5 million from this trade compared to the projected cost of achieving the same target load reduction by upgrading their facility. The seller's net profit will be 20% of nominal price of all credits minus transaction fee, e.g., $60,000. The selling price for each trading credit can be simply calculated as $24,000 in this trade. In fact, the prices for each credit that buyer should pay would be varied. Smith (2004) provided a detailed discussion on the trading price for such WQT scenarios. Based on the marginal utility theory of economics, the price of the first credit would be very different from the price of last credit (Smith, 2004).



The cost for WWTP implementing new facility to produce 10 kg/day load reduction is $1 million; the cost for upstream farmer to gain 10 kg/day load reduction is $0.1 million and 20 kg/day is $0.4 million.

If disregarding the potential profit and other intangible costs such as transaction fee, the potential cost saving for downstream WWTP from a trade could be:

1. For 1:1 TR:

   Saving = $1 million - $0.1 million = $0.9 million

2. For 2:1 TR:

   Saving = $1 million - $0.4 million = $0.6 million

Figure 2-1 A Trading Scenario between Upstream Farmer and Downstream WWTP

2.2.1.2 *Trading Type and Market Structure*

The type of WQT model can be classified by either the pollutant source characteristic or the market structure required to address the difference among trading cases. Centers for Public Leadership Studies at Texas A&M University (CPLS, 1999) categorized trading models into five major types, depending on the source of pollution: intra-plant, pretreatment, PS/PS, PS/NPS, and NPS/NPS trading. Intra-plant trading describes trades among multiple discharge outlets within a single PS facility. It could be feasible to trade the pollutant load between its multiple pipes by managing the overall level of discharge to achieve the water quality goal of this PS (CPLS, 1999). Pretreatment is the scenario that an industry discharges to a publicly-owned WWTP. It provides an opportunity for government to trade with the industry with pre-treating its discharge instead of upgrading treatment technology at the WWTP (CPLS, 1999). The other types describe the potential buyer and seller of PSs and NPSs within a trade. The processes for these trades might be similar but have different level of trading risk for each type.

Woodward and Kaiser (2002) defined four major types of WQT models based on market structure: exchanges, bi-lateral negotiations, clearinghouses, and sole-source offsets. They mainly focused on transaction cost to discuss the effectiveness of market structures. There is significant variability associated with transaction costs among different market structures. Exchanges may have the lowest transaction cost. However, exchanges require a standardized unit of trading to capture all trading uncertainties of pollutant load reduction. Bilateral negotiations have higher transaction cost but are more flexible. Water quality clearinghouses provide a compromise solution between exchanges and bilateral negotiations. Nevertheless, State government needs to take the responsibility associated with WQT clearinghouses and the additional risks associated with trading. Sole-source offsets are not actually involving a trading process and its costs vary case by case.

Morgan and Wolverton (2005) suggested three types of trading models also based on market structure: bilateral, clearinghouse and third party. Oregon Department of Environmental Quality (DEQ) suggested three types of trading model based on market structure: Single "Buyer", Multi-Party/Closed Market, Multi-Party/Open-Market (Oregon DEQ, 2005). In the single "buyer" scenario, only one permitted organization or facility may obtain credits from one or more PS or NPS. A potential example is one in which the upstream pollution sources trade with organizations trying to prevent water quality degradation of a downstream lake or estuary. Multi-party/closed market defines a system in which the trading is restricted to a group of pre-approved sources. Participants may explicitly buy and sell credits on the closed market, or may make decisions about additional treatment options and not actually exchange credits or monies. In contrast, Multi-party/open-market does not restrict trades solely to or from participants in a specific group of sources or purchasing organizations.

Probably the most effective type of WQT program, the Multi-Party/Open-Market, would be most suitable for maintaining good water quality or implementing watershed TMDLs (Oregon DEQ, 2005). However, the most appropriate trading type may not exist (Woodward and Kaiser, 2002). Mixed trading types with two or more market structures may function side by side in a real WQT program. Selection of a suitable WQT trading model for a watershed will depend on a number of factors. These factors include, but are not limited to: pollutant properties, spatial and temporal scale of the watershed, type of potential participants, water quality regulation and mandate, and importantly, the participants' incentive and willingness to trade.

2.2.1.3 *Trading Direction within Watershed*

One important factor related to both participant availability and environmental suitability is the direction of a trade. The trading direction depends on the spatial location of each trading partner, the buyer and seller of pollutant load reduction. In most of cases, WQT provides an opportunity for a buyer to purchase environmental credits from a seller to replace its specific load reduction requirement. Based on the relative location of the buyer and the targeted waterbody of the WQT program, the direction of a trade can be categorized as upstream or downstream trading. Figure 2-2 illustrates the spatial location for buyer (PS) and seller (NPS) in both downstream and upstream scenarios. If sellers reside upstream and trade their credits to downstream buyers, it defined as a downstream trade. In contrast, when sellers are in the downstream and trade their credits to upstream buyers, it called an upstream trade. The third type of scenario, which is not illustrated in Figure 2-2, is mixed direction. In this scenario, sellers and buyers are located in either upstream or downstream position, thus the scenario cannot be categorized clearly as solely a downstream or upstream trade.

For a downstream trade, an NPS that sells its pollutant load reductions to a downstream PS will reduce the total amount of pollution discharging to the river, which will improve the water quality of that river section. In contrast, an upstream trade in which the NPS sells its credits to an upstream PS; the PS discharges its pollution first and then reduces the total pollutant load by purchasing load reduction from the downstream NPS. Both downstream and upstream trade might reduce the overall pollutant loads discharging from the watershed outlet or to the target waterbody (such as a lake or reservoir). However, the upstream trade may not solve the local water quality issue at the river section between the PS and NPS, and might also cause some localized environmental degradation or "hot-spot" issues. The hot-spot is due to the total pollutant loads in the stream sections between buyers and sellers becoming too high to meet the water body's designated use. The factors that might contribute to create a hot-spot include the nature and quantity of pollutants, a low-flow condition, or a lack of availability of pollution assimilative capacity in the receiving water (Rowles, 2005). The hot-spot might violate the TMDLs or worsen local water quality. Applying TMDL constraints to a specific river section or splitting a watershed into several sub-trading regions can prevent the hot-spot effects. Due to the geophysical difference between lakes and streams, lakes often provide suitable locations to divide a watershed into two discontinued trading regions. Similar to the upstream trade scenario, the mixed trading direction scenario may have an uncertain trading result in intermediate river sections. Consequently, the downstream trade scenario is generally preferable. In this study, all the trading direction was fixed as downstream trade.

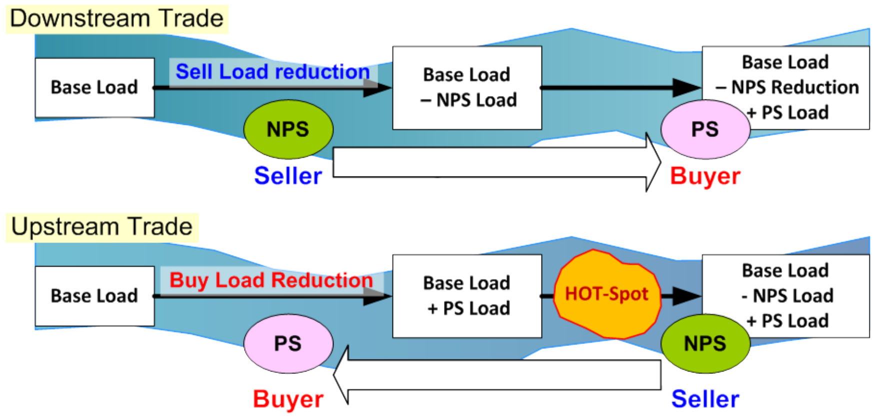


Figure 2-2 Direction of WQT Partners and Potential Hotspot

2.2.1.4 *Effect of Fixed Trading Ratio*

The TR is the ratio of pollution reductions purchased from a supplier to the pollution reductions intend to be replaced by a demander. The ratio is based on the probability of pollutant load reduction from supplier at a specific confidence level. Comparing the daily-based PS to event-based NPS, one unit pollutant load reduction from PS might not equal to the one from NPS. For example, 1 credit of load reduction having 100% certainty would be equivalent to 2 credits of load reduction having 50% certainty. The TR in this case would by 2:1. In order to account for the difference in certainty (or risk) among potential source reductions and to help ensure an environmental equivalent between seller and buyer, current researches use either fixed or variant (floating) TR in their WQT programs.

Fixed TR means only one or several ratios can be used for any trade in a WQT program. In this WQT program, the PS purchasing credits is simply equal to the demanded credits multiplied by the TR, no matter what risk is introduced by the alternative land management practice or what distance (and potential for natural degradation) exists between buyer and seller. A variant or floating TR either uses an individual ratio for each trading partner or a series of ratios for different management practices in each sub-area of a WQT program. The variant TR accounts for the variance of soil type, land management, climate, landscape slope, and land management practices in spatiotemporal scale as well as the pollutant delivery effects along stream network from source to target. In general, fixed TR is easier to implement in a trading program and also simplifies the calculation of total cost, but the environmental benefits resultant from each trade would be varied. In contrast, a variant TR, which is based on the watershed spatiotemporal heterogeneity and the probability of load reduction ability for each management practice, would increase the complexity in implementation and calculation of each trade and the overall WQT program. However, it could provide more precise and consistent environmental benefit for each trade at a certain level of confidence.

Figure 2-3 demonstrates both fixed and variant (floating) TR scenarios. Consider a case in which there is a PS that requires x pollutant load reduction (L/R) credits to meet a new regulation, and also two NPS, NPS1 and NPS2, that have unlimited amount of pollutant load reduction credits to sell to the PS. With a watershed-wide fixed TR of 2:1, the PS is mandated to purchase 2x credits from either NPS1 or NPS2. The NPS with a lower price of credit would be the best choice for PS. However, the delivery effect between NPS1 and PS is dramatically different to that between NPS2 and PS. If the delivery ratio (R_D) between NPS1 and PS is 0.8 and the R_D between NPS2 and PS is 0.4, the final amount of load reduction from the purchase of 2x credits transported from NPS1 to PS would be 1.6x credits and from NPS2 to PS would be 0.8x credits. In this case, a trade with NPS1 would meet the water-quality target (> x actual delivered reduction) whereas a trade with NPS2 would not result in sufficient pollutant load reduction to meet the target (< x actual delivered reduction). This case demonstrates that utilizing a fixed TR might risk making a trade that results in insufficient load reduction.

In contrast, if a float TR system is implemented in a watershed, a set of TRs that retain the 2:1 factor of safety might be 2.5:1 for NPS1 and 5:1 for NPS2. Due to variant TR including in-field load reduction uncertainty and in-stream delivery attenuation effects, the actual delivered reduction for both NPS1 and NPS2 would be similar. Therefore, the PS would be required to purchase 2.5x credits from NPS1 or 5x credits from NPS2 according to their individual TRs.

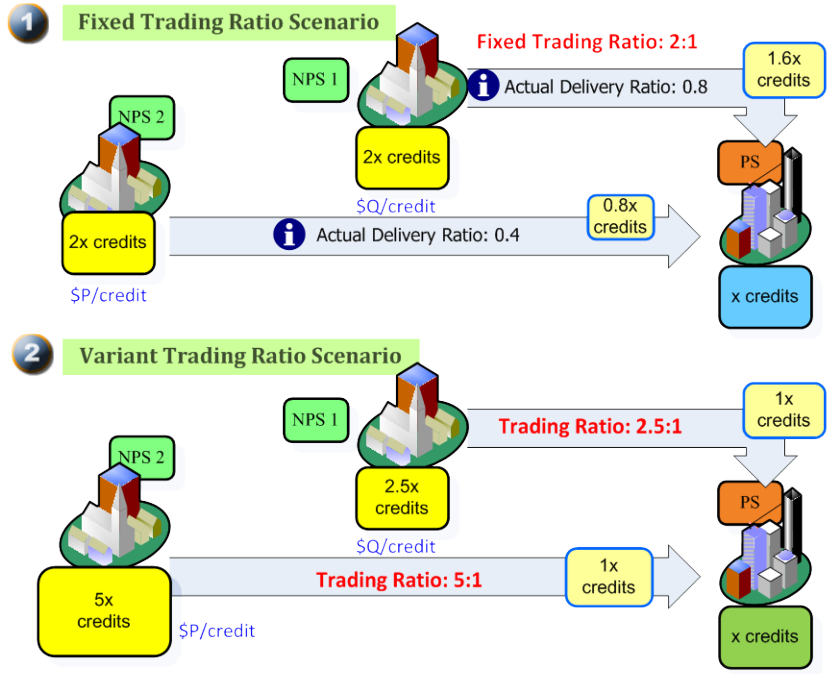


Figure 2-3 Fixed and Variant TR Scenario

2.2.1.5 *Limitation of WQT Program*

WQT might provide a policy option for reducing pollution with less cost while also achieving TMDL targets (Kerr et al., 2000; King and Kuch, 2003; Wood and Bernknopf, 2003; King, 2005). However, it is not an all purposes solution and not a panacea for pollution abatement in a watershed. Indeed, WQT is not a substitute for the regulatory framework and also not a way of letting polluters avoid their full responsibility (USEPA, 2004). Moreover, the theory of WQT is based on several hypotheses. If one of these hypotheses cannot be true or be consistent, the trade will not be allowed even if the NPS reduction cost is significantly less than the PS cost.

The first concern of a WQT program is the participants. Creating an effective trading market for WQT requires sufficient stakeholders who voluntarily participate and are willing to trade. Because NPS pollution is unregulated under the Clean Water Act (Hoag and Hughes-Popp, 1997), any water quality improving strategy targeting NPSs should involve voluntary efforts coupled with existing state and federal programs aimed at pollution control (KDHE, 2004). Sufficient traders in market program are the key to keep market operating (Nelson and Keeler, 2005). In a prior research of WQT in Middle Kansas watershed, Smith (2004) used more than 500 hypothetical NPSs and 50 PSs to simulate the WQT processes. Another major concern with a WQT program is the need for supervision to guarantee that water quality has been improved. A justice organization is needed to summarize trading information, verify agreements, monitor implementation, and evaluate the trading results. Unfortunately, this type of organization is hard to find outside a government structure.

The last concern of WQT is the trading objectives. Not all kinds of water pollutants are eligible for WQT. EPA suggests only four types of suitable pollutant to trade: nitrogen, phosphorus, sediment, and temperature (USEPA, 2004). This does not mean only these four types of pollutant can be traded, but it indicates that the other pollutants, such as highly toxic heavy metal or bacteria, might not be suitable for some types of trading scenarios. The environmental fate and transport uncertainty of other NPS pollutants will require more studies to ensure the trading activities can improve water quality (USEPA, 2004). Nelson and Keeler (2005) also pointed out uncertainty is the major barrier that limits trading programs from developing accurate results.

2.2.2 Analysis of PS and NPS Load

The design of a WQT program requires sufficient knowledge and understanding of the targeted pollutant in the given watershed (Kerr et al., 2000). The candidate pollutants (for example, TN or TP) might be produced from either PS or NPS, but may impact a watershed differently depending on the pollutant origins, discharge timing, or the pollutant fate and transport (Wood and Bernknopf, 2003). Most of time, PSs discharge a relatively consistent concentration of effluents. Its total pollutant load depends on the amount of inflow wastewater concentration and flow rate, and treatment dynamics. Daily PS pollutant loads are relatively constant except for flow situations with excessive flows resulting in temporary by-pass operation. In contrast, NPS pollution, a by-product of storm water runoff, is event-based with widely varying daily pollutant loads. The amount of NPS load depends on the climate condition, precipitation amount and timing, soil factors, topographic factors, and landcover at the time of surface runoff produced.

Figure 2-4 demonstrates a hypothetical example of a daily pollutant loads for both PS and NPS in a watershed. In Figure 2-4, the two bluish curves represent the daily loads of PS with (1) current facilities and (2) upgraded technology. The reddish curves illustrate the daily potential loads of NPS with (3) current land management practice and (4) an alternative land management method. Comparing the curves (1) and (2) to curves (3) and (4), PS pollutant loads have a relative constant trend. In contrast, NPS loads have a variant trend that is similar to the rainfall pattern in this watershed area. The blue area below curve (1) and curve (2) to the X-axis represents the annual PS pollutant load. The potential annual load reduction for PS implementing new technology is the area between curve (1) and curve (2). Likewise the area below curve (3) and curve (4) to the X-axis represents the annual NPS pollutant load with current land management practice and with an alternative practice. The potential annual load reduction for NPS utilizing alternative management practice is the area between curve (3) and curve (4).

Defining L as the annual pollutant load, the daily PS and NPS loads can be described as a function of time P(t) and N(t), respectively. Hence, the annual pollutant load for any PS (L_{PS}) and NPS (L_{NPS}) will be described as the Integrals of the daily function P(t) and N(t) as Eq. 2-1. The potential pollutant load reduction between current status and alternative scenario for PS and NPS will be the area between the two curves, which will equal the integrals of the difference between the two daily functions. Assuming current status pollutant load function is $P_1(t)$ and alternative method is $P_2(t)$ for PS as well as $N_1(t)$ and $N_2(t)$ for NPS, the relationship between annual load reduction and daily load function can be derived as Eq. 2-2.

$$L_{PS} = \int_1^{365} P(t)dt \quad L_{NPS} = \int_1^{365} N(t)dt \qquad \text{Eq. 2-1}$$

$$L'_{PS} = \int_1^{365} (P_1(t) - P_2(t))dt \quad L'_{NPS} = \int_1^{365} (N_1(t) - N_2(t))dt \qquad \text{Eq. 2-2}$$

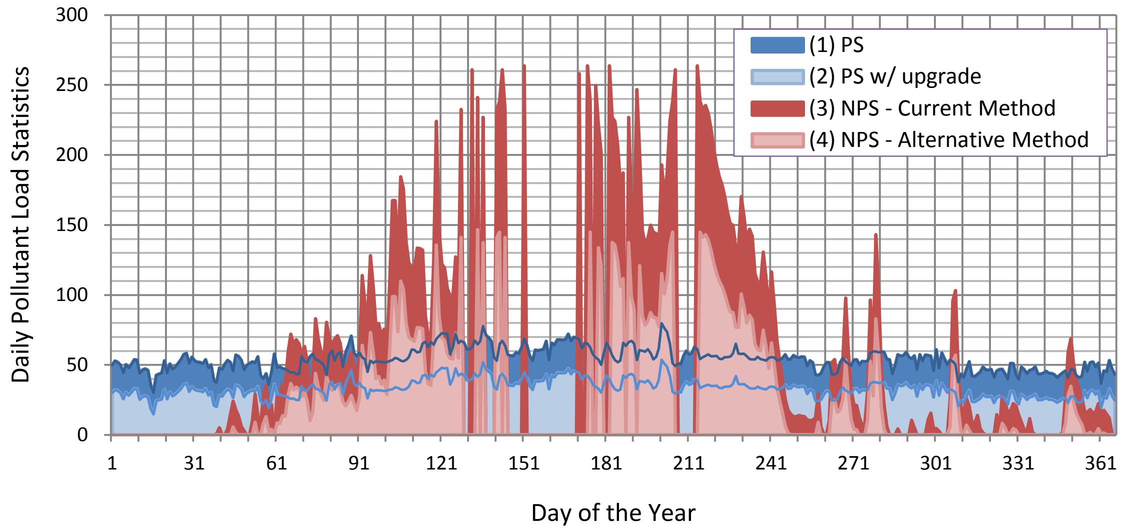


Figure 2-4 Hypothetical example of Daily Pollutant Loads for PS and NPS

As previously discussed, a WWTP with advanced technology or improved facilities can directly reduce pollution, whereas implementing alternative land management practices on the field might result in less reliable results. In addition to the differences of measurement scale and pollution origins, discharging locations may also impact potential load reductions since the pollutant load transport effect for a trade between PS and NPS could be substantial. Figure 2-5 illustrates probability of exceedance curves for daily PS pollutant loads with a current NPDES requirement versus an example new NPDES requirement. Both curves are smooth and slightly inclined in the middle of chart and steeper at both ends. The area between two curves represents the load reduction requirement for PS when implementing the example new NPDES requirement. In contrast, the probability of exceedance versus NPS annual load curves shown in Figure 2-6 are not smooth and have a very steep trend around 0% probability of exceedance but relatively flat response around 100%. Moreover, the delivered NPS loads have smaller amount than in-field load with similar overall trend to the in-field curves.

The area between the two curves represents the potential load reduction. Thus, block (a) in Figure 2-6 represents the potential delivered loss for current NPS load and block (c) represents NPS load “w/ BMP”. The potential in-field load reduction between current and “w/ BMP” scenario is the total area of block (a) plus block (b); the potential delivered load reduction between current and “w/ BMP” scenario is equal to the area of block (b) plus block (c).

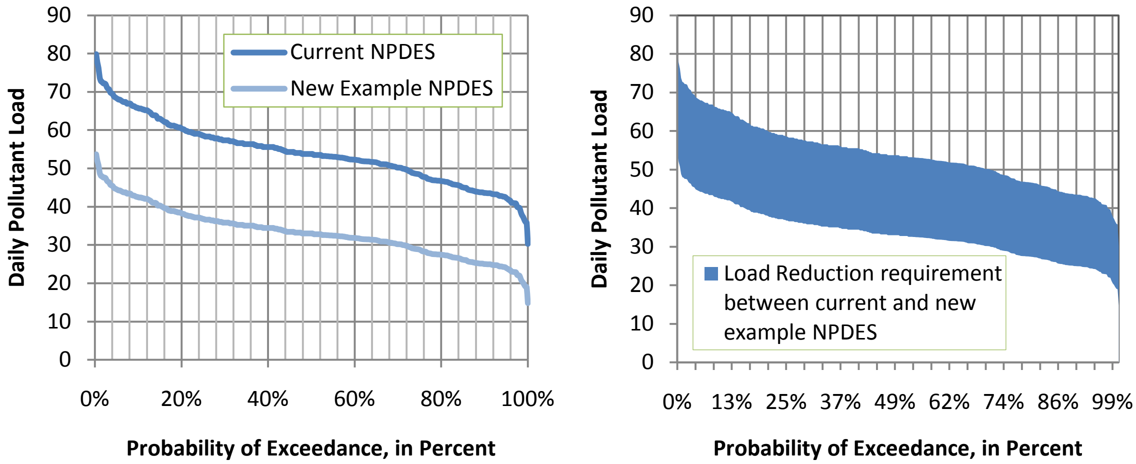


Figure 2-5 Hypothetical Probability of Exceedance Curve for PS Annual Loads

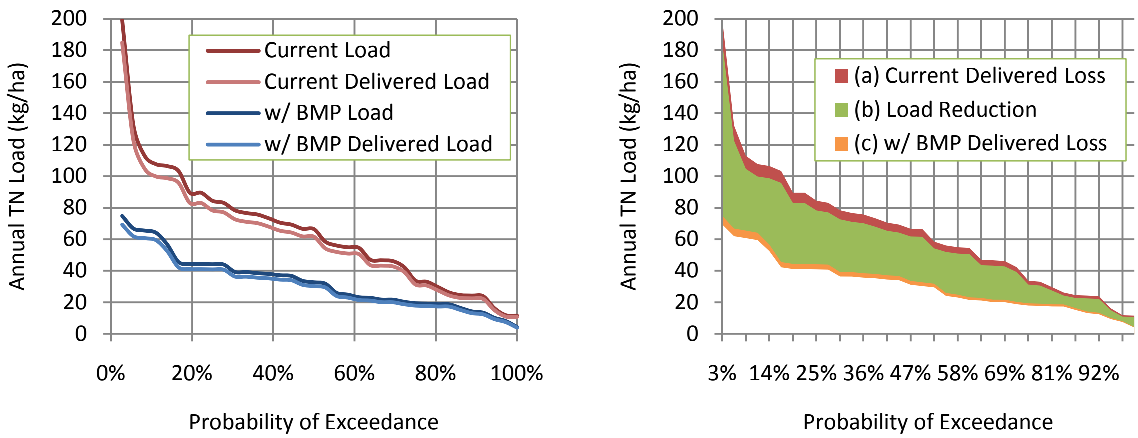


Figure 2-6 Hypothetical Probability of Exceedance Curve for NPS Annual Loads

In order to calculate more precise total maximum loads of a river for a period of time, the discharge data interval should be some fraction of the summary interval. For example, calculating a total maximum daily loads, the suitable time interval for data acquiring is in sub-daily, e.g., hourly or half-hourly. Figure 2-7 illustrates the similar curves and block areas as Figure 2-6, but uses a different time interval. Using decreased data time interval in Figure 2-7 results in capturing more detail in reach information. In contrast, the coarse data time interval used in Figure 2-6 results in a single value being assigned to represent the summation or average for the period of time; extreme values might be truncated or leveled. In practice, the time intervals for PS data may not be an issue. PS has relative constant load yield and load reduction between alternative methods. However, a suitable time interval for NPS will be a critical issue in analyzing its potential load reduction.

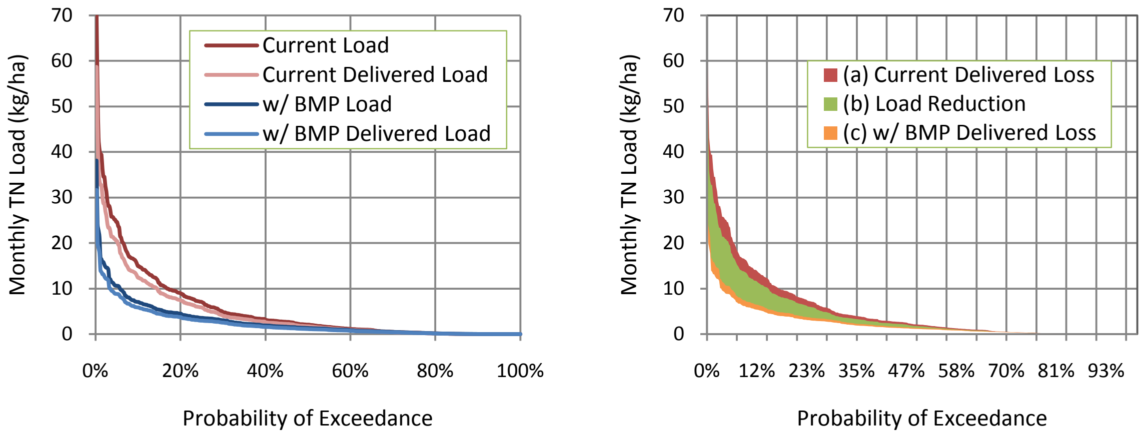


Figure 2-7 Hypothetical Probability of Exceedance Curve for NPS Monthly Load Reduction

Comparing the loads between PS and NPS in Figure 2-8, block (1) represents the reduction requirement for PS with a new regulation, block (a) plus block (b) represent the total load reduction for NPS with alternative BMP, and block (b) plus block (c) represent the load in delivered scenario. The vertical line (I) indicates an exceeding percentage of time for both current NPS load and current PS load. Right of line (I), NPS would not produce as much pollutant load as PS does; left of line (I), NPS might produce more pollutant load than PS. In other words, the line (I) indicates the percentage of time that PS load will equal to NPS load. If accounting for the pollutant load delivery effects, line (II) will be the new indicator where frequency of delivered PS load will equal delivered NPS load. The area between delivered current (a) and alternative (c) loading curves concerns WQT

Figure 2-8 also shows that 90% confidence is achieved with very different PS or NPS loads. The PS load reduction with 10% probability of exceedance would be the part of block (1) right of line (III) whereas the delivered NPS load reduction would be the total area of block (b) and block (c) right of line (III). The TR can be defined as a ratio of the area of NPS (b+c) to the area of PS (1), which can be represented mathematically by series integrals of both PS and NPS loading functions.

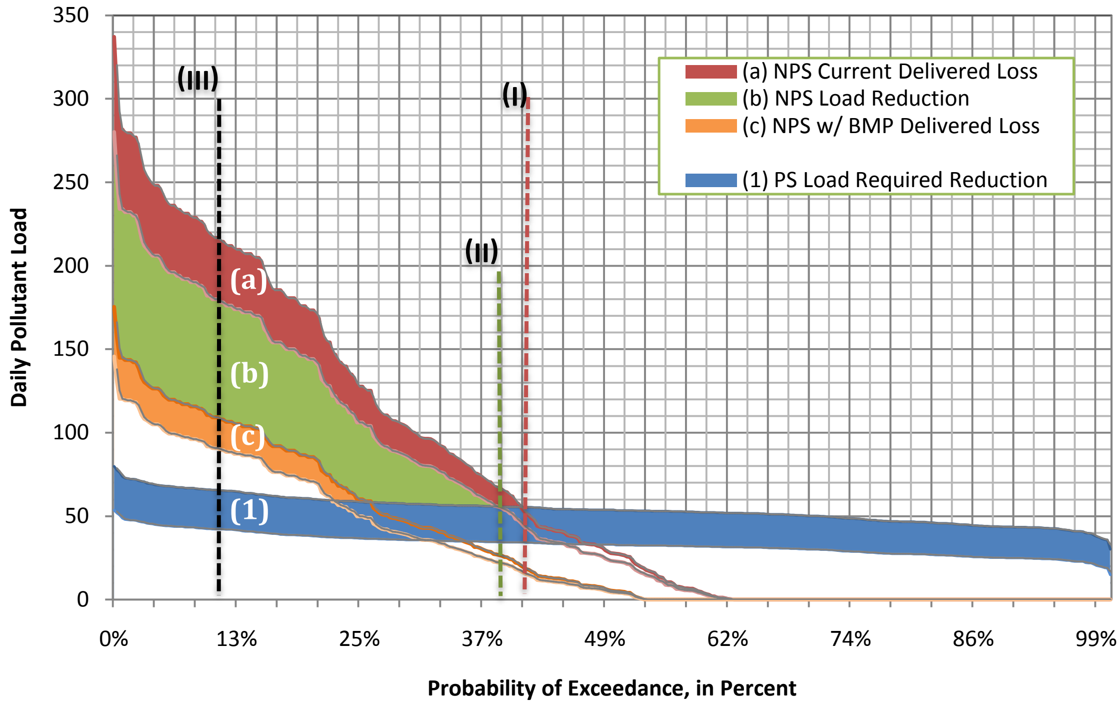


Figure 2-8 Hypothetical Potential Pollutant Load Reductions between PS and NPS

Some skeptics may criticize WQT because equivalence between PS and NPS loads is not achievable. Indeed, PS and NPS loads have different origins and properties. Directly comparing the daily pollutant load from these two sources does not make any sense. However, WQT may be more appropriate when focused on the potential load reductions between alternative scenarios for a longer period of time rather than the absolute, daily pollutant loads of each scenario. Another challenge is that there exist different chemical forms of pollutants such as nitrogen and phosphorus in effluents. However, because transformations from one form to another occur, WQT programs typically focus on the TN or TP, including elemental equivalents of all types or forms of nutrient in discharges.

2.2.3 Uncertainty of Water Quality Trading

WQT is a market-based approach to improve water quality. The ideas were modified from the market structure of air emission trading program. Several key elements have led to successful air emission trading programs. The size of trading market must be large enough to supply the environmental credits adequate to meet the load reductions sought by buyers (Rowles, 2005). Motivation of a trading market is based on having a large number of pollution sources willing to trade and a large disparity in the costs of pollution reduction among these sources. For example, the total cost for an agricultural producer to implement agricultural best management practices (BMPs), an alternative operational land management procedure or installing certain structural remedies, is smaller than the total costs of reducing the same amount of pollutants by installing expensive, complex industrial pollution control technologies. The program pricing method, fixed TR and an applicable model also affected stakeholders' willingness to participate in a trading program. Hoag and Hughes-Popp (1997) pointed out improving trading processes and methods of simulating trading results are the keys for success trading programs.

The uncertainties among the trading processes and methods are varied. For environmental processes, the uncertainties may include variations in pollutant loads among fields, pollutant attenuation during transport in a stream network, sedimentation in lake, multi-pollutant interactions, and/or spatiotemporal variation due to watershed/precipitation heterogeneities. In economics, the uncertainties might include the structures of trading market, stakeholders' willingness, life span of BMPs, operation and maintenance costs, government policy, water quality standard and regulation, and the other intangible costs of WQT. In a traditional approach, these sources of uncertainties can be easily identified but cannot clearly be quantified (Curley, 2003). Therefore, some WQT research categorized all uncertainties as one of the transaction costs (Curley, 2003; Jones et al., 2005). In fact, all of the uncertainties discussed before are mainly related to pollutant sources and trading market structures. Woodward and Kaiser (2002) defined the transaction coast as following types: search and information, bargaining and decision, monitoring and enforcement, and transportation and setup. EPA WQT assessment handbook (USEPA, 2004) gave the following definition for the transaction cost: "the (transaction) costs represent all the resources needed to implement the trade, including information gathering, negotiation, execution, and monitoring". A method to separate uncertainties from traditional transaction cost approach is urged.

Another element of WQT related to uncertainties is the trading credit and its price. EPA WQT assessment handbook (USEPA, 2004) incorporated the uncertainty with control cost for NPS. That means the amount for credits will be based on the demand of PS. The total amount of credits needed by PS is a constant within a trade, no matter where the credits provider (in this case, the NPS) is located. The cost for each credit is calculated from the NPS's characteristics - location, uncertainty, or TRs. The EPA method is easy to understand for a PS, but would be complex for a NPS. If a NPS trades the same amount of pollutant load reduction to a different PS, the amount and price for selling credits are different. Hence, the cost for each credit of NPS can be redefined as the share of NPS land management practice implementation costs plus an intangible transaction cost of information disclosure. The price of a tradable credit from different agricultural producers may vary, but it will be fixed for any buyer.

In order to address the uncertainties in a WQT program, the NPS load reduction to be traded will include two components: the load reduction at the edge of the field, expressed as an average with a certain statistical distribution, and the delivered effects of pollutant load defined by the natural pollutant attenuation and deposition phenomena in the stream network between seller and buyer. The TR will then be defined as an index addressing the uncertainties of both the pollutant load reduction at the edge of field and the loss of load transported in stream network. Analysis of the uncertainties for these two components will be discussed in following sections.

2.2.4 Environmental Equivalents of WQT

The distribution of NPS pollutant reduction will be simplified as a normal distribution (a curve) and the required abatement of PS will be assumed to be a constant (a vertical line). The ideal match point between PS and NPS would be located on the mean of NPS reduction distribution curve, shown as a red line in Figure 2-9. To minimize the trading risks, it is necessary either to increase the purchased amount or to decrease the effective load reduction from NPS. This can be represented by shifting the intersection of the PS line and NPS curve to the left of NPS mean, as shown by the black line in Figure 2-9. This shift implies that a lower PS load (in this case, 700 kg) is equivalent to a given NPS load (1000 kg) at a higher confidence (lower risk) level.

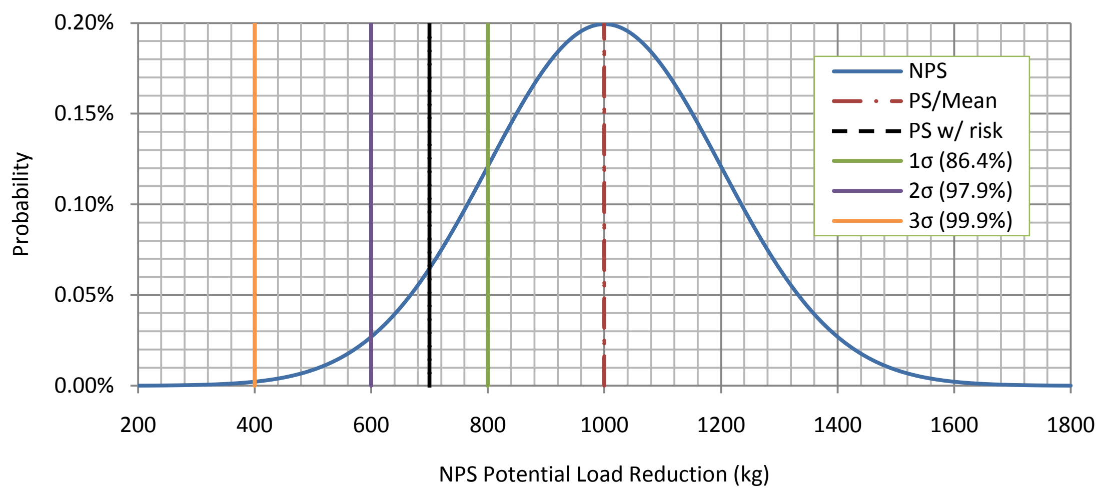


Figure 2-9 Hypothetical Potential Pollutant Load Reduction Distribution Curves for NPS

The area below the NPS curve to the X-axis and between PS line and Y-axis is the total probability of failure for a PS-NPS trade. Once the distribution of load reduction is found, it would be easy to estimate the TR with given confidence level or find the confidence level from given load reduction threshold. For example, the area below a normal distribution curve and right of mean value minus one standard deviation ($\mu - \sigma$) line would represent an 86.4% confidence level. Furthermore, the area for mean minus two standard deviations ($\mu - 2\sigma$) represents 97.9% confidence level, and mean minus three standard deviations ($\mu - 3\sigma$) represents 99.9% confidence level. The X-axis values for each intersection represent the trading results of potential load reduction at that confidence level. For instance, assuming NPS load reduction mean is equal to 1000 kg and standard deviation is 200 kg, for mean minus one standard deviation confidence, the trading results are 800 kg. That means when purchasing 1000 kg load reduction from NPS, at least 800 kg are effective under one standard deviation or 86.4% confidence level. In other words, NPS has a confidence of providing at least 800 kg load reduction to PS for 86.4% of the time. The TR, also known as Environmental Equivalent Ratio (USEPA, 2004), can then be defined as the purchased amount divided by effective amount of pollutant load reduction. For the 86.4% confidence case (Figure 2-9), the TR would be 1000/800 = 1.25.

2.2.4.1 *Pollutant Load Reduction and Trading Ratio*

In WQT, TRs are used to calculate the equivalence of load reductions to compensate the trading uncertainty between different pollutant sources based on their physical characteristics, land management practices, multi-pollutant cross-effects, and the other spatiotemporal influences within trading partners. It could be treated as an exchange rate that establishes equivalence among trading partners who may have different measures and baselines of the pollutant load. TRs are also used to ensure that the equivalence of trades can be achieved at a specific confidence level. Traditionally, fixed, universal TRs (commonly 2:1) used in WQT programs intended to provide a 'safety' factor for the empirical method of trading result estimation. However, this artificial level may force a trade to be operated under an unreasonable confidence level, which might require a PS to purchase more credits from NPS than needed and with higher total cost. Alternatively, a variable, floating TR system, based on the pollutant load reduction uncertainty and watershed spatiotemporal variation, can provide a matrix of TRs for each scenario and geographical location. A fixed TR gives a simple solution for WQT, but a floating TR provides more accurate information upon which to define the trade.

There are several definitions for TRs from both environmental and economic perspectives. Jones et al. (2005) suggested the TR should include five elements: uncertainty ratio, delivery ratio, water-quality ratio, retirement ratio, and cross-pollutant ratio. CTIC (2006) defined TR as a ratio that accounts for distance between trading partners (delivery ratio) and the uncertainty associated with practice effectiveness for specific pollutant load reduction (uncertainty ratio). It also needs to be adjusted with the baseline deduction and seasonal variability. Among these elements of TR, the complex interactions among some forms of pollutants may be handled with a watershed model, which estimates the overall pollutant responses for each pollutant. If interactions are already addressed by the model, it would be unnecessary to address this element separately in calculating TR. The intent of retirement ratio is addressing the decline of BMP effectiveness, the life span, and operation and maintenance cost for BMPs renovation. The effectiveness of BMP renovation could be included in the BMP cost category. The purpose of water quality ratio is obscure and could artificially limit a trade. Baseline deduction, which was suggested by CTIC (2006) as the prerequisite that must be met before a seller can sell their extra credits, is a constant threshold or "tax amount" that does not involve uncertainty. In practice, some consider the baseline deduction as unfair for the seller and has not been required in most WQT programs. From an engineering perspective, WQT TR can be separated into an in-field uncertainty ratio and an in-stream delivery ratio, which can be derived from the probability distributions of pollutant load reductions using sound, scientific watershed model and GIS techniques.

Assuming P_{LMP1} is the annual pollutant load from current land management practice (LMP_1) and P_{LMP2} is the annual pollutant load from an alternative land management practice (LMP_2), the annual pollutant load reduction between LMP_1 and LMP_2 is (P_{LMP1} - P_{LMP2}). Due to environmental uncertainty within the watershed, the pollutant load reduction of each year might be different. If $P_{AVG(1-2)}$ is the mean value of n years of pollutant load reduction for the land management practice changing from LMP_1 to LMP_2, $P_{AVG(1-2)}$ would be equal to the weighted average of all annual load reductions as Eq. 2-3. If current land management practice is used as a baseline scenario, the pollutant load reduction for reach baseline-alternative scenario can be explained as the relative pollutant load reduction index, or BMP reduction efficiency factor ($BMP_{R(b-*)}$), where the "b" represents the baseline scenario and the "*" could be any other potential alternative land management practice which is applied on the field. Assuming current land management practice as LMP_1 and an alternative practice as LMP_2, Eq. 2-4 describes the relationship of $BMP_{R(1-2)}$, the relative pollutant load reduction index between P_{LMP1} and P_{LMP2}.

$$P_{AVG(1-2} = \frac{1}{n}\sum_{i=1}^{n} w_i\left(P_{LMP_1} - P_{LMP_2}\right)_i \qquad \text{Eq. 2-3}$$

$$BMP_{R(1-2)} = \frac{1}{n}\sum_{i=1}^{n} \frac{w_i\left(P_{LMP_1} - P_{LMP_2}\right)_i}{P_{LMP_1}} \qquad \text{Eq. 2-4}$$

If there is no any prerequisite required by WQT program, such as baseline deduction of tradable load reduction, and the unit for P_{LMP1} and P_{LMP2} is kilograms per hectare per year (kg/ha-yr), the nominal tradable load reduction at the edge of field of the seller (P_{NR}) can be expressed as Eq. 2-5 which is similar to $P_{AVG\,(1-2)}$ in Eq. 2-4.

$$P_{NR} = P_{LMP_1} \times BMP_{R(1-2)} \cong P_{AVG(1-2)} \quad \text{Eq. 2-5}$$

To account for the potential environmental uncertainty or trading risk of a trade, two ratios, uncertainty ratio for in-field pollutant load reduction (R_U) and delivery ratio for in-stream load reduction attenuation (R_D), are developed to explain the uncertainty due to land management practice or in-stream transport. Furthermore, the in-field R_U is defined as the potential deviation of pollutant load reduction due to the uncertainty at specific confidence level divided by the arithmetic mean of all load reductions. For a general case, the R_U should range from 0 to 1. For the special cases, when R_U is equal to 0, there is no potential deviation of load reduction. In contrast, if R_U is equal to 1, the potential load reduction deviation is equal to its mean, which represents a non recommended scenario with an extremely high uncertainty. Moreover, the in-stream R_D is defined as the outflow pollutant load divided by the inflow load one within a watershed or a river section. For a general case, the R_D also ranges from 0 to 1. For some extreme cases, when R_D is equal to 0, there is no outflow pollutant load. This may imply all the pollutant load will settle upon that watershed or river section. If R_D is equal to 1, the entire inflow pollutant load will be completely transported to the outlet without any attenuation or degradation. Thus the actual pollutant load reduction (P_{AR}) transported from upstream seller to downstream buyer is revised using Eq. 2-6, in which both R_D and R_U imply the spatial variation and potential temporal variances of a trade.

$$P_{AR} = P_{LMP_1} \times BMP_{R(1-2)} \times (1 - R_U)R_D \cong P_{AVG(1-2)} \times (1 - R_U)R_D \quad \text{Eq. 2-6}$$

As described previously, a TR is the exchange rate to maintain the pollutant load reduction equivalence between seller and buyer of a trade. It can be explained as the nominal tradable load reduction (P_{NR}) divided by actual pollutant load reduction (P_{AR}). Therefore, a TR can be simplified as a function of in-field R_U, and in-stream R_D as Eq. 2-7.

$$\begin{aligned} TR &= \frac{\textit{In Field Load Reduction}}{\textit{Delivered Load Reduction}} = \frac{P_{NR}}{P_{AR}} = \frac{P_{LMP_1} \times BMP_{R(1-2)}}{P_{LMP_1} \times BMP_{R(1-2)} \times (1 - R_U)R_D} \\ &\cong \frac{P_{AVG\,(1-2)}}{P_{AVG\,(1-2)} \times (1 - R_U)R_D} = \frac{1}{(1 - R_U)R_D} \end{aligned} \quad \text{Eq. 2-7}$$

2.2.4.2 *In-Field Uncertainty Ratio*

To quantify the uncertainty of in-field pollutant load reduction, the load reduction between current and alternative land management practice must be defined. If the load reduction between current and alternative method is not significant, the change in land management practice will not produce a significant difference of pollutant load, which implies that the alternative method would not be a tradable option. Even if the load reduction is statistically significant, it should be positive to be beneficial to the environmental. A method should also assess and quantify the probability associated with in-field load reduction uncertainty. Based on statistical theory (e.g., t-test) with given confidence level, the R_U then can be derived to address the degree of difference among alternatives.

If the current land management practice is LMP_1 and alternative land management practice is LMP_2, the average of in-field pollutant load for LMP_1 and LMP_2, or the statistical sample mean for LMP_1 and LMP_2, can be derived as $\bar{X}_1$ and $\bar{X}_2$ in Eq. 2-8, respectively. Similarly, the estimated sample variances for both LMP_1 and LMP_2 are S_1^2 and S_2^2 which can be derived with Bessel's correction as described in Eq. 2-9 from a series of sampled pollutant load with n observations. In order to simplify the research question in statistical analyses, each sampled pollutant load of LMP_1 and LMP_2 is assumed to be statistically independent with an unknown variance, which may or may not be equal to each other.

$$\bar{X}_1 = \frac{1}{n}\sum_{i=1}^{n} x_{1_i} \quad \bar{X}_2 = \frac{1}{n}\sum_{i=1}^{n} x_{2_i} \qquad \text{Eq. 2-8}$$

$$S_1^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_{1_i} - \bar{X}_1\right)^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_{1_i}\right)^2 - \frac{1}{n(n-1)}\left(\sum_{i=1}^{n} x_{1_i}\right)^2$$
$$S_2^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_{2_i} - \bar{X}_2\right)^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_{2_i}\right)^2 - \frac{1}{n(n-1)}\left(\sum_{i=1}^{n} x_{2_i}\right)^2 \qquad \text{Eq. 2-9}$$

The t-test is a statistical hypothesis test which tests the null hypothesis that the means of two normally distributed populations are equal. The original Student's t-test procedures are performed for two series of pollutant load observations (LMP_1 and LMP_2), which are assumed to have normal distributions with equal variances. The different versions of the t test for two series of observations with unknown variance, which is also named as Behrens-Fisher Problem, were developed as Welch's t-test or Welch's approximate t solution (Welch, 1947; Wang, 1971). Paired or unpaired methods are used for two series of pollutant load observations if they are independent (unpaired) or not (paired). The unpaired observations t-test determines if the mean of the first series of observations is equal or not equal to the mean of the second series observations. In contrast, the paired observations t-test determines if the mean value of differences between each pair observations is equal or not. In other words, unpaired t-test tests the equality of the mean of two groups load observations, but paired t-test tests if the mean of the series of load reductions is equal to zero (SAS Institute Inc., 2004).

Based on the original Student's t-test theory with the assumption of variances of the two populations may or may not be equal, the Welch's t-test method is used for testing the sampled pollutant load of LMP_1 and LMP_2 in either paired (dependent) or unpaired (independent) scenario. The null hypothesis (H_0) for testing load differences between two series of observations is $\mu_1 - \mu_2 = 0$, where μ_1 and μ_2 are the population means of pollutant load of LMP_1 and LMP_2. Eq. 2-10 describes the t-test problem for the paired observations with a null hypothesis that the mean of a load reduction distributed population is zero. This is also similar to the original Student's t-test equation. In Eq. 2-10, the $\bar{X}_d$ and S_d represent the sample mean and standard deviation for the differences of each pair observation (SAS Institute Inc., 2004). For the unpaired observations scenario, n_1 and n_2 are assumed to be the number of pollutant load observations randomly sampled from normally distributed LMP_1 and LMP_2. The population variance σ_1^2 (LMP_1) and σ_2^2 (LMP_2) are unknown and may not be equal to each other, this testing scenario is referred to as the Behrens-Fisher (B-F) problem (Lauer and Han, 1974). Under these assumptions, the approximate statistic t can be computed with Eq. 2-11, which is Welch's approximate t solution (Welch, 1947; Wang, 1971). The effective degrees of freedom ν associated with this linear combination of sample variance estimates (S_1^2 and S_2^2) is approximated using the Welch-Satterthwaite method as Eq. 2-12 (Satterthwaite, 1946; SAS Institute Inc., 2004).

The p-value is obtained as the probability that a result at least as extreme as the one that was actually observed, assuming that the null hypothesis, the statistical means of two series of sampled pollutant load are equal, is true. If the calculated p-value is below the threshold chosen for statistical significance (usually the 0.10, or 0.05 confidence level), then the null hypothesis, which states that the means of two series of pollutant load do not differ, is rejected in favor of an alternative hypothesis, which states that the means do differ. For a watershed pollutant load study, assuming two series of observations are independent, the unpaired method can be applied to analyze the relationship between current and alternative land management practice. Conversely, if every set of observations of two pollutant load series has a unique relationship, such as with precipitation or temperature at that time step, it can be considered dependent. Therefore, the paired analysis method will be used to discuss the relationship between current and alternative options.

$$t = \frac{\bar{X}_d - \mu_0}{\frac{S_d}{\sqrt{n}}} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(x_{1_i} - x_{2_i}\right) - 0}{\frac{S_d}{\sqrt{n}}} \quad \text{Eq. 2-10}$$

$$t' = \frac{\bar{X}_i - \bar{X}_j - \mu_0}{\sqrt{\frac{S_i^2}{n_i} + \frac{S_j^2}{n_j}}} = \frac{\bar{X}_1 - \bar{X}_2 - 0}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad \text{Eq. 2-11}$$

$$\nu = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{\left(\frac{S_1^2}{n_1}\right)^2}{(n_1 - 1)} + \frac{\left(\frac{S_2^2}{n_2}\right)^2}{(n_2 - 1)}} = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1 - 1)} + \frac{S_2^4}{n_2^2(n_2 - 1)}} \quad \text{Eq. 2-12}$$

When the statistical mean of sampled pollutant loads of LMP_1 and LMP_2 is not statistically equal, in other words, the pollutant load difference between LMP_1 and LMP_2 is statistically significant, the mean of pollutant load differences between LMP_1 and LMP_2 with n observations can be expressed as $P_{AVG\,(1-2)}$ with Eq. 2-13. Eq. 2-13 represents the potential load reduction for changing the land management practice from LMP_1 to LMP_2. The relative pollutant load reduction index, or BMP reduction efficiency factor ($BMP_{R(1-2)}$), which was described in Eq. 2-4, can be rewritten as Eq. 2-14 with $\bar{X}_1$ and $\bar{X}_2$.

$$P_{AVG(1-2)} = (\bar{X}_1 - \bar{X}_2) \quad \text{Eq. 2-13}$$

$$BMP_{R(1-2)} = \frac{(\bar{X}_1 - \bar{X}_2)}{\bar{X}_1} = \frac{P_{AVG(1-2)}}{\bar{X}_1} \quad \text{Eq. 2-14}$$

Assuming α is type I error in the statistical analysis, the approximate 100(1-α) % confidence interval (CI) for paired observations of pollutant load reduction can be derived as Eq. 2-15 with its mean ($\bar{X}_d$) and standard deviation (S_d). For unpaired observations scenario, with the mean of LMP_1 and LMP_2 ($\bar{X}_1$ and $\bar{X}_2$), their variance (S_1^2 and S_2^2), and the number of observations (n_1 and n_2), the confidence interval (CI) can be explained as Eq. 2-16. Both Eq. 2-15 and Eq. 2-16 are good to estimate the confidence interval and its lower or higher bound limits. For studying the probability of pollutant overload cases, only the lower bound limit is interested. Therefore, Eq. 2-15 can be rewritten as lower bound limit equations as Eq. 2-17 for paired analysis and Eq. 2-16 as Eq. 2-18 for unpaired analysis. An effective pollutant load reduction of WQT infers a potential positive load reduction from a trade. Hence, the confidence limits in Eq. 2-17 and Eq. 2-18 need to be greater than zero to support a potential WQT case.

$$CI(\bar{X}_d) = \bar{X}_d \pm t_{(1-\frac{\alpha}{2}),\nu} \cdot \frac{S_d}{\sqrt{n}} \quad \text{Eq. 2-15}$$

$$CI(\mu_1 - \mu_2) = \bar{X}_1 - \bar{X}_2 \pm t_{(1-\frac{\alpha}{2}),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \qquad \text{Eq. 2-16}$$

$$CI_L(\bar{X}_d) = \bar{X}_d - t_{(1-\alpha),v} \cdot \frac{S_d}{\sqrt{n}} \qquad \text{Eq. 2-17}$$

$$CI_L(\mu_1 - \mu_2) = \bar{X}_1 - \bar{X}_2 - t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \qquad \text{Eq. 2-18}$$

With lower bound confidence limit at 100(1-α) % confidence level equations described as Eq. 2-17 and Eq. 2-18, the magnitude of load reduction uncertainty can be described as the observations deviated from the mean of potential load reduction. Thus, the potential magnitude of uncertainty or the observed load reduction deviation at 100(1-α) % confidence level can be explained as a deviation radius (D_R) as Eq. 2-19 for paired and Eq. 2-20 for unpaired scenarios. Furthermore in statistics, the same distribution about a larger mean value produces a larger standard deviation. Therefore, in order to compare the magnitude of potential uncertainty of pollutant load reduction or the D_R of baseline scenario within several alternative methods, the absolute value is often transformed into relative form. To formulate this transformation of D_R, Eq. 2-19 and Eq. 2-20 can be divided by its mean as the relative D_R. This process is similar to utilizing the relative standard deviation (RSD) or coefficient of variation (CV) to compare the variations among several series of observations. Therefore, the R_U is defined as the relative D_R. Eq. 2-21 formulate R_U at 100(1-α) % confidence level with the mean of load reduction ($\bar{X}_d$), standard deviation (S_d), and the number of observations (n) for paired scenario. Similarly, Eq. 2-22 formulate R_U at 100(1-α) % confidence level with the mean of load reduction ($\bar{X}_1 - \bar{X}_2$), variance (S_1^2 and S_2^2), and the number of observations (n_1 and n_2) for unpaired scenario.

$$D_R = t_{(1-\alpha),v} \cdot \frac{S_d}{\sqrt{n}} \qquad \text{Eq. 2-19}$$

$$D_R = t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \qquad \text{Eq. 2-20}$$

$$R_U = Relative\ D_R = \frac{t_{(1-\alpha),v} \cdot \frac{S_d}{\sqrt{n}}}{\bar{X}_d} \qquad \text{Eq. 2-21}$$

$$R_U = Relative\ D_R = \frac{t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}{\bar{X}_1 - \bar{X}_2} \qquad \text{Eq. 2-22}$$

As mentioned previously, a trade with a potential positive load reduction implies an effective WQT case. That means the primary assumption for Eq. 2-21 and Eq. 2-22 is that $\bar{X}_d$ and $\bar{X}_1 - \bar{X}_2$ need to be greater than zero to derive a meaningful R_U. With the definition of sample standard deviation (S) in Eq. 2-9, the R_U in Eq. 2-21 and Eq. 2-22 is always greater than or equal to zero as long as $t_{(1-\alpha),\nu}$.is greater than zero. For extreme cases, when the sample mean of load reduction is less than zero ($\bar{X}_d < 0$), R_U will be assigned as 0 to represent the potential water-quality trade for these cases are not applicable.

In a simplified WQT scenario, if the pollutant transport or delivery effect can be neglected, the potential load reduction or tradable environmental credits will only account for the uncertainty of in-field load reduction. Therefore, the R_D in Eq. 2-7 can be assumed as 1, and Eq. 2-7 can be rewritten as Eq. 2-23. In this simplified WQT scenario, TR is solely decided by in-field load reduction R_U; this TR is defined as in-field trading ratio (TR_{IF}).

$$TR_{IF} = \frac{1}{(1 - R_U) \cdot R_D} = \frac{1}{(1 - R_U) \cdot 1} = \frac{1}{(1 - R_U)} \qquad \text{Eq. 2-23}$$

2.2.4.3 *In-Stream Delivery Ratio*

If a watershed is large enough, the time of concentration for storm water would not be negligible. In other words, without any new source of pollutant, the amount of pollutant load at a stream reach inlet might not be equal to that at its outlet. Thus, in-stream nutrient load attenuation or degradation, pollutant deposition, natural assimilation and other delivery effects could be substantial. Pollutant load delivery effect is a gross term that describes the changes of pollutant load in stream and/or lake due to transport or detention effects. The in stream pollutant load attenuation and transport effect usually estimated with modeling works or monitoring data analysis. The delivery ratio (R_D) includes the both effects of pollutant load transported via stream network ($\prod R_{D_S}$) and the load detained in lake/reservoir ($\prod R_{D_L}$). Within an individual sub-watershed, the delivery ratio is defined as a ratio of the amount of pollutant load transported at the downstream sub-watershed outlet to the original amount of same pollutant load at the inlet as Eq. 2-24. The delivery ratio also can be defined as the ratio of the amount of pollutant load transported at the PS to its original amount of the load at edge of field from the NPS.

For a large watershed with a complex stream network, it usually is delineated into several subbasins, and the stream is divided into several sections for monitoring or modeling purposes. For connecting several stream sections or waterbodies, the delivery ratio for load transported from source to sink can be expressed as the product of all the individual R_D of each stream segment and lake/reservoir as Eq. 2-25. This TR is defined as an aggregated or cumulative delivery ratio (R_D^*).

$$R_{D_i} = \frac{N_{OUT_i}}{N_{IN_i}} \qquad \text{Eq. 2-24}$$

$$R_D^* = \prod_{i=1}^{n} R_{D_i} = \prod_{j=1}^{p} R_{D_{S_j}} \times \prod_{k=1}^{q} R_{D_{L_k}} \qquad \text{Eq. 2-25}$$

where:

R_D^* = Cumulative delivery ratio

R_{D_i} = individual delivery ratio within the ith waterbody. The i = 1 ~ n

$R_{D_{S_j}}$ = individual delivery ratio within the jth stream segment. The j = 1 ~ p

$R_{D_{L_k}}$ = individual delivery ratio within the kth lake. The k = 1 ~ q

If one only considers pollutant transport attenuation for the load reduction uncertainty of a trade, the potential load reduction or tradable environmental credits can be calculated based on the delivery effect in the stream. That means in Eq. 2-7, the R_U can be assumed as 0 and Eq. 2-7 can be revised as Eq. 2-26. TR for this scenario is solely decided by R_D in the water body (stream and/or lake), and it is defined as in-stream trading ratio (TR_{IS}).

$$TR_{IS} = \frac{1}{(1 - R_U) \cdot R_D} = \frac{1}{(1 - 0) \cdot R_D} = \frac{1}{R_D} \qquad \text{Eq. 2-26}$$

2.2.4.4 *Site-specific Effect*

Site-specific effects describe the differences in hydrologic responses due to the geospatial (location) and temporal (time scale) heterogeneity within a watershed. Different sub areas of a watershed with specific climate, soil types, land cover, and topography, may induce different hydrologic responses and generate varied soil erosion and pollutant loads. The major sources of surface runoff are rainfall precipitation and snow melt. Irrigation operations also could contribute to runoff. Surface runoff strongly influences soil erosion and pollutant loads. More surface runoff represents more opportunities to generate soil erosion and pollutant loads from a field. In Kansas, seasonal variability in hydrology and landcover might be quite substantial (Sophocleous, 1998). After crops mature, biomass on a field can construct a canopy over the field to reduce surface runoff and soil erosion. Other land-management factors, such as alternative land management practices on a field, might also produce distinct pollutant loads between wet and dry seasons as well as among individual months. In order to address the magnitude of generated loads on event-, monthly- or seasonal time periods, a watershed-scale model is required.

Site-specific effects can be addressed by delineating a watershed into smaller pieces in geospatial scale (such as by grouping hydrologic response units [HRUs] with similar soil, slope and land-cover characteristics) and dividing the modeling time step into shorter temporal scale. Each subbasin and HRU can be modeled individually to determine the specific pollutant load, load reduction, R_U and TR at each time step. The model simulations for each time step can be aggregated into a larger subbasin or longer time intervals.

In order to present and illustrate the potential site-specific effect in geospatial scale within a watershed, a geospatial application or GIS is a better solution than traditional tables and charts. Moreover, to address the site-specific effect in temporal scale, the idea of contribution factor (CF) can be used. The CF was used to define the nominal tradable load reduction at the edge of field for seller (P_{NR}) in Eq. 2-5. If the annual reduction is AP_{NR} and the reduction for a single season or month is SP_{NR}, the contribution factor (CF) for a specific month or season can be defined as a ratio of SP_{NR} to AP_{NR} as Eq. 2-27.

$$CF = \frac{Seasonal\ (monthly) Load\ Reduction}{Annual\ Load\ Reduction} = \frac{SP_{NR}}{AP_{NR}} \qquad \text{Eq. 2-27}$$

2.3 Model selection

Watershed models can be categorized as lumped or distributed models (Beven, 2001). Lumped models treat a watershed as a single unit and model water and chemical movement to the watershed outlet using effective parameters. Distributed models divide the watershed into several Hydrologic Response Units (HRUs) based on its soil, topographic, and/or land-use properties and model water and chemical movement from one unit to the others, including overland processes, along the stream channel, and eventually to the watershed outlet. The distributed models are more complex than lumped models due to the processes of these models and the need for parameters for each unit (Chapra, 1997). In this study, a distributed watershed model was used to estimate the pollutant loads at the edge of field as well as the attenuation of load delivered via stream network and waterbody. The modeling tool interfaced with geospatial techniques for data collection, preparation and analysis, which was important for simulating site-specific and in-stream variability of pollutant loads.

The Soil and Water Assessment Tool (SWAT) watershed model was selected to simulate water-quality outcomes of trades in this project. SWAT is a physically-based, river-basin/ watershed scale, continuous simulation model developed by a team lead by Dr. Jeff Arnold at the USDA Agricultural Research Service (ARS), Temple, TX, since 1990s (Neitsch et al., 2005). SWAT predicts the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land-uses, and management conditions over long periods of time (Neitsch et al., 2005). The model is not designed to simulate detailed, single-event flood routing.

Based on topography and given hydrology thresholds, SWAT simulates a watershed that has been delineated into several subbasins for modeling purposes. Each subbasin is simulated as a homogeneous area in terms of climatic conditions and topography, but additional subdivisions are used within each subbasin to represent unique land cover, soil, and management combinations. Each of these individual areas is referred to as a HRU, which is assumed to be uniformly distributed and to inherit the geospatial properties from that subbasin. Therefore, SWAT can model hydrologic and water quality responses of a watershed with reasonably realistic representations of the specific soil, topography, landuse, climate and management practices at a particular area.

In SWAT, the water balance influences most processes in the watershed. To simulate the hydrologic processes of a watershed, SWAT can be separated into two major divisions. The first division is the land phase, which controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each subbasin. The second division is the water or routing phase, which can be defined as the movement of water, sediments or other effluents through the stream network of watershed to the designated outlet (Neitsch et al., 2005). In addition to track mass flow in the channel, SWAT models the transformation of chemicals in the stream and streambed (Neitsch et al., 2005).

Many crop and management components used in the field have been added to SWAT. It can simulate an extensive set of agricultural BMPs, including crop rotation types (over 80 crops/plants), tillage practices (over 100 practices), manure/fertilizer management (over 50 sources), and conservation practices. Consequently, it can represent the actual cropping, tillage and nutrient management practices typically used in Northeastern Kansas. SWAT also models in-stream processes affecting nutrient and sediment transport, including sorption and desorption to bed sediment and scouring and deposition of sediment. In addition, PS loads and outputs from other models can be input to the model.

SWAT has been used in several States for WQT pilot study or evaluation, such as the Great Miami River Watershed, Ohio (Fang, 2005) and Fox-Wolf River, Wisconsin (Kramer, 2003; Baumgart, 2005). SWAT has also been developed and is currently being tested within the Kansas Kanopolis watershed (Tuppad et al., 2003; Tuppad, 2006), Clinton Lake (Parajuli, 2007), Rattlesnake Creek basin (Sophocleous et al., 1999), Delaware subbasin (Nelson et al., 2006), and other study regions (Sophocleous and Perkins, 2000). Van Liew et al. (2003) showed that SWAT gave more consistent results than HSPF in estimating stream flow for agricultural watersheds under various climatic conditions. Although HSPF has a long history of usage by hydrologists in the Chesapeake Bay area (Chesapeake Bay, 2001) and has been used in the first online nutrient trading system, NutrientNet (WRI, 2007), SWAT was considered to be better suited for investigating the long-term impacts of alternative land management practices with climate variability in Kansas.

2.4 Feasibility Case Study

2.4.1 Study Area

In order to test the WQT theory and equations discussed in this study as well as gather information prior to a larger study, a pilot or feasibility case study of nutrient load reduction was established. Following WQT program site-selection criteria, and potential trading partners availability, Lower Kansas watershed (USGS HUC8: 10270104) was selected as this study area. It is located on Kansas and Delaware River Basin (USGS HUC6: 102701) in northeastern Kansas. It encompasses a large proportion of the Kansas population within its 429,000 ha (1,060,000 ac) drainage basin, which also includes a large number and diverse range of PS and NPS sources. The watershed has 99.6% of its area in Atchison, Douglas, Jefferson, Johnson, Leavenworth, Osage, Shawnee, Wabaunsee, Wyandotte, and Wyandotte Counties of northeastern Kansas and 0.4% in Jackson County, Missouri. Grassland and woodland cover approximately 46% of this area as well as 18% in crop land, 17% in forest and 2% in water classes. Figure 2-10 illustrates terrain elevation of study watershed. The elevation ranges from 424 m to 220 m, with an average around 301 m. Figure 2-11 renders a map of surface slope in percentage. The reddish blocks in Figure 2-11 represent a steep slope area and imply more potential for soil erosion from these areas.

To simplify the trading problem for this case study, only NPS-PS trades will be allowed for this WQT market in the watershed. The stream path with its natural flow direction was used for network analysis and estimate delivery effects. A downstream trade is only allowed for an upstream farmer (NPS) to trade its load reduction to a downstream WWTP (PS). Upstream or bi-direction trade was not feasible for this pre-run study.

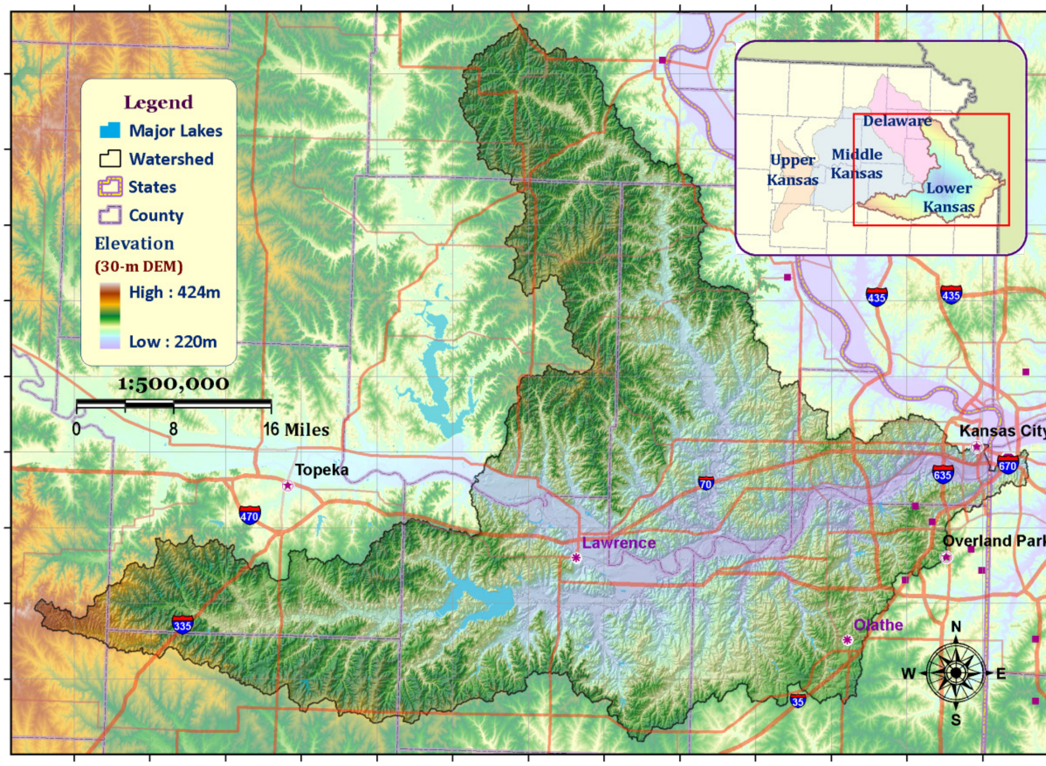


Figure 2-10 Elevation of Lower Kansas Watershed, Kansas

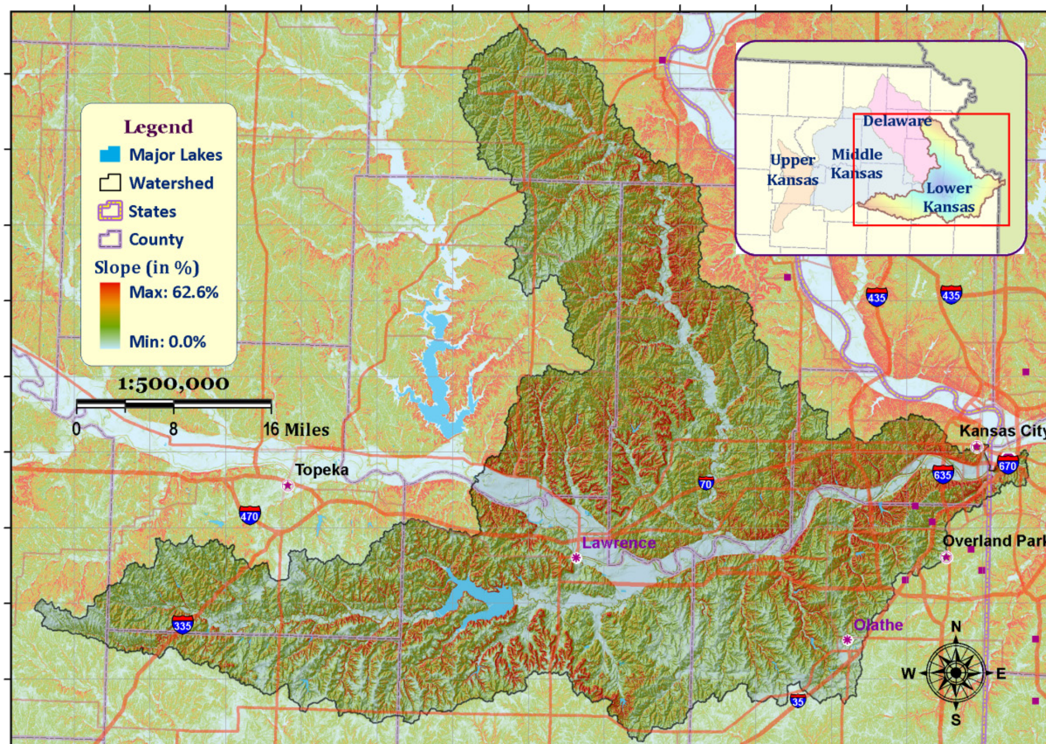


Figure 2-11 Watershed Surface Slope (in percentage)

2.4.2 Alternative Scenario Design

The primary goal of watershed modeling in WQT is to assess the impact of land management activities on the given area and also to estimate the potential environmental benefit for a given trading scenario. Connecting watershed modeling results with an economic model, the potential effects of WQT program in the watershed were estimated. To coordinate the economic analysis scenarios, which are the comparison scenarios in the field survey of "choice experiments of producers (NPS)" in the study watershed (Peterson et al., 2007; Smith et al., 2007); five specific alternative land management practices have been simulated. Table 2-1 lists the details of the five cases, one for baseline and the others for four alternatives, which were simulated with the watershed model and integrated with economic estimations. These five land management practices are based on a two-year corn-soybean rotation with surface-broadcast fertilizer application. The baseline case used a traditional minimum tillage system without VFSs or grazing at the edge of field. Case1 and Case2 have similar modeling design but different tillage systems. Case1 used no-till, and Case2 used 50% no-till and 50% in minimum tillage. Case3 is also based on baseline scenario but adding an edge-of-field VFS. The Case4 is similar to Case3 design but adds fall haying and grazing on the VFS.

Table 2-1 Design of Baseline and Four Potential Alternative BMPs

Case #	Crop[1]	Abbrev.[2]	Tillage[3]	Fertilizer	VFS	Grazing	Description
Baseline		CS4SB	MT				2-yr Rotation Minimum Tillage
Case1		CS1SB	NT				2-yr Rotation No-till
Case2	CORN-SOYB	CS2SB	OT	Surface Fertilizer			2-yr 50% No-till/Minimum Rotation
Case3		CS4SBFS	MT		Yes		Baseline applied VFS
Case4		CS4SBFSGZ	MT		Yes	Yes	Case3 applied grazing method

Note: **1.** CORN-SOYB: 2-yr corn-soybean rotation. **2.** C: corn; S: soybean; CS: 2-yr corn-soybean rotation; SB: general surface fertilizer application (surface broadcast); FS: with edge-of-field VFS; GZ: with grazing event on VFS. **3.** NT: no-till; OT: rotational tillage, which is a tillage system with halftime no-till (NT) and halftime minimum tillage (MT); RT: reduced tillage; MT: minimum tillage; CT: conventional tillage.

Kansas State University Cooperative Extension Service watershed specialist and professionals of the Agricultural Experiment Station were interviewed by e-mail or personal discussion about the five case scenarios concerning details of tillage operation, planting timing, crop growth season, VFS and grazing event as well as the approximate percentage of acreage in Kansas River Basin. Similar information was also collected from a literature review, including the USDA NRCS field office and USDA NRCS electronic field office technical guides (eFOTGs) website. After summarizing these field experiences and prior research results, the detail designs for these cases were developed.

A 30 m digital elevation model (DEM) acquired from National Elevation Dataset (NED) was imported into the SWAT model interface, AVSWATX as the fundamental GIS dataset. With built-in watershed delineating tool in AVSWATX, the study watershed was divided into 286 subbasins with a stream definition threshold area of 990 ha (2450 ac). Figure 2-12 shows the total 286 subbasin areas identified, including location of the main channel and two major tributary channels. Individual HRU delineation was performed by overlaying NLCD2001 landuse, and the Natural Resources Conservation Service (NRCS) SSURGO soil database. A total of 5395 HRUs (within the 286 subbasins) with multiple HRU thresholds in landuse with more than 4% of total area and soil with more than 7% of each selected landuse area within a subbasin were identified.

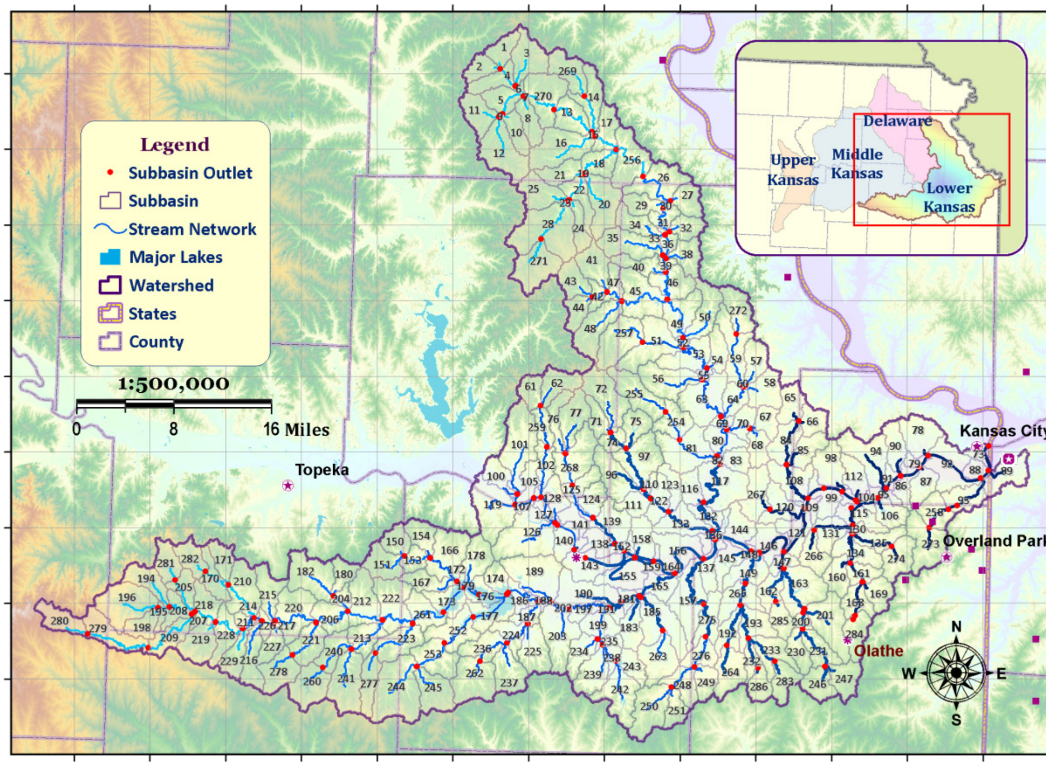


Figure 2-12 Subbasin and Stream Delineation in Study Watershed

Model-input climate data for daily precipitation as well as maximum and minimum daily temperature were developed using historical climate data (1960-2006) collected from NOAA NCDC SOD weather stations within a 32 km (20-mi) buffer of the watershed (NCDC, 2009). There are total 41 rain gages and 20 temperature gage stations were used. For those missing data in above gage stations, the historical data from two USGS operated weather stations were used by weather simulation/generation program in SWAT. Values for solar radiation, wind speed, and relative humidity were generated by the model. In order to stabilize model responses, all cases used weather data from 1968 to 2006 for simulation with SWAT, but only the modeling outputs ranges from 1971 to 2006 were analyzed for potential trading effects. More details for alternative scenario design as well as data preparation and parameters setting were discussed in Appendix A.

2.5 Results and Discussion

2.5.1 Model Simulation

The environmental benefit for WQT was concerned largely with load reduction at the watershed outlet. Pollutant load reduction in nutrient (TN and TP) loads leaving the edge of field and entering the stream network to the watershed main outlet were determined for corn-soybean cropland acreage within the Lower Kansas watershed. The baseline case and four other alternative cases were modeled with SWAT from 1968 to 2006 for 39 years, with the analysis based on the 1971 to 2006 (36 years) modeling period.

Annual values were simulated for pollutant load and load reduction for both TN and TP at a daily time step. With 286 subbasins and 5395 HRUs in study area, there are only 255 subbasins and 1053 HRUs classified as cropland area. Each simulation was calculated for all HRUs in every subbasin. However, only the cropland area was subjected to changing land management practices. In other words, only cropland HRUs could produce load reduction between two alternative cases. The subbasin level outputs were aggregated using the area-weighted values of each HRU within each subbasin. Hence, the overall watershed level information was calculated as the average of each subbasin level output for the study watershed for later comparisons.

In this pilot study, SWAT model was used to obtain the annual nutrient load associated with five case scenarios. Before the modeling post-analysis could be conducted, it was necessary to ensure that SWAT could reasonably predict pollutant load in the Lower Kansas watershed. Therefore, several minor modifications were applied to SWAT parameters and management operations. Table 2-2 depicts the modeling parameters for each study cases in pilot study. Based on the research conducted by Maski et al. (2007), the soil and management properties for modeling no-till tillage system with SWAT are needed to be adjusted. Hence, for simulating no-till, the runoff curve number of moisture condition II (CN2) was adjusted based on the hydrologic soil groups of local soil and usually promoted one group; the USLE Crop cover management factor (USLE-C) was decreased due to no-till would increase surface coverage; conversely, no-till will consolidate the soil surface, the soil saturated hydraulic conductivity (K_{SAT}) value were multiplied by 2 to compensate this phenomenon (Maski et al., 2007). Furthermore, SWAT default used single roughness coefficient (Manning's n) for overland flow on the same type of surface coverage plant, and a single Manning's n for the channel flow along the whole stream network. These defaults were not reasonable for modeling a huge watershed. Therefore, surface Manning's n for overland flow was increased due to the surface impermeable of no-till operation (Neitsch et al., 2005). The channel flow Manning's n of was designed as 0.050 for the tributary and 0.025 for the main channel based on channel condition in study watershed (Wanielista et al., 1997; Neitsch et al., 2005). For simulating the rotational tillage system, it's CN2, USLE-C and K_{SAT} properties are the average of adjusted no-till values and the original SWAT defaults of the other rotated tillage.

Furthermore, different tillage systems have specific cultivating operation dates as well as the type of fertilizer application chemicals, amount, applying dates and methods. These parameters were also adjusted based on the watershed specialist experience as well as the reports from NRCS field office (Whitney et al., 1991; Fjell et al., 1997; Whitney et al., 1999; Leikam et al., 2003; Fjell et al., 2007). The SWAT default VFS trapping efficiency was modified based on USDA NRCS technical notes and several literature reviews (NRCS-Kansas, 2003; Neitsch et al., 2005; Mankin et al., 2006). For simulating fall grazing event on VFS, the parameters were assigned according to ASABE standard (ASAE Standard, 2005) and field experiences (Moore et al., 2001; Honeyman et al., 2006). Table 2-3 lists partial schedule of major field operations, such as planting and harvesting dates, and cultivating operations.

Table 2-2 Major SWAT Parameters for Baseline and Four Alternative Scenarios

Case	Crop Rotation	Till[1]	Abbrev.[2]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[3] A	B	C	D	Manning's n	K_{SAT}
Baseline		MT	CS4SB			0.27	67	77	84	88	0.12	---
Case1		NT	CS1SB			0.12	77	84	88	90	0.24	2x
Case2	CORN-SOYB (2-yr)	OT[2]	CS2SB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.2	72	80	86	89	0.18	1.5x
Case3		MT	CS4SB/FS			0.27	67	77	84	88	0.12	---
Case4		MT	CS4SB/FS-GZ			0.27	67	77	84	88	0.12	---

Note: **1.** NT: no-till; OT: rotational tillage, which is the tillage system with halftime no-till (NT) with corn and halftime minimum tillage (MT) with soybean; MT: minimum tillage. **2.** SB: general surface fertilizer application (surface broadcast); C corn; S soybean; CS: 2-yr corn-soybean rotation; FS with edge-of-field VFS; FS-GZ implementing edge-of-field VFS with fall grazing event on it. **3.** CN2: curve number for moisture condition II or antecedent moisture condition II (AMC II); HSG: hydrologic soil group.

Table 2-3 Cultivation and Fertilizer Application Date for each Tillage System

Till	Crop	TL	Chisel Plow Gt15ft	Tandem Disk Reg. 14-18ft	Field Cultivator Lt15ft	Fertilizer Pre-plant	No-till Mixing	Planting	Fertilizer at Planting	Row Cultivator Lt15ft	Fertilizer mid-growing	Harvest
NT	COR2	--					05/01/01	05/01/01	05/01/01		06/01/01	09/15/01
	SOY2	---					05/15/02	05/15/02	05/15/02			10/07/02
OT	COR2	NT					05/01/01	05/01/01	05/01/01		06/01/01	09/15/01
	SOY1	MT	11/05/01	04/15/02	05/10/02	05/10/02		05/15/02	05/15/02			10/07/02
MT	COR1	--	11/05/02	04/10/01	04/25/01	04/25/01		05/01/01	05/01/01	06/01/01	06/01/01	09/15/01
	SOY1	--	11/05/01	04/15/02	05/10/02	05/10/02		05/15/02	05/15/02			10/07/02

2.5.2 Potential Nutrient Load

We analyzed TN and TP loads from 1971 to 2006 for 286 subbasins and 5395 HRUs among five cases. Due to only 255 out of 286 subbasins and 1053 out of 5395 HRUs being classified as cropland area, a specific analysis focusing on cropland also applied. Table 2-4 presents the watershed scale annual TN load which is the area weighted average of all 286 subbasin, 5395 HRUs, or agricultural cropland only HRUs (AGH). The symbol "SUB" represents subbasin data subset, "HRU" for hydrology response units data subset, and "AGH" for the analysis focusing on cropland only data subset. For example, the HRU mean is the average load of all HRUs, the SUB mean is the average of the area weighted HRU statistics summations within each subbasin, and the AGH mean is the average of area weighted HRU statistics having cropland. Similarly, Table 2-5 presents the watershed scale annual TP load for each data subset. The overall average of 36 year nutrient load response as well as maximum, minimum, and several percentile values were listed in Table 2-4 and Table 2-5.

As described previously, SWAT modeled the HRUs for each subbasin. The HRU subset is the collection of these modeling outputs. The SUB subset statistics is the area weighted average of each HRU within the subbasin. The AGH subset, agricultural cropland HRU subset, only accounts for modeling output in the cropland HRUs. For the watershed scale statistics in Table 2-4 and Table 2-5, an arithmetic mean is simply applied for each data subset. That means the value in SUB subset represents the mean of 286 subbasin nutrient loads. Likewise, the value in HRU subset represents the mean of 5395 HRUs loads as well as in AGH subset represents the mean of 1053 cropland HRUs or 255 cropland subbasins loads. A percentile describes the value of the nutrient loads below which a certain percent of all observations in the subset. So the 10th percentile (P10) of SUB subset is a potential load below 10% of the all observations (10296 totals) in 286 subbasins for 36 years. Both tables list the 10th (P10), 25th (P25 or Q1), 50th (P50 or Q2), 75th (P75 or Q3), and 90th (P90) percentiles as well as the maximum (Max) and minimum (Min) value for each subset.

Table 2-4 Statistics of Annual TN Load for SUB, HRU, and AGH Data Subset

	(kg/ha)	**Mean**	**Min.**	**P10**	**P25**	**P50**	**P75**	**P90**	**Max.**
Baseline	*SUB*	18.00	0.00	4.20	8.10	15.44	24.34	35.30	105.43
	HRU	15.74	0.00	0.08	0.88	4.37	16.97	51.87	314.10
	AGH	55.76	0.00	11.03	27.67	51.70	77.92	104.52	314.10
Case1	*SUB*	13.85	0.00	3.93	6.90	12.19	18.38	25.92	69.81
	HRU	11.48	0.00	0.08	0.89	4.41	15.96	34.80	155.76
	AGH	33.75	0.01	10.00	19.76	31.26	45.43	60.17	155.76
Case2	*SUB*	14.85	0.00	3.87	7.08	12.78	19.73	28.39	88.99
	HRU	12.51	0.00	0.08	0.88	4.38	16.03	38.26	219.44
	AGH	39.06	0.00	9.39	20.51	35.52	52.79	72.21	219.44

	(kg/ha)	Mean	Min.	P10	P25	P50	P75	P90	Max.
Case3	*SUB*	8.36	0.00	2.00	3.95	7.00	11.14	16.09	50.11
	HRU	6.12	0.00	0.07	0.81	3.51	7.59	15.53	130.31
	AGH	5.99	0.00	1.18	2.97	5.55	8.36	11.22	33.72
Case4	*SUB*	8.44	0.00	2.00	4.00	7.08	11.25	16.27	50.40
	HRU	6.20	0.00	0.07	0.81	3.55	7.78	15.77	130.31
	AGH	6.40	0.00	1.18	3.09	5.91	8.91	12.10	38.43

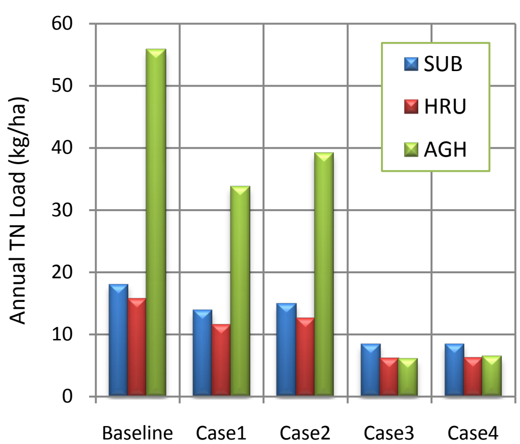
Table 2-5 Statistics of Annual TP Load for SUB, HRU, and AGH Data Subset

	(kg/ha)	Mean	Min.	P10	P25	P50	P75	P90	Max.
Baseline	*SUB*	3.67	0.00	0.85	1.66	3.04	4.90	7.37	23.37
	HRU	3.39	0.00	0.01	0.10	0.88	2.97	11.77	57.72
	AGH	13.09	0.00	2.63	6.57	12.12	18.30	24.63	57.72
Case1	*SUB*	3.80	0.00	0.94	1.76	3.14	5.01	7.55	22.95
	HRU	3.48	0.00	0.01	0.11	0.89	3.08	12.11	52.65
	AGH	13.53	0.02	3.72	7.53	12.42	18.28	25.00	52.65
Case2	*SUB*	3.78	0.00	0.88	1.69	3.06	4.98	7.62	26.17
	HRU	3.46	0.00	0.01	0.11	0.88	3.02	11.73	58.62
	AGH	13.46	0.00	3.15	6.92	12.06	18.18	25.14	58.62
Case3	*SUB*	1.41	0.00	0.36	0.72	1.23	1.87	2.62	7.60
	HRU	1.13	0.00	0.01	0.09	0.72	1.67	2.83	17.82
	AGH	1.41	0.00	0.28	0.71	1.30	1.97	2.65	6.20
Case4	*SUB*	1.46	0.00	0.37	0.75	1.27	1.92	2.72	7.65
	HRU	1.18	0.00	0.01	0.09	0.73	1.76	2.98	17.82
	AGH	1.65	0.00	0.30	0.79	1.51	2.29	3.12	7.50

Comparing the statistics listed in Table 2-4 and Table 2-5 for each data subset, the range from minimum to maximum is usually greater than the mean, often at least four times the mean value for any subset. This reflects that the nutrient load varied from subbasin to subbasin as well as year to year. The 50th percentile, or the median, represents the middle value of a data series. For a typical normal distribution, it would be near to the arithmetic mean. From these tables, none of three data subset has the statistics value closed to each other in both TN and TP load. In fact, AGH subset usually has a higher value than any other subset. The reason of this phenomenon is HRU subset included all landuse types and SUB aggregated the area weighted information of HRU. The non-agricultural area in HRU and SUB subset intended to produce different trends of TN and TP load. In contrast, AGH subset solely contains the cropland area information. It eliminated the other noise and reserved only the effect of changing land management practice on cropland among scenarios. Therefore, without eliminating unnecessary information, the HRU and SUB subset minimized the effect of outliers by averaged or weighted information within its area. For these reasons, SUB and HRU data subset might not fully present the nutrient load variation while land management changes; AGH might be a better option.

Comparing the maximum of HRU and AGH for each case may reflect similar information. The maximum of HRU and AGH were identical for both TN and TP load in Baseline, Case1 and Case2 scenario, but very different in Case3 and Case4. Moreover, the maximum of HRU for Case3 and Case4 are identical in both TN and TP load. That implies agricultural cropland may still produce a larger nutrient load than any other landuse area, even it applied no-till on the field. However, applied edge-of-field BMP such as VFS could dramatically reduce the nutrient load yield from cropland.

The mean values of both nutrient loads illustrate in Figure 2-13 have similar trends: the load of SUB was slightly larger than HRU, and the AGH load in Baseline, Case1 and Case2 were substantially larger than SUB and HRU. However, AGH load in Case3 and Case4 had either larger or smaller values than SUB and HRU. The alternative scenario studied made changes only to the tillage system, fertilizer application and edge-of-field BMPs in cropland area, thus the AGH subset responded with a substantial change in nutrient load amounts between cases. Although the other landuse areas may still yield a certain amount of nutrient load, the changes in the scenarios would not affect land other than cropland.



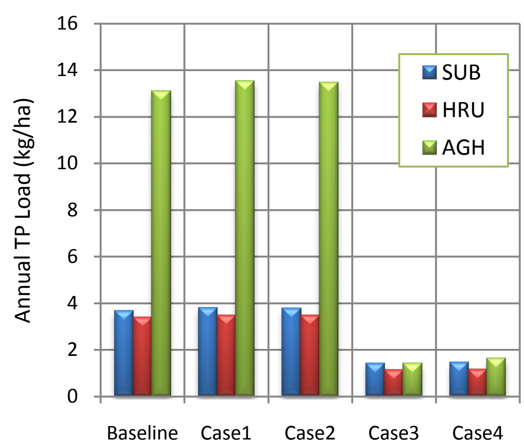


Figure 2-13 Annual TN Load for Each Scenario

The average decrease in nutrient load between Baseline and other alternative cases was expected due to the practices selected. The mean of annual Baseline (minimum tillage) TN load of SUB subset was 18.00 kg/ha, Case1 (no-till) was 13.85 kg/ha, and Case2 (rotational tillage) was 14.85 kg/ha (Table 2-4). Because rotational tillage (Case2) contained alternative years of no-till corn and minimum tillage soybean, it was expected to produce more nutrient loads than no-till (Case1) but smaller than minimum tillage system (Baseline).

The similar load decrease also presents in Case3 and Case4. The mean of annual TN load of SUB subset is 8.36 kg/ha for Case3 and 8.44 kg/ha for Case4. Case3 implemented VFS at the edge of field and was expected to reduce total sediment yield as well as nutrient load. Similarly, Case4 also implemented VFS but with additional fall cattle grazing events. The fall grazing might save the fuel energy for replacing the mowing actives on the VFS, but grazing also left certain amount of fresh manure on the ground. Figure 2-14 illustrates watershed monthly precipitation statistics. The twin peaks of precipitation will reoccur at June and September of a year. The cattle manures left on the ground in Case4 might be flushed into river with storm water runoff due to the grazing period also the high rainfall season. That will cause Case4 generating a higher nutrient yield than Case3.

The same analysis was performed for TP. It performed similar to TN load except Case1 had higher TP load than Case2 or the Baseline scenario. As described previously, surface runoff played an important role in transporting substances from the field. The no-till operation can substantially reduce soil erosion by keeping crop and plant residue on the surface longer. It does not disturb the soil through tillage and at least 30% crop residue remains on soil surface after harvesting. However, for some specific soil types such as heavier clay soils or compacted soils, no-till might reduce the surface runoff infiltration and then decrease crop yields. Unlike nitrogen which is highly mobile, phosphorus solubility is limited in most environments. In this study, the fertilizer application solely used surface broadcast application. With a potential high surface runoff in Case1, the phosphorus near the soil surface might be directly flushed away before plant uptake. Sharpley and Syers (1979) observed that surface runoff is the primary mechanism by which phosphorus is exported from most catchments (Neitsch et al., 2005).

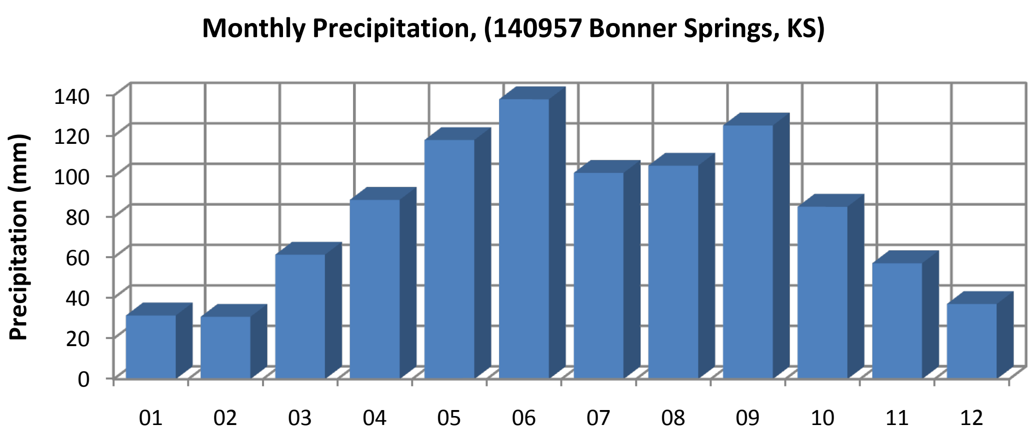


Figure 2-14 Watershed Monthly Precipitation Statistics

2.5.3 Potential Load Reduction

Based on the pollutant load reduction equation in Eq. 2-13, a set of watershed scale annual TN and TP load reduction presented in Table 2-6 and Table 2-7 can be calculated from loads presented in Table 2-4 and Table 2-5. For each table, three subsets for all combination of alternative scenario pairs were listed. In these tables, scenarios in columns represent the current scenario; the scenarios listed in rows represent an alternative; the number in the intersection cell is the potential annual nutrient load reduction in units of kg/ha (negative value indicates load increase). For instance, in Table 2-6 (c) AGH subset, if the current scenario is Baseline and alternative is Case2, the potential annual TN load reduction would be 16.70 kg/ha.

Table 2-6 Annual TN Load Reduction (kg/ha) for Each Subset

(a) SUB subset

	BASE	Case1	Case2	Case3	Case4
BASE		-4.15	-3.15	-9.64	-9.55
Case1	4.15		1.00	-5.49	-5.41
Case2	3.15	-1.00		-6.49	-6.41
Case3	9.64	5.49	6.49		0.08
Case4	9.55	5.41	6.41	-0.08	

(b) HRU subset

	BASE	Case1	Case2	Case3	Case4
BASE		-4.26	-3.23	-9.62	-9.54
Case1	4.26		1.03	-5.37	-5.29
Case2	3.23	-1.03		-6.39	-6.31
Case3	9.62	5.37	6.39		0.08
Case4	9.54	5.29	6.31	-0.08	

(c) AGH subset

	BASE	Case1	Case2	Case3	Case4
BASE		-22.01	-16.70	-49.78	-49.36
Case1	22.01		5.31	-27.77	-27.35
Case2	16.70	-5.31		-33.07	-32.65
Case3	49.78	27.77	33.07		0.42
Case4	49.36	27.35	32.65	-0.42	

Table 2-7 Annual TP Load Reduction (kg/ha) for Each Subset

(a) SUB subset

	BASE	Case1	Case2	Case3	Case4
BASE		0.13	0.11	-2.26	-2.21
Case1	-0.13		-0.03	-2.39	-2.34
Case2	-0.11	0.03		-2.36	-2.32
Case3	2.26	2.39	2.36		0.05
Case4	2.21	2.34	2.32	-0.05	

(b) HRU subset

	BASE	Case1	Case2	Case3	Case4
BASE		0.08	0.07	-2.26	-2.21
Case1	-0.08		-0.01	-2.34	-2.30
Case2	-0.07	0.01		-2.33	-2.28
Case3	2.26	2.34	2.33		0.05
Case4	2.21	2.30	2.28	-0.05	

(c) AGH subset

	BASE	Case1	Case2	Case3	Case4
BASE		0.44	0.37	-11.68	-11.44
Case1	-0.44		-0.07	-12.12	-11.88
Case2	-0.37	0.07		-12.05	-11.81
Case3	11.68	12.12	12.05		0.24
Case4	11.44	11.88	11.81	-0.24	

Based on equation of BMP reduction efficiency in Eq. 2-14, a set of watershed scale relative annual TN and TP load reduction index can be calculated from Table 2-6 and Table 2-7 as Table 2-8 and Table 2-9, respectively. The way to read these tables and cells is similar to reading Table 2-6 and Table 2-7: the column field represents current scenario, and row tag represents alternative method; the cell at the intersection store the relative potential annual nutrient load reduction index, or the BMP reduction efficiency for this alternative scenario pair. In these tables, the cell value with "ntp" sign represents a scenario pair that is not suggest to trade (non-tradable scenario pair), either because it produced a negative load reduction or represented a no-change practice combination.

Table 2-8 Relative Annual TN Load Reduction Index (BMP Reduction Efficiency)

(a) SUB subset

	BASE	Case1	Case2	Case3	Case4
BASE		ntp	ntp	ntp	ntp
Case1	23.0%		6.7%	ntp	ntp
Case2	17.5%	ntp		ntp	ntp
Case3	53.5%	39.6%	43.7%		1.0%
Case4	53.1%	39.1%	43.2%	ntp	

(b) HRU subset

	BASE	Case1	Case2	Case3	Case4
BASE		ntp	ntp	ntp	ntp
Case1	27.0%		8.2%	ntp	ntp
Case2	20.5%	ntp		ntp	ntp
Case3	61.1%	46.7%	51.1%		1.3%
Case4	60.6%	46.0%	50.5%	ntp	

(c) AGH subset

	BASE	Case1	Case2	Case3	Case4
BASE		ntp	ntp	ntp	ntp
Case1	39.5%		13.6%	ntp	ntp
Case2	30.0%	ntp		ntp	ntp
Case3	89.3%	82.3%	84.7%		6.5%
Case4	88.5%	81.0%	83.6%	ntp	

Table 2-9 Relative Annual TP Load Reduction Index (BMP Reduction Efficiency)

(a) SUB subset

	BASE	Case1	Case2	Case3	Case4
BASE		3.5%	2.8%	ntp	ntp
Case1	ntp		ntp	ntp	ntp
Case2	ntp	0.7%		ntp	ntp
Case3	61.5%	62.9%	62.6%		3.2%
Case4	60.3%	61.7%	61.4%	ntp	

(b) HRU subset

	BASE	Case1	Case2	Case3	Case4
BASE		2.4%	2.1%	ntp	ntp
Case1	ntp		ntp	ntp	ntp
Case2	ntp	0.4%		ntp	ntp
Case3	66.6%	67.5%	67.3%		4.0%
Case4	65.3%	66.1%	65.0%	ntp	

(c) AGH subset

	BASE	Case1	Case2	Case3	Case4
BASE		3.3%	2.7%	ntp	ntp
Case1	ntp		ntp	ntp	ntp
Case2	ntp	0.5%		ntp	ntp
Case3	89.3%	89.6%	89.6%		14.6%
Case4	87.4%	87.8%	87.8%	ntp	

As discussed in previous section, the AGH subset might present much more reasonable representation of the effects of alternative scenario changes. For example, the relative TN load reduction index in Table 2-8 for changing from current Baseline to alternative Case3 pair: SUB is 53.54%, HRU is 61.74%, and AGH is 89.27%. Similarly in Table 2-9, the relative TP load reduction index is 61.53% for SUB, 66.63% for HRU, and 89.27% for AGH. The interesting thing is the both TN and TP load reduction index for AGH is identical. Comparing Baseline and Case3 scenario, the difference is Case3 used 20-m wide VFS at the edge of field. With the empirical VFS trapping efficiency equation describe in SWAT Theoretical Documentation Version 2005 Chapter 6:1.11, the nutrient trapping efficiency for 20 m VFS is exactly equal to 89.27%. It shows that only AGH subset can exactly translate the modeling response information of management changed on cropland area.

2.5.4 Uncertainty Ratio

Additional analysis was performed to determine if the amount of pollutant load reduction associated with the change of alternative scenario was significant or not within the study watershed. As described previously, unpaired t-test determined whether the mean values of annual load reduction between current and alternative scenarios were equal or not. The paired t-test determined whether the mean value of annual load reduction in each pair observations was 0 or not. The 36-year average annual nutrient loads for each of three sets of the 286 subbasins (SUB), 5395 HRUs (HRU) and 1053 agricultural cropland HRUs (AGH) were tested to determine if the load reduction was significant or not based on t-test theory described in Eq. 2-11 and Eq. 2-12 with 95% confident interval. In addition, the R_U associated with a significant pollutant load reduction, or a potential positive load reduction, was determined utilizing a series of equations from Eq. 2-15 to Eq. 2-19 for both paired and unpaired load reduction scenarios. With a significant series of load reductions, the additional t-tests were performed to test if the potential deviation of load reduction was significant or not based on the equation Eq. 2-10 theory with both 90% and 95% confidence levels as well as paired and unpaired sets.

Each alternative scenario pair with positive load reduction defined a potential "bargain" trade and was assigned a value of "I"; and each non-bargain trade was left blank. Table 2-10 and Table 2-11 were established for TN and TP load reduction of unpaired AGH subset at 90% and 95% confidence level. For a special case that its potential pollutant load reduction was positive but it failed to pass the significant test, the tag "0" was assigned to it in both tables. Moreover, in these tables the highlighted cells represent a bargain trade combination; the cells under the diagonal line from up-left to down-right are no-change combinations that can be neglected.

Table 2-10 TN Load Reduction Tradable Matrix for Unpaired AGH Subset

(a) 90% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline					
Case1	1		1		
Case2	1				
Case3	1	1	1		1
Case4	1	1	1		

(b) 95% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline					
Case1	1		1		
Case2	1				
Case3	1	1	1		1
Case4	1	1	1		

Table 2-11 TP Load Reduction Tradable Matrix for Unpaired AGH Subset

(a) 90% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		1	1		
Case1					
Case2		0			
Case3	1	1	1		1
Case4	1	1	1		

(b) 95% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		1	1		
Case1					
Case2		0			
Case3	1	1	1		1
Case4	1	1	1		

Based on the equations from Eq. 2-21 and Eq. 2-22, the watershed scale R_U for TN and TP load reduction of unpaired AGH subset can be derived as the Table 2-12 and Table 2-13. Following the Table 2-10 and Table 2-11 results, if the alternative scenario pair is a non-bargain trade, its R_U will be set to 1, which means the uncertainty of the load reduction is too large to make it a trade. Similar to previous tables, highlighted cells represent a potential positive trade, and cells under the diagonal line are no-change combinations that can be neglected.

Table 2-12 TN Load Reduction Uncertainty Ratio Matrix for Unpaired AGH Subset

(a) 90% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		1	1	1	1
Case1	0.0125		0.0401	1	1
Case2	0.0177	1		1	1
Case3	0.0049	0.0047	0.0052		0.0927
Case4	0.0050	0.0048	0.0053	1	

(b) 95% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		1	1	1	1
Case1	0.0160		0.0515	1	1
Case2	0.0227	1		1	1
Case3	0.0063	0.0061	0.0066		0.1189
Case4	0.0064	0.0062	0.0067	1	

Table 2-13 TP Load Reduction Uncertainty Ratio Matrix for Unpaired AGH Subset

(a) 90% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		0.1774	0.2215	1	1
Case1	1		1	1	1
Case2	1	1		1	1
Case3	0.0048	0.0045	0.0049		0.0395
Case4	0.0049	0.0046	0.0050	1	

(b) 95% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		0.2276	0.2842	1	1
Case1	1		1	1	1
Case2	1	1		1	1
Case3	0.0062	0.0058	0.0063		0.0507
Case4	0.0063	0.0059	0.0065	1	

Comparing the uncertainty ratio between 90% and 95% confidence level, 90% confidence level R_U is usually smaller than 95% one. That means the pollutant load reduction for an alternative scenario pair at lower confidence level will have lower variation. In contrast, in order to include much more confidence in load reduction, 95% confidence level will require a wider range of variation. These imply a trade of pollutant load reduction from this source with higher level confidence will require buyer to purchase more load reductions, which are more than they actually required, providing greater assurance of attaining the desired load reduction replacement.

2.5.5 Trading Ratio

With the uncertainty ratio calculated in Table 2-12 and Table 2-13, if the pollutant transport or delivery effect can be neglected in equation Eq. 2-7, the in-field TR (TR_{IF} in Eq. 2-23) for TN and TP load reduction of unpaired AGH subset with 90% and 95% confidence level can be derived as Table 2-14 and Table 2-15. Following the Table 2-10 and Table 2-11 results, if the alternative scenario pair is a non-bargain trade, its TR will be set to 0, which means the pollutant load reduction of this alternative scenario pair is not tradable. Moreover, the highlighted cells represent a potential positive trade and the cells under the diagonal line are no-change combinations that can be neglected in further analysis.

Table 2-14 TN Load Reduction In-field TR for Unpaired AGH Subset

(a) 90% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		0	0	0	0
Case1	1.0126		1.0418	0	0
Case2	1.0180	0		0	0
Case3	1.0049	1.0048	1.0052		1.1021
Case4	1.0050	1.0049	1.0053	0	

(b) 95% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		0	0	0	0
Case1	1.0163		1.0542	0	0
Case2	1.0233	0		0	0
Case3	1.0063	1.0061	1.0067		1.1350
Case4	1.0064	1.0062	1.0068	0	

Table 2-15 TP Load Reduction In-field TR for Unpaired AGH Subset

(a) 90% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		1.2156	1.2844	0	0
Case1	0		0	0	0
Case2	0	0		0	0
Case3	1.0048	1.0045	1.0050		1.0411
Case4	1.0049	1.0046	1.0051	0	

(b) 95% Confidence Level

	Baseline	Case1	Case2	Case3	Case4
Baseline		1.2947	1.3971	0	0
Case1	0		0	0	0
Case2	0	0		0	0
Case3	1.0062	1.0058	1.0064		1.0534
Case4	1.0064	1.0060	1.0065	0	

Similar to the uncertainty ratio, a higher confidence level will produce a higher TR, which means that the buyer needs to purchase more load reduction to secure the environmental equivalence of the trade. Comparing an individual TR to a traditional, fixed, empirical TR such as 2:1, the TRs in Table 2-14 and Table 2-15 are much smaller. These processes demonstrate the floating TR system can provide a high confidence of load reduction for a trade and also reduce the cost for buyer to purchase enough load reduction to maintain environmental equivalence.

Assuming the current land management practice is Baseline, the potential TN and TP load reduction for the other four alternative cases can be calculated in every piece of agricultural cropland. Associating these data series with a watershed subbasin map, the geospatial distribution of TN or TP load reduction as well as TR can be rendered. Figure 2-15 illustrates the potential annual TN load reduction distribution with the alternative scenario Case1. Similarly, Figure 2-16 demonstrates its TR distribution across the watershed. In these figures, both load reduction and TR were derived from the unpaired AGH subset data. In Figure 2-15, the darker areas indicate greater potential pollutant load reduction. For a special case, the red block in Figure 2-15 represent a negative pollutant load reduction within this alternative scenario change. In Figure 2-16, the more reddish areas represent subbasins with higher uncertainty or TR; the more greenish areas represent subbasins with more-stable load reductions. The grayed subbasins in both figures represent areas with no agricultural cropland. Figure 2-15 and Figure 2-16 imply the pollutant load reduction, uncertainty ratio, and TR having a strong geospatial variation within the study watershed, and these site-specific geospatial effects can be quantified.

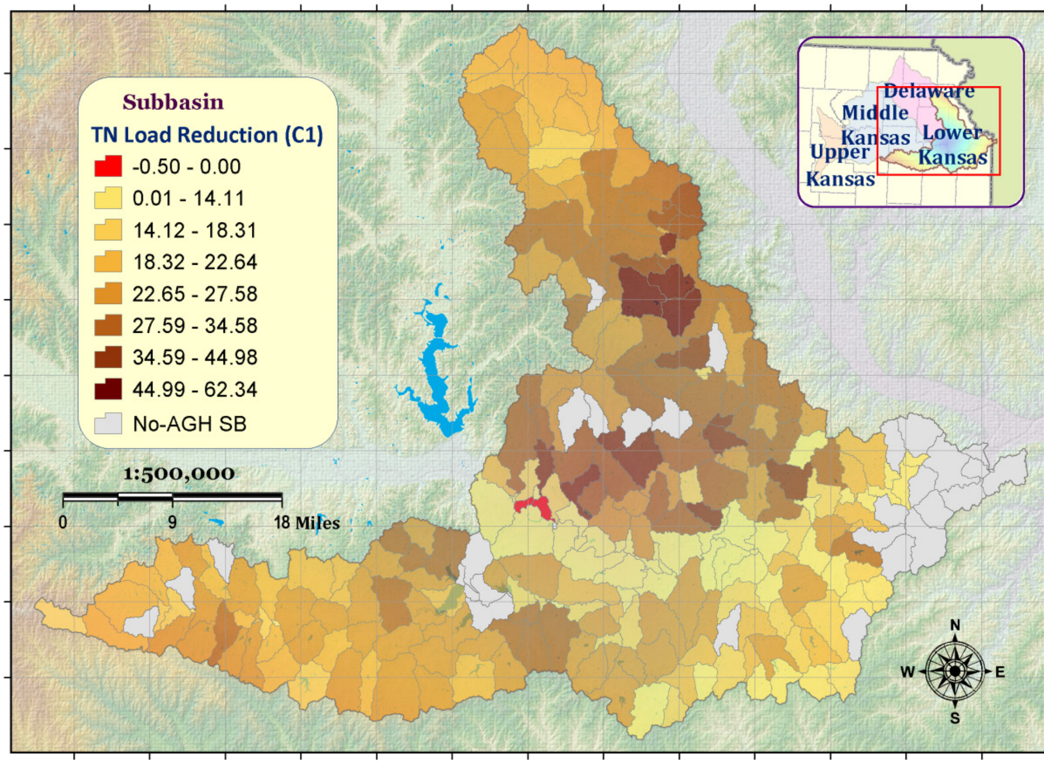


Figure 2-15 Potential Annual TN Load Reduction for Baseline to Case1

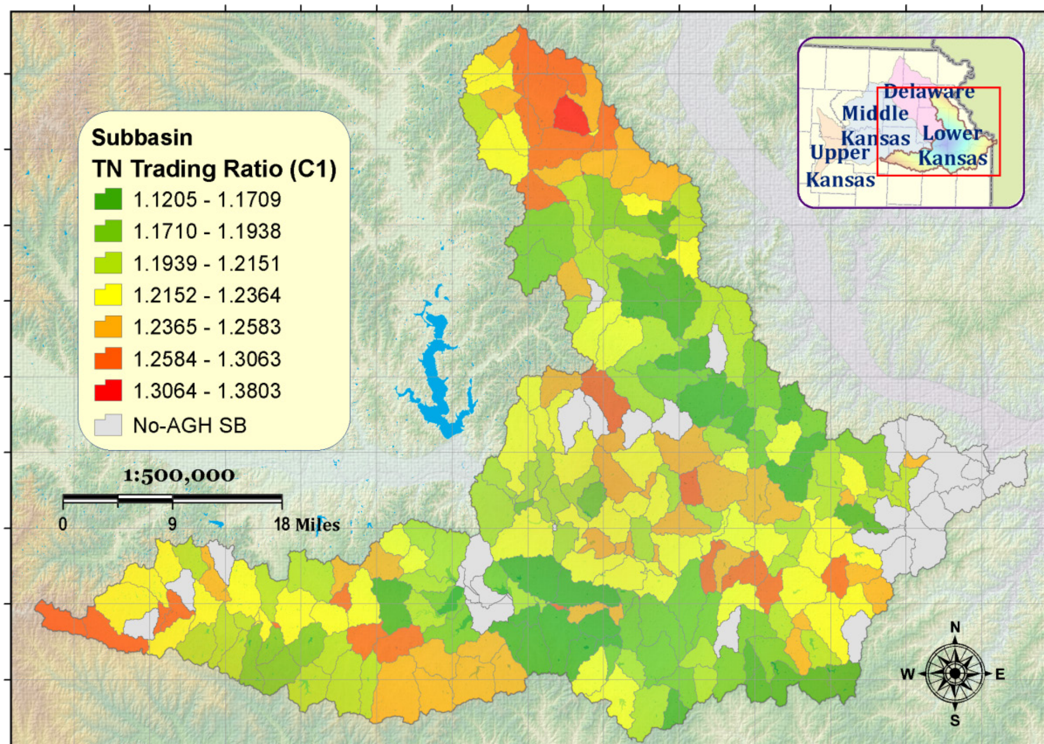


Figure 2-16 Potential Annual TN Load Reduction TR for Baseline to Case1

2.6 Conclusion

Ten years after U.S. EPA released draft guidelines for water-pollution trading, the WQT assessment handbook was formally released at the end of 2004. In October 2006, USDA-NRCS and EPA Office of Water signed a Partnership Agreement to collaborate on encouraging farmers to participate in WQT programs. However, many trading issues remained, and still remain, unresolved.

The biggest issue of WQT is that the actual traded volume is still smaller than anticipated. A small trading volume in a WQT program fails to lower transaction cost and cannot yield significant cost savings. These phenomena might originate from several impediments: misinterpretation of pollution problems, inadequate watershed data, variant characteristics of stakeholders, inappropriate market structure, unreasonable achieving goals or regulation, less incentive and low willingness, lack of information about WQT and inaccuracy of model estimations. Moreover, these impediments are actually inter-dependent.

This study developed a method using watershed model and floating TR system to solve the unreasonable TR issue. Based on statistical theory and equations, we developed the equations for calculating potential pollutant load reduction and estimating its potential deviation or uncertainty for each trade. The uncertainty ratio based on statistical confidence interval analysis was then introduced as one of the fundamental elements for TR calculation. Accounting for the distance between buyer and seller as well as the pollutant load transport effect, the delivery ratio was launched as another fundamental element for TR calculation.

Based on the WQT theory and method discussed in this paper, a pilot study was conducted to examine each WQT element. Preliminary results for TN and TP load, load reduction, uncertainty ratio, and TR for each scenario pair were then calculated. Within modeling scenarios, minimum tillage, surface fertilizer application, and a lack of BMPs will produce higher TN loads, while no-till, surface fertilizer application and a lack of BMPs produce higher TP loads. The scenarios with lower potential loads occurred in cropland with sub-surface fertilizer application and a VFS BMP. Therefore, alternative scenarios that provide the most potential pollutant load reduction would be applying conservative tillage methods. For specific alternative scenario pairs, the potential pollutant load reductions vary by subbasin. The TRs of potential pollutant load reductions also show similar trends, indicating the best alternative scenario pair might change from one subbasin to another, and scenarios with higher potential load reductions may or may not produce a lower TR.

The pilot study was successful in providing evidence for utilizing the floating TR system for a WQT program. Strong site-specific effects for load reduction and TR in Lower Kansas watershed were shown.

To assess the potential WQT benefit of a trade, the more variety in modeling land management scenario design to create a sufficient database of alternative scenarios is necessary. Moreover, the potential load reduction of selected alternative scenario pairs and the TRs would have to be individually evaluated for a trading partner's subbasin. Furthermore, the float TR system used in this study incorporated only land management scenario changes; other spatial and temporal site-specific effects need to be addressed in further analysis and study.

Acknowledgements

The authors gratefully acknowledge Dr. Chun-Yen C. Cochrane, research associate professor of Human Nutrition, for assistance in statistics analysis; Dr. Amir Pouyan Nejadhashemi, former research assistant professor of Biological and Agricultural Engineering, for his insight on watershed delineation and model operation. We also acknowledge Dr. J.M. Shawn Hutchinson, associate professor of Geography, for his comments on geospatial analysis and GIS techniques. Appreciation is also extended to Drs. Jeffrey M. Peterson, and John Leatherman, professor of Agricultural Economics, and Mr. Craig Smith, watershed specialist and research assistant, for their expertise in the field survey of water quality trading program in Kansas.

We are grateful for the partial financial supports from the U.S. EPA Section 319 grant and Kansas Water Plan funds provided by the Kansas Department of Health and Environment (KDHE) (Project #: 2004-0017), and U.S. EPA, the National Center for Environmental Research (NCER) Science to Achieve Results (STAR) Program Grant #R831774. Although the research described in the article has been funded in part by KDHE project and the U.S. EPA's STAR program grant, it has not been subjected to any KDHE or EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

2.7 References

ASAE Standard. 2005. D384.2: Manure production and characteristics. St. Joseph, MI: Am. Soc. Agric. Eng. (ASAE).

Barnes, P. L. 2006. Personal communication. Manhattan, KS.

Baumgart, P. 2005. Lower Green Bay and Lower Fox Tributary Modeling Report. Available at: basineducation.uwex.edu/lowerfox/WatershedPlan.html. Accessed April 30, 2009.

Beven, K.J. 2001. *Rainfall-Runoff Modeling: The Primer*. Chichester, England: John Wiley and Sons.

Bhattarai R., P. K. Kalita, and M. K. Patel. 2008. Nutrient transport through a Vegetative Filter Strip with subsurface drainage. *J. Environ. Management*. 90(5): 1868-1876.

Blanco-Canqui, H., C. J. Gantzerb, S. H. Anderson, E. E. Alberts, and A. L. Thompson. 2004. Grass barrier and vegetative filter strip effectiveness in reducing runoff, sediment, nitrogen, and phosphorus loss. *Soil Sci. Soc. Am. J.* 68: 1670-1678.

Boyer, W. R. 2006. Interview by author. E-mail communication. Manhattan, KS.

Breetz, H. L., K. Fisher-Vanden, L. Garzon, H. Jacobs, K. Kroetz, and R. Terry. 2004. Water quality trading and offset initiatives in the U.S.: a comprehensive survey. Hanover, NH: Dartmouth College. Available at: www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf. Accessed April 30, 2009.

CPLS. 1999. *Effluent Trading: A Policy Review for Texas*. College Station, TX: Texas A&M University, the Bush School of Government and Public Service, Center for Public Leadership Studies (CPLS).

CTIC. 2006. *Getting Paid For Stewardship: An Agricultural Community Water Quality Trading Guide*. West Lafayette, IN: Conservation Technology Information Center (CTIC). Available at: www.conservationinformation.org. Accessed December 12, 2006.

Chapra, S. C. 1997. *Surface Water-Quality Modeling*. Boston, MA: McGraw-Hill.

Crutchfield, S. R., and D. Letson. 1994. Feasibility of point-nonpoint source trading for managing agricultural pollutant loadings to coastal waters. *Water Resour. Res.* 30(10): 2825-2836.

Curley, D. E. 2003. An analysis of trading ratio for water pollution control trading system using a geographic information system and the finite segment method. PhD diss. Philadelphia, PA: University of Pennsylvania, Department of City and Regional Planning.

Environomics. 1999. A summary of U.S. Effluent trading and offset projects. Bethesda, MD: Environomics. Available at: www.epa.gov/OWOW/watershed/trading/traenvrn.pdf. Accessed April 30, 2009.

Fang, F., M. S. Kieser, D. L. Hall, N. C. Ott, and S. C. Hippensteel. 2005. A preliminary analysis of water quality trading opportunities in the Great Miami River watershed, Ohio. In *Proc. 3rd Watershed Management to Meet Water Quality Standards and Emerging TMDL Conference*, 27-37. P. Gassmann, ed. ASABE Paper No.701P0105. St. Joseph, Mich.: ASABE.

Fjell, D. L., D. Peterson, D. A. Whitney, 1997. *Soybean Production Handbook*. C-449. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., R. L. Vanderlip, K. L. Roozeboom, 2007. *Corn Production Handbook*. C-560 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Hoag, D. L., and J. S. Hughes-Popp. 1997. Theory and practice of pollution credit trading. *Rev. Agr. Econ.* 19: 252-262.

Honeyman, M., J. Russell, D. Morrical, D. Maxwell, D. Busby and J. Sellers. 2006. Beef cattle on grass supplemented with self-fed by-products. In annual progress reports-2005. Armstrong Research and Demonstration Farm. ISRF05-12. Ames, IA: Iowa State University. Available at: www.ag.iastate.edu/farms/reports.html. Accessed April 30, 2009.

Jones, C., L. Bacon, M. S. Kieser, and D. Sheridan. 2005. *Water-Quality Trading: A Guide for the Wastewater Community*. Water Environment Federation. New York, NY: McGraw-Hill.

KDHE. 2004. *Surface Water Nutrient Reduction Plan*. Topeka, KS: Kansas Department of Health and Environment (KDHE).

KDHE. 2008. 2008 Kansas Integrated Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

Kerr, R. L., S. J. Anderson, and J. Jaksch. 2000. Crosscutting analysis of trading programs: case studies in air, water, and wetland mitigation trading systems. Washington, D.C.: National Academy of Public Administration. Available at: www.napawash.org/pc_economy_environment/epafile06.pdf. Accessed April 30, 2009.

King, D. M. 2005. Crunch time for water quality trading. *Choices* 20(1): 71-75. Am. Agric. Econ. Assoc.

King, D. M. and P. J. Kuch. 2003. Will nutrient trading ever work? An assessment of supply and demand problems and institutional obstacles. *Environmental Law Reporter* (33): 10352-10368. Washington, D.C.: Environmental Law Institute.

Kramer, J. M. 2003. *Lessons from the Trading Pilots: Applications for Wisconsin Water Quality Trading Policy*. Fox-wolf Watershed Alliance. Madison, WI: Resource Strategies, Inc. Available at: www.fwwa.org. Accessed April 10, 2007.

KSU. 2006. Common Kansas Crop Rotations. Unpublished technical note. Manhattan, KS: Extension Agronomy, Kansas State University (KSU).

Lauer, G. N. and C. P. Han. 1974. Power of Cochran's test in the Behrens-Fisher problem. *Technometrics* 16(4): 545-549.

Leatherman, J., J. M. Peterson, and K. R. Mankin. 2005. Is water quality trading a policy option for Kansas? In *Proc. 22nd Annual Water and the Future of Kansas Conference*. Topeka, KS: Kansas State University.

Leikam, D. F., R. E. Lamond, D. B. Mengel. 2003. *Soil Test Interpretations and Fertilizer Recommendations*. MF-2586. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Letson, D., S. R. Crutchfield, and A. Malik. 1993. *Point/Nonpoint Source Trading For Controlling Nutrient Loadings to Coastal Waters: A Feasibility Study*. Ag. Econ. Report No. 674. Washington, D.C.: USDA ERS, Research and Technical Division. Available at: www.ers.usda.gov/AboutERS/Sales/index.asp?PDT=2&PID=670. Accessed April 30, 2009.

Maddux, L. D. 2006. Interview by author. E-mail communication. Manhattan, KS. February 23.

Mankin, K. R., P. L. Barnes, J. P. Harner, P. K. Kalita, and J. E. Boyer. 2006. Field evaluation of vegetative filter effectiveness and runoff quality from unstuck feedlots. *J. of Soil and Water Cons*. 61(4): 209-217.

Mankin, K. R., D. M. Ngandu, C. J. Marden, S. L. Hutchinson, and W.A. Geyer. 2007. Grass-shrub riparian buffer removal of sediment, phosphorus, and nitrogen from simulated runoff. *J. Amer. Water Resour. Assoc.* 43(5): 1108-1116.

Maski, D., K. R. Mankin, K. A. Janssen, and P. Tuppad. 2007. Sensitivity analysis of SWAT nutrient modeling under different management practices. 2007 ASABE Annual Meeting Paper No. 072060. St. Joseph, Mich.: ASABE.

Moore, K. J., M. H. Wiedenhoeft, E. C. Brummer, J. R. Russell, R. Hintz, J. Secor, and D. Maxwell. 2001. Sequential grazing systems for beef cattle production. In annual progress reports-2000. Armstrong Research and Demonstration Farm. ISRF00-35. Ames, IA: Iowa State University. Available at: www.agaware.iastate.edu/farms/2000reports/mcnay/. Accessed April 30, 2009.

Morgan, C. and A. Wolverton. 2005. *Water Quality Trading In the United States*. EPA Working Paper #05-07. Washington, D.C.: USEPA, National Center for Environmental Economics (NCEE).

NCDC. 2009. Daily surface data. Climate Data Online (CDO), National Climatic Data Center (NCDC). NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and U.S. Department of Commerce. Available at: cdo.ncdc.noaa.gov. Accessed March 31, 2009.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, and J. R. Williams. 2005. *Soil and Water Assessment Tool Theoretical Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS & Blackland Research and Extension Center, Texas A&M University.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and J. R. Williams. 2004. *Soil and Water Assessment Tool Input / Output File Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS.

Nelson, N. and A. Keeler. 2005. Water quality trading in Georgia: addressing two potential impediments to success. In *Proc. 2005 Georgia Water Resources Conference*. Kathryn J. ed. Athens, GA: Institute Ecology, University of Georgia. Available at: www.uga.edu/water/GWRC/Papers/NelsonN-GWRCpaper%20April13.pdf. Accessed April 30, 2009.

Nelson, R. G., J. C. Ascough II, and M. R. Langemeier. 2006. Environmental and economic analysis of switchgrass production for water quality improvement in northeast Kansas. *J. Environ. Management* 79(4): 336-347.

NRCS-Kansas. 2006. Crop field management record (dry land). Unpublished technical note. Lyndon, KS: USDA-NRCS, Kansas Division, Osage County Field Office.

Oregon DEQ. 2005. *Water Quality Trading - Internal Management Directive*. Portland, OR: Oregon Department of Environmental Quality (Oregon DEQ). Available at: www.deq.state.or.us/wq/trading/trading.htm. Accessed April 30, 2009.

Parajuli, P. B. 2007. SWAT bacteria sub-model evaluation and application. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

Peterson, J. M., J. A. Fox, J. C. Leatherman, and C. M. Smith. 2007. Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market. In *Proc: 2007 Annual Meeting,* July 29-August 1, 2007, Portland, OR: AAEA.

Rowles, K. 2005. A Feasibility analysis of applying water quality trading in Georgia watersheds. Water Policy Working Paper 2005-020. Atlanta, GA: Georgia State University, Andrew Young School of Public Policy.

SAS Institute Inc. 2004. *SAS OnlineDoc® 9.1.3*. Cary, NC: SAS Institute Inc.

Satterthwaite, F. E. 1946. An approximate distribution of estimates of variance components. *Biometrics Bulletin* 2: 110-114.

Schauder, H. and K. Auerswald. 1992. Long-term trapping efficiency of a vegetated filter strip under agricultural use. *Zeitschrift für Pflanzenernährung und Bodenkunde (J. Plant Nutr. Soil Sci.)* 155(5): 489-492.

Sharpley, A. N. and J. K. Syers. 1979. Phosphorus inputs into a stream draining an agricultural watershed: II. Amounts and relative significance of runoff types. *Water, Air & Soil Pollution* 11: 417-428.

Smith, C. M. 2004. A Water Quality Trading Simulation for Northeast Kansas. MS Thesis. Manhattan, KS: Kansas State University, Department of Agricultural Economics.

Smith, C. M., J. M. Peterson, and J. C. Leatherman. 2007. Attitudes of Great Plains Producers about Best Management Practices, Conservation Programs, and Water Quality. *J. Soil and Water Conserv.* 62: 97A-103A.

Sophocleous, M. A. 1998. Water resources of Kansas - a comprehensive outline. In: Sophocleous, M. A. ed. *Perspectives on Sustainable Development of Water Resources in Kansas*. Lawrence KS: Kansas Geological Survey, Bulletin 239: 1-59.

Sophocleous, M. A. and S. P. Perkins. 2000. Methodology and application of combined watershed and ground-water models in Kansas. *J. Hydrology* 236(3-4): 185-201.

Sophocleous, M. A., J. K. Koelliker, R. S. Govindaraju, T. Birdie, S. R. Ramireddygari and S. P. Perkins. 1999. Integrated numerical modeling for basin-wide water management: The case of the Rattlesnake Creek basin in south-central Kansas. *J. Hydrology* 214(1-4): 179-196.

Shiono T., H. Nakamura, N. Haraguchi, and T. Miyamoto. 2004. Sediment removal efficiency of vegetative filter strips under a rainstorm condition. In *Proc. International Symposium on Identification and Use of Microbial Resources for Sustainable Agriculture*. Paper No. P-52. Kumamoto, Japan.

Tuppad, P., K. R. Mankin, J. M. S. Hutchinson, J. A. Harrington, and J. K. Koelliker. 2003. Targeting watershed improvement efforts using AGNPS-GIS modeling results. In *Proc. AWRA Agricultural Hydrology and Water Quality Conference*. Kansas City, MO: AWRA

Tuppad, P., 2006. Hydrologic modeling response to NEXRAD and raingage spatial variability and strategic watershed management. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

USEPA. 2000a. *Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria - Rivers and Streams in Nutrient Ecoregion IX*. Washington, D.C.: USEPA, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Available at: www.epa.gov/waterscience/criteria/nutrient/ecoregions. Accessed March 31, 2009.

USEPA. 2000b. *Ambient Water Quality Criteria Recommendations-Lakes and Reservoirs in Nutrient Ecoregion IX*. EPA-822-B-00-011. Washington, D.C.: USEPA, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Available at: www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes. Accessed April 30, 2009.

USEPA. 2001. *Chesapeake Bay Program Nutrient Trading Fundamental Principles and Guidelines*. EPA 903-B-01-001. Washington, D.C.: Chesapeake Bay Program Nutrient Trading Negotiation Team, USEPA.

USEPA. 2004. *Water Quality Trading Assessment Handbook*. Washington, D.C.: Office of Water. USEPA.

Van Liew, M. W., J. G. Arnold, and J. D. Garbrecht, 2003. Hydrologic simulation on agricultural watersheds: choosing between two models. *Trans. ASAE* 46(6): 1539-1551.

Wang, Y. Y., 1971. Probability of the type I error of the Welch tests for the Behrens-Fisher problem. *J. Amer. Statistical Assoc.* 66: 605-608.

Wanielista, M. P., R. Kersten, and R. Ealgin, 1997. *Hydrology: Water Quantity and Quality Control*. New York, NY: John Wiley & Sons.

Welch, B. L., 1947. The generalization of "student's" problem when several different population variances are involved. *Biometrika* 34: 28-35.

Whitney, D. A., L. R. Stone, K. A. Janssen, and J. H. Long. 1991. *The Effects of Nitrogen Fertilizer on Soil*. C-625. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Whitney, D. A., D. L. Devlin, and D. J. Jardine. 1999. *Kansas No-Till Handbook*. S-126. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Wood, A. and R. Bernknopf, 2003. Preliminary Review for a Geographic and Monitoring Program Project: A review of point source-nonpoint source effluent trading /offset systems in watersheds. Open file report 03-79. Washington, D.C.: USGS.

Woodward, R. T., and R. A. Kaiser, 2002. Market Structures for U.S. Water Quality Trading. *Rev. Agr. Econ.* 24: 366-383.

WRI, 2007. NutrientNet. World Resources Institute (WRI), Available at: www.nutrientnet.org. Accessed April 30, 2009.

Chapter 3 Assessing Site-specific Nutrient Load Reduction Using SWAT for Water Quality Trading

Abstract

Water quality trading (WQT) is a market-based approach to improve water quality. The potential issue impeding WQT is its inability to address trading risks and quantify the uncertainty of reducing potential nutrient load. This study simulates agricultural cropland with several alternative land management practices to identify trends among these scenarios. Based on previous WQT pilot studies, we developed a systematic method with SWAT watershed model and 225 potential alternative scenarios to analyze the potential nutrient load reduction, uncertainty, and the in-field trading ratio in the Lower Kansas watershed, Kansas. Several approaches quantified the environmental benefits of WQT. Uncertainty was used with the pairwise comparison and t-test method to estimate variation in potential NPS load reduction at several confidence levels. With the variation of the uncertainty in potential nutrient load reduction, the uncertainty ratio and trading ratio are then calculated. The analyses of site-specific effects in both geospatial and temporal aspects were also applied on subbasin level nutrient load analyses in the study watershed. The variant loading patterns and time distributions of each subbasin show strong site-specific phenomena. Advanced ANOVA tests and LSD statistics were performed on scenario design variables. The main effects and cross effects show significant differences among design criteria. Therefore, the pairwise comparison results in LSD provide a good potential alternative for scenario evaluation and selection for WQT programs.

3.1 Introduction

3.1.1 Rationale and Overview for WQT

Agricultural activities strongly influence surface water quality conditions in Kansas. Soil erosion from cropland elevates concentrations of silt in many streams and lakes. In stormwater runoff, the flushed fertilizers containing nitrogen and phosphorus promote algal growth and eutrophication, and detract from recreational and drinking uses of surface water. Discharging inorganic nitrogen and phosphorus from wastewater treatment facilities (WWTFs) and the other point sources also influence surface water quality throughout Kansas (KDHE, 2008). Moreover, both nutrient sources eventually degrade water quality in the Gulf of Mexico (Burkart and James, 1999; Osterman et al., 2006; Dale et al., 2007).

Nutrient loads exported across the Kansas border toward the Gulf of Mexico consist of about 46,266 Mg (51,000 tons) of total nitrogen (TN) and 6,985 Mg (7,700 tons) of total phosphorus (TP) in 2004 (KDHE, 2004). The portion of point sources (PS) contributing to each nutrient pollutant are about 18% for TN and 25% for TP compared to 82% for TN and 75% for TP of the non-point sources (NPS) (KDHE, 2004). Reducing NPS pollution is critical to improving water quality. However, the traditional voluntary programs to alleviate NPS pollution show little promise of achieving the water quality targets on schedule. Thus, alternative methods and innovative policy solutions are needed. One innovative idea to manage the non-point source pollution is the water quality trading (WQT) program (Leatherman et al., 2004). This idea pulls the trading-market structure into a water quality control program that optimizes both economic and environmental benefits.

WQT is a market-based approach to improving water quality. The basic idea behind WQT is to create a market in which all the sources of pollution are jointly charged with the task of meeting a water quality goal. WQT provides a platform for participants to find the least-cost method to achieve both their financial goal and water quality mandate. Assuming all sources account for a minimum level of pollution prevention and that no “backsliding” or degradation of water quality is permitted, the trading program would allow industrial and municipal facilities (PS) with higher reduction cost to purchase equal or higher (e.g., two times) equivalent pollutant load reduction from agricultural producers (NPS), who have lower costs. The PS would achieve a targeted level of pollution reduction for less because NPS sell equivalent environmental credits to reduce pollution. This trading process might allow both seller and buyer to economically achieve water quality improvements in the watershed.

The framework for WQT programs has been in place for more than a decade (USEPA, 2004), with at least 40 projects nationwide and another 26 watersheds proposed projects in 2004 (Environomics, 1999; Breetz et al., 2004). The design of a WQT program requires an understanding of the targeted pollutant and the watershed it affects. The candidate pollutant (e.g., TN or TP) may come from either PS or NPS, but the pollutant loading processes might be quite different depending upon the source. Most PS pollutant loads are nearly consistent from day to day, but NPS loads, the by-product of storm water runoff, is event based with widely varying pollutant loads. While improving WWTFs can directly reduce PS pollution, implementing agricultural best management practices (BMPs) in the field may or may not offer any decrease in NPS pollution. The differences of measurement scale, pollution origins, and source locations make the uncertainty of a trade between PS and NPS significant. To describe the uncertainty of a trade and calculate environmental equivalents that incorporate uncertainty, a trading ratio was introduced as an exchange rate between PS and NPS to address trading risk.

The description of the uncertainties of a trade and the calculation the pollutant load reduction equivalents is the trading ratio. Trading ratio is the exchange rate between seller and buyer, addressing the potential risk of being unable to complete the trade. A higher trading ratio represents a higher risk in the trade with a subsequent reduced incentive for stakeholders. Traditionally, for a WQT program, an empirical, fixed trading ratio was used, treating the whole watershed as a homogeneous system and neglecting the natural and environmental uncertainty. This causes an overestimate (or underestimate) of the variation and interaction of pollutant load in spatiotemporal scale.

WQT programs have attempted to modify the market structure of the air emission trading program. Although sulfur dioxide (SO_2) emission trading programs have shown some success, fewer trades have actually occurred in each WQT program (Nelson and Keeler, 2005). The differences in the geospatial scale of trading markets as well as the pollutant fate from buyer to seller might explain the less successful results of WQT. The most likely impediments to low trading volume include, but are not limited to, lack of information among stakeholders, excessive transaction costs, fixed trading ratio, inability to address environmental uncertainties, and other intangible costs among stakeholders (Smith, 2004; Lee et al., 2005). These impediments in the WQT market relate to the trading risks and strongly decrease incentives to trade, reducing the willingness of stakeholders to participate.

In summary, trading credit pricing methods, use of a trading ratio and the selected modeling tool affect stakeholders' willingness to participate in a WQT program. An improved trading process and simulation for WQT should provide better results and a more successful WQT program (Hoag and Hughes-Popp, 1997). The key to these proposed improvements in WQT programs is improved representation and incorporation of uncertainty.

3.1.2 Uncertainty of WQT

The uncertainties among the trading processes and simulation methods are various, including uncertainties of the in-field pollutant load and load reduction, in-stream delivery effects, lake detention effects, multi-pollutant interactions, and watershed heterogeneity in space and time. In economic terms, the uncertainties may originate from market structure, willingness of stakeholders, life span of BMPs, operation and maintenance costs of BMPs, government policy, water quality standards and regulation, and the other intangible costs of WQT. In prior research, the sources of uncertainty were easy to identify, but those uncertainties could not be clearly quantified using scientific methods. Therefore, research addressed the uncertainties of WQT as a transaction cost (Curley, 2003). However, the transaction costs primarily relate to WQT processes and market structure. Woodward and Kaiser

(2002) defined the transaction costs as search and information, bargaining and decision, monitoring and enforcement, and transportation and set up. The EPA WQT assessment handbook (USEPA, 2004) defined transaction costs as “the costs represent[ing] all the resources needed to implement the trade, including information gathering, negotiation, execution, and monitoring.” Including pollutant load uncertainty into transaction costs is not viable, and the meaning of “transaction cost” itself could be misconstrued if it is included. Moreover, the uncertainty of PS is relatively smaller than NPS.

The other elements of WQT related to uncertainty are the trading credit and its price. The total amount of pollutant load reduction needed at the PS site is nearly constant within a trade, no matter where the load reduction actually occurred. Hence, the effective load reduction traded from NPS to PS will depend on NPS-PS spatial location, land management practice, and the other characteristics. The WQT assessment handbook defined trading credit as "a measured or estimated unit of pollutant reduction representing a level of control beyond that needed to meet a water quality based effluent limit (for an NPDES permitted) or a TMDL allocation (for a nonpoint source) which may be exchanged in a trading program" (USEPA, 2004). If an NPS trades with different PS, even one with the same pollutant load reduction, the amount of effective load reduction for each PS will vary. In other words, the same NPS in-field load reduction may provide different effectiveness for different PS. That means NPS must provide different trading credits for different PS, or PS must purchase different amounts of trading credits from different NPS to meet its water quality goal. Therefore, the constant NPS control cost divided by the variable number of trading credit in each NPS-PS trading case means the price of each trading credit for each trading case will also vary. In this method uncertainty is incorporated directly into the price of trading credits, which obscures the calculation processes and confuses stakeholders.

A new approach may quantify the uncertainties of WQT. The trading credits could be based on the average in-field pollutant load reduction. WQT could show the magnitude of environmental uncertainty at the edge of field and in the stream network as an uncertainty ratio, a delivery ratio, and then a TR. The price for each trading credit would be fixed with the total implementation cost of NPS. Furthermore, the total cost for PS would depend on total credits purchased with the other transaction costs incorporated with economic uncertainty. Therefore, the uncertainty can be separated into environmental and economic areas that should provide a clearer picture of the WQT program.

3.1.3 Objectives

The objective of this study was to find a method to quantify and represent the spatial and temporal uncertainties of WQT for a test watershed. This research used a watershed model and GIS applications to capture site specific differences among alternative land management practices for potential pollutant loads, load reduction, uncertainty ratio, and trading ratio for TN and TP. The hypothesis was that accurate representation of uncertainties will decrease user costs of a WQT system while maintaining target water quality benefits.

3.2 Materials and Methods

3.2.1 Environmental Equivalence and Trading Ratio

To simplify the distribution of NPS pollutant reduction, it will be treated as a normal distribution (a curve), while the required abatement of PS will be assumed to be a constant (a vertical line). If the uncertainty of pollutant load can be neglected, the match point of load equivalence between PS and NPS would be on the mean of NPS reduction distribution curve, shown as a red line in Figure 3-1. However, in most of cases, the uncertainty of pollutant load is large enough that it cannot be eliminated from a WQT program. To minimize the trading risks, either the purchased amount must be increased or the effective load reduction from NPS decreased by shifting the intersection of the PS line and NPS curve to the left of the NPS mean, as shown by the black dashed line in Figure 3-1. This shift implies that a lower PS load (in this case, 700 kg) is equivalent to a given NPS load (1000 kg) given a higher confidence (lower risk) level in the same trade. The area below the NPS curve extending to the X-axis and between the PS line and Y-axis is the total probability of failure for a PS-NPS trade. Once the distribution of load reduction is found, estimating the TR with given confidence level would be easy, as would finding the confidence level from given load reduction threshold. For example, the area below a normal distribution curve and right of mean value minus one standard deviation ($\mu - \sigma$) line would represent an 86.4% confidence level.

The X-axis value for the intersection represents the trading result of potential load reduction at that confidence level. For instance, assuming the NPS load reduction mean equals 1000 kg and the standard deviation is 200 kg, for mean minus one standard deviation confidence, the trading results are 800 kg. Thus, purchasing 1000 kg load reduction from NPS would mean at least 800 kg are effective under one standard deviation or 86.4% confidence level. In other words, NPS has a confidence of providing at least 800 kg load reduction to PS 86.4% of the time. The trading ratio (TR), also known as environmental equivalent ratio (USEPA, 2004), can then be defined as the purchased amount divided by effective amount of pollutant load reduction. For the 86.4% confidence case (Figure 3-1), the TR would be 1000/800 = 1.25.

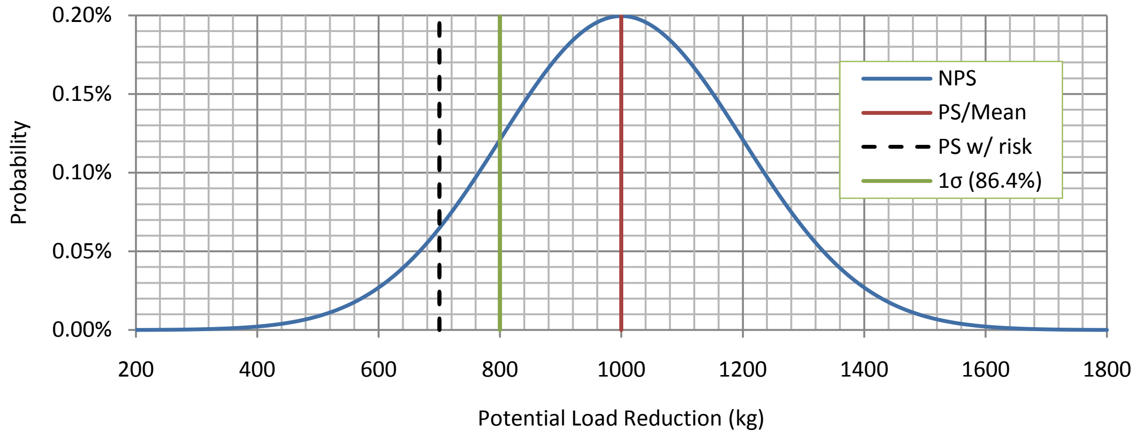


Figure 3-1 Hypothetical Probability Distribution Curves of NPS Pollutant Load Reduction

In WQT, TRs are used to calculate the equivalence of load reductions to compensate for trading uncertainty between different pollutant sources based on their physical characteristics, land management practices, multi-pollutant cross-effects, and the other spatiotemporal influences between trading partners. It could be treated as an exchange rate that establishes equivalence between trading partners who may have different measures and baselines of pollutant load. TRs also can ensure that the equivalence of trades be achieved at a specific confidence level. Traditionally, fixed, universal TRs (commonly 2:1) used in WQT programs provide a safety factor for empirically estimating trading results. However, this artificial level may force a trade with an unreasonable confidence level, which might require a PS to purchase more credits from NPS than needed and at higher total cost. Alternatively, a variable, floating TR system, based on the pollutant load reduction uncertainty and watershed spatiotemporal variation, can provide a matrix of TRs for each scenario and geographical location. Thus, although a fixed TR gives a simple solution for WQT, a floating TR provides more accurate information upon which to define the trade. Therefore, in this study, WQT TRs are separated into an in-field uncertainty ratio and an in-stream delivery ratio derived from the probability distribution of pollutant load reduction with sound scientific watershed model and GIS techniques.

Assuming P_{LMP1} is the annual pollutant load from current land management practice (LMP_1) and P_{LMP2} is the annual pollutant load from an alternative land management practice (LMP_2), the annual pollutant load reduction between LMP_1 and LMP_2 is (P_{LMP1} - P_{LMP2}) for the same year. Environmental uncertainty within the watershed may cause the pollutant load reduction of each year to differ. If $P_{AVG\,(1-2)}$ is the mean value of n years of pollutant load reduction for the land management practice changing from LMP_1 to LMP_2, $P_{AVG\,(1-2)}$ would be equal to the weighted average of all annual load reductions (see Eq. 3-1). If current land management practice is used as a baseline scenario, the pollutant load reduction for each baseline-alternative scenario can be explained as the relative pollutant load reduction index, or BMP reduction efficiency factor ($BMP_{R(b-*)}$), where b represents the baseline scenario and the * could be any other potential alternative land management practice applied to the field. Assuming current land management practice LMP_1 and alternative practice LMP_2, Eq. 3-2 describes the relationship of $BMP_{R(1-2)}$, the relative pollutant load reduction index between P_{LMP1} and P_{LMP2}.

$$P_{AVG(1-2} = \frac{1}{n}\sum_{i=1}^{n} w_i\left(P_{LMP_1} - P_{LMP_2}\right)_i \qquad \text{Eq. 3-1}$$

$$BMP_{R(1-2)} = \frac{1}{n}\sum_{i=1}^{n} \frac{w_i\left(P_{LMP_1} - P_{LMP_2}\right)_i}{P_{LMP_1}} \qquad \text{Eq. 3-2}$$

To account for the potential environmental uncertainty or trading risk of a trade, two ratios, uncertainty ratio for pollutant load reduction at the in-field (R_U) and delivery ratio for in-stream load reduction attenuation (R_D), are developed to explain the uncertainty due to land management practice or in-stream transport. The in-field R_U is defined as the potential deviation of pollutant load reduction due to the uncertainty divided by the arithmetic mean of all load reductions. Generally, R_U should range from 0 to 1. For special cases, when R_U equals 0, there is no potential deviation in load reduction. In contrast, if R_U equals 1, the potential load reduction deviation is equal to its mean, which represents a non-recommended scenario with extremely high uncertainty. The in-stream R_D is defined as the outflow pollutant load divided by the inflow load within a watershed or a river section. In general, R_D also ranges from 0 to 1. For some extreme cases, when R_D equals 0, there is no outflow pollutant load. This may imply that the entire pollutant load settled or otherwise removed within that watershed or river section. If R_D equals 1, the entire inflow pollutant load was completely transported to the outlet without any attenuation or degradation.

As described previously, a TR is the expected pollutant load reduction produced when NPS is divided by the actual pollutant load reduction received by PS, which provides an exchange rate required to maintain the pollutant load reduction equivalence between the seller and buyer in a trade. Hence, a TR can be rewritten as a function of R_U for in-field pollutant load reduction and R_D for in-stream pollutant load transportation (see Eq. 3-3).

$$TR = \frac{In\ Field\ Load\ Reduction}{Delivered\ Load\ Reduction} = \frac{P_{LMP_1} \times BMP_{R(1-2)}}{P_{LMP_1} \times BMP_{R(1-2)} \times (1 - R_U)R_D} = \frac{1}{(1 - R_U)R_D} \qquad \text{Eq. 3-3}$$

3.2.2 In-Field Uncertainty Ratio

To quantify the uncertainty of in-field pollutant load reduction, the load reduction between current and alternative land management practice must be defined. If the load reduction is not significantly different between current and alternative scenarios, changes in land management will not produce significantly different pollutant load, which implies that the alternative method would not be a tradable option. Even if the load reduction is statistically significant, it should be positive to benefit the environment. A method should also allow us to assess and quantify the probability associated with in-field load reduction uncertainty. Based on statistical theory (e.g., t-test) with a given confidence level, the R_U can then be derived to address the degree of difference among alternatives.

3.2.2.1 *Test Equality of Mean*

The average of in-field pollutant load for current land management practice LMP_1, or the statistical sample mean for LMP_1, can be derived as $\bar{X}_1$. The estimated sample variance for LMP_1 is S_1^2, which can be derived with Bessel's correction from a series of sampled pollutant loads with n observations. Similarly, for alternative land management practice LMP_2 we can define $\bar{X}_2$ and S_2^2. To test the research question with statistical analyses, each sampled pollutant load of LMP_1 and LMP_2 was assumed to be statistically independent or dependent with an unknown variance, which may not be equal to each other. With these assumptions, Welch's t-test method was developed to test two series of pollutant load observations with either paired (dependent) or unpaired (independent) analyses. The unpaired observations t-test determined if the mean of first series of observations was equal or not equal to the mean of second series observations. In contrast, the paired observations t-test determined if the mean value of differences between each pair observations was equal or not. In other words, the unpaired t-test tested the equality of the mean of two groups of load observations, but the paired t-test tested whether the mean of the series of load reductions was equal to zero (SAS Institute Inc., 2004).

The null hypothesis (H_0) for testing load differences between two series of observations is $\mu_1 - \mu_2 = 0$, where μ_1 and μ_2 are the population means of pollutant loads for LMP_1 and LMP_2. Eq. 3-4 describes the t-test problem for the paired observations. In Eq. 3-4, $\bar{X}_d$ and S_d represent the sample mean and standard deviation for the differences of each paired observation (SAS Institute Inc., 2004). For the unpaired observations, n_1 and n_2 were assumed to be the number of pollutant load observations randomly sampled from normally distributed LMP_1 and LMP_2. The population variance is unknown and may not be equal to each other; this testing scenario is the Behrens-Fisher problem (Lauer and Han, 1974). Using these assumptions, the approximate statistic t can be computed with Eq. 3-5, which is

Welch's approximate t solution (Welch, 1947; Wang, 1971). The effective degrees of freedom ν associated with this linear combination of sample variance estimates is approximated using the Welch-Satterthwaite method (see Eq. 3-6; Satterthwaite, 1946; SAS Institute Inc., 2004).

The statistical p-value is obtained as the probability that a result at least as extreme as the one that was actually observed, assuming that the null hypothesis (i.e., the statistical means of two series of sampled pollutant load are equal) is true. If the calculated p-value is below the threshold chosen for statistical significance (usually the 0.10 or 0.05), then the null hypothesis, which states that the means of two series of pollutant loads do not differ, is rejected in favor of an alternative hypothesis, that the means do differ. For a watershed pollutant load study, assuming two series of observations are independent, the unpaired analysis can be applied to the relationship between current and alternative land management practice. Conversely, if every set of observations of two series of pollutant loads has a unique relationship, as with precipitation or temperature at that time step, it is dependent. Therefore, the paired analysis will be used to define the relationship between current and alternative options.

$$t = \frac{\bar{X}_d - \mu_0}{\frac{S_d}{\sqrt{n}}} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(x_{1_i} - x_{2_i}\right) - 0}{\frac{S_d}{\sqrt{n}}} \qquad \text{Eq. 3-4}$$

$$t' = \frac{\bar{X}_i - \bar{X}_j - \mu_0}{\sqrt{\frac{S_i^2}{n_i} + \frac{S_j^2}{n_j}}} = \frac{\bar{X}_1 - \bar{X}_2 - 0}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \qquad \text{Eq. 3-5}$$

$$\nu = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{\left(\frac{S_1^2}{n_1}\right)^2}{(n_1 - 1)} + \frac{\left(\frac{S_2^2}{n_2}\right)^2}{(n_2 - 1)}} = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1 - 1)} + \frac{S_2^4}{n_2^2(n_2 - 1)}} \qquad \text{Eq. 3-6}$$

When the statistical mean of sampled pollutant loads of LMP_1 and LMP_2 is not statistically equal, in other words, the pollutant load difference between LMP_1 and LMP_2 is statistically significant, the mean of pollutant load difference between LMP_1 and LMP_2 with n observations can be expressed as $P_{AVG(1-2)}$ (see Eq. 3-7). The relative pollutant load reduction index, or BMP reduction efficiency factor ($BMP_{R(1-2)}$), which was described in Eq. 3-2, can be rewritten as Eq. 3-8 with $\bar{X}_1$ and $\bar{X}_2$.

$$P_{AVG(1-2)} = \left(\bar{X}_1 - \bar{X}_2\right) \qquad \text{Eq. 3-7}$$

$$BMP_{R(1-2)} = \frac{\left(\bar{X}_1 - \bar{X}_2\right)}{\bar{X}_1} = \frac{P_{AVG(1-2)}}{\bar{X}_1} \qquad \text{Eq. 3-8}$$

3.2.2.2 *Estimate Relative Load Reduction Uncertainty*

Assuming α is a type I error in the statistical analysis, the approximate 100(1-α) % confidence interval (CI) for paired observations of pollutant load reduction can be derived as Eq. 3-11 with its mean ($\bar{X}_d$) and standard deviation (S_d). For the unpaired observations, with the mean of LMP_1 and LMP_2 ($\bar{X}_1$and $\bar{X}_2$), their variances (S_1^2 and S_2^2), and the number of observations (n_1 and n_2), the confidence interval (CI) can be explained by Eq. 3-12. In studying the probability of pollutant overload cases, only the lower bound confidence limit is of interest. Therefore, Eq. 3-11 is written in estimating the lower bound confidence limit for paired scenarios, and Eq. 3-12 is in estimating the lower bound confidence limit for unpaired scenarios. An effective pollutant load reduction of WQT infers a potential positive load reduction from a trade. Hence, the confidence limits in Eq. 3-11 and Eq. 3-12 need to be more than zero to support a potential trade.

$$CI(\bar{X}_d) = \bar{X}_d \pm t_{(1-\alpha/2),v} \cdot \frac{S_d}{\sqrt{n}} \qquad \text{Eq. 3-9}$$

$$CI(\mu_1 - \mu_2) = \bar{X}_1 - \bar{X}_2 \pm t_{(1-\alpha/2),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \qquad \text{Eq. 3-10}$$

$$CL_L(\bar{X}_d) = \bar{X}_d - t_{(1-\alpha),v} \cdot \frac{S_d}{\sqrt{n}} \qquad \text{Eq. 3-11}$$

$$CL_L(\mu_1 - \mu_2) = \bar{X}_1 - \bar{X}_2 - t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \qquad \text{Eq. 3-12}$$

With the lower bound 100(1-α)% confidence limit equations described in Eq. 3-11 and Eq. 3-12, the magnitude of load reduction uncertainty can be described as the observations deviating from the mean of potential load reduction. Thus, the potential magnitude of uncertainty, or the observed load reduction deviation at 100(1-α) % confidence level, can be explained as a deviation radius. Therefore, to compare the magnitude of potential uncertainty of pollutant load reduction or the deviation radius of baseline scenario within several methods, the absolute value is often transformed into relative form. To formulate this transformation of deviation, the radius term in both Eq. 3-11 and Eq. 3-12 can be divided by its mean as the relative deviation radius. The R_U is formulated at 100(1-α) % confidence level with the mean load reduction, standard deviation or variance, and number of observations by Eq. 3-13 (for the paired scenario) and Eq. 3-14 (for the unpaired scenario).

$$R_U = \frac{t_{(1-\alpha),v} \cdot \frac{S_d}{\sqrt{n}}}{\bar{X}_d} \qquad \text{Eq. 3-13}$$

$$R_U = \frac{t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}{\bar{X}_1 - \bar{X}_2} \qquad \text{Eq. 3-14}$$

As previously stated, a trade with a potential positive load reduction implies a case for WQT. That means the primary assumption for Eq. Eq. 3-11 and Eq. 3-12 is that $\bar{X}_d$ and $\bar{X}_1 - \bar{X}_2$ need to be more than zero to derive a meaningful R_U. For extreme cases, when the sample mean of load reduction is less than zero ($\bar{X}_d < 0$), R_U will be assigned 0 to show the potential for WQT in these cases is not applicable.

In a simplified WQT scenario, if the pollutant transport or delivery effect can be neglected, the potential load reduction or tradable environmental credits will only account for the uncertainty of in-field load reduction. Therefore, the R_D can be assumed to be 1, and Eq. 3-3 can be rewritten as Eq. 3-15. In this simplified WQT scenario, the TR is solely based on the in-field load reduction R_U; this TR is defined as in-field trading ratio (TR_{IF}).

$$TR_{IF} = \frac{1}{(1 - R_U) \cdot R_D} = \frac{1}{(1 - R_U) \cdot 1} = \frac{1}{(1 - R_U)} \qquad \text{Eq. 3-15}$$

3.2.3 Site-specific Effect

Owing to watershed heterogeneity, there might be site-specific effects within the study area. Site-specific effects describe the differences in hydrologic responses because of geospatial (location) and temporal (time scale) heterogeneity within a watershed. Different sub areas of a watershed with specific climate, soil types, land cover, and topography may induce different hydrologic responses and generate different soil erosion and pollutant loads. The major sources of surface runoff are rainfall and snow melt. Irrigation operations could also contribute to runoff. Surface runoff strongly influences soil erosion and pollutant loads. More surface runoff provides more opportunities for soil erosion and pollutant loads from a field. In Kansas, seasonal variability in hydrology and landcover are often quite substantial (Sophocleous, 1998). Other land-management factors, like alternative land management practices on a field, might also produce distinct pollutant loads from wet to dry seasons as well as in individual months. To address the magnitude of generated loads on event-, monthly- or seasonal periods, a watershed-scale model is required.

Site-specific effects can be addressed by delineating a watershed into smaller pieces in geospatial scale (such as by grouping hydrologic response units [HRUs] with similar soil, slope, and land-cover characteristics) and dividing the modeling time step into shorter temporal scales. Each subbasin and HRU can be modeled individually to determine the specific pollutant load, load reduction, uncertainty ratio, and TR at each time step. The model simulations for each time step can be aggregated into a larger subbasin or longer time intervals.

To present and illustrate the potential site-specific effects on a geospatial scale within a watershed, a geospatial application or GIS is better than traditional tables and charts. Moreover, to address the site-specific effect on a temporal scale, a contribution factor (CF) can be used. The contribution factor defined the nominal tradable load reduction at the edge of field for the seller (P_{NR}). If the annual reduction is AP_{NR} and the reduction for a single season or month is SP_{NR}, the contribution factor for a specific month or season can be defined as a ratio of SP_{NR} to AP_{NR} as in Eq. 3-16.

$$CF = \frac{Seasonal\ (monthly) Load\ Reduction}{Annual\ Load\ Reduction} = \frac{SP_{NR}}{AP_{NR}} \qquad \text{Eq. 3-16}$$

3.2.4 SWAT Model Overview

SWAT is the acronym for Soil and Water Assessment Tool, a physically based, river basin/ watershed scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS) (Neitsch et al., 2005). SWAT has been used in several states for WQT pilot studies or evaluations, such as the Fang's (2005) evaluation of the Great Miami River Watershed, Ohio, and Kramer's (2003) and Baumgart's (2005) studies of Fox-Wolf River, Wisconsin. SWAT is currently being tested in the Kansas Kanopolis watershed (Tuppad et al., 2003; Tuppad, 2006), the Clinton Lake area (Parajuli, 2007), Rattlesnake Creek basin (Sophocleous et al., 1999), and Delaware subbasin (Nelson et al., 2006), as well as in other research (Sophocleous and Perkins, 2000). Based on these prior investigations, SWAT is well suited for examining the long-term impact of climate variability in Kansas. Therefore, SWAT was selected to simulate watershed water-quality outcomes for each potential WQT scenario in this study.

SWAT was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, landuse, and management practices over long periods (Neitsch et al., 2005). It is a continuous time, distributed parameter hydrologic model that uses spatially distributed data on topography, landuse, soil, and climate for hydrologic modeling, operating on a daily time step (Arnold et al., 1998). The model is not designed to simulate detailed, single-event flood routing. Based on topography, SWAT divides a watershed into several subbasins for modeling. Each subbasin delineated within the model is simulated as a homogeneous area for climatic conditions and topography, but additional subdivisions are used within each subbasin to represent unique land cover, soil, and management combinations. Each of these individual areas is called a hydrologic response unit (HRU), assumed to be uniformly distributed and to inherit the geospatial properties of that subbasin. SWAT predicts runoff separately for each HRU at a time step and then aggregates the weighted results to each subbasin as well as routing to obtain the final surface runoff for the watershed at the same time step.

A SWAT model of watershed processes is based on the hydrologic cycle with water balance equation. The simulation processes can be separated into two major divisions: the land phase and the water or routing phase of hydrologic cycle. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrient, and pesticide loadings to the main channel in each subbasin. Based on the water balance equation and hydrologic cycle, SWAT simulates land phase processes with several components, like precipitation, snow, soil temperature, infiltration, evapotranspiration, lateral flow, surface runoff, soil water, groundwater, nutrients/pesticides/ bacteria estimation, plant growth, land management practices, as well as sediment erosion and nutrient, pesticide, and bacteria transport via overland flow. Once SWAT determines the in-field pollutant loads in the land phases, the routing phases of SWAT are activated to route water, sediment, nutrient, pesticide, bacteria, or heavy metals in both stream and lake. In addition to keeping track of mass flow in the waterbodies, SWAT models the transformation of nutrient and pesticide between the water and benthos (Neitsch et al., 2005).

For this study, the daily water budget in each HRU was computed based on historical daily precipitation and temperature as well as simulated runoff, evapotranspiration (ET), percolation, and return flow from the sub-surface and groundwater flow. Runoff and infiltration volume in each HRU was computed using the Soil Conservation Service (now the Natural Resource Conservation Service, NRCS) runoff curve number method (NRCS, 2004). Peak runoff rate was computed with a modified rational method (Neitsch et al., 2005). Potential evapotranspiration (PET) was estimated using Hargreaves method (Hargreaves and Samani, 1985), which requires daily air temperature only. Lateral sub-surface flow was computed using a kinematic storage model (Sloan et al., 1983; Sloan and Moore, 1984). The transmission losses were estimated with the ephemeral procedure described in Chapter 19 of Part 630 Hydrology of USDA NRCS National Engineering Handbook (NRCS, 2007a).

Flow in a watershed can be classified as overland or channelized. The primary difference between the two flow processes is that water storage and its influence on flow rates is considered in channelized flow (Neitsch et al., 2005). SWAT computed both overland flow and channel flow using Manning's equation but with a different Manning's roughness coefficient n. Channel flow assumed delivery in a trapezoidal intersection with 2:1 side slopes and a 10:1 bottom width-depth ratio and adjusted for transmission losses, evaporation, diversions, and return flow (Neitsch et al., 2005).

SWAT uses a single plant growth model, a simplified version of EPIC plant growth model, to simulate annual and perennial plants for all types of land covers (Neitsch et al., 2005). As in EPIC, phonological plant development is based on daily accumulated heat units, potential biomass is based on a method developed by Monteith(Neitsch et al., 2005), a harvest index is used to calculate yield, and plant growth can be inhibited by temperature, water, and nitrogen or phosphorus stress. However, annual plants grow from the planting date to the harvesting date or until the accumulated heat units equal the potential heat units for the plant. In contrast, perennial plants maintain their root systems throughout the year, becoming dormant after frost. Perennial plants resume their growth when the average daily air temperature exceeds the minimum, or base, temperature required (Neitsch et al., 2005). The plant growth model o simulates all types of land covers in the watershed and assesses total water and nutrient removal from the root zone, as well as transpiration and biomass production.

Erosion includes the detachment, transport, and deposition of soil particles by the erosive forces of raindrops and surface flow of water. Erosion caused by rainfall and runoff in SWAT is computed with the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977). MUSLE is a modified version of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965; Wischmeier and Smith, 1978), deriving a sediment yield estimation model based on runoff characteristics, as the best single indicator for sediment yield prediction. As shown in Eq. 3-18, MUSLE redefined sediment yield prediction as the function of runoff volume (Q), peak flow rate (q_P), and other KLSCP factors from original USLE in Eq. 3-17. Moreover, the crop management factor (C) is recalculated every day that runoff occurs and is a function of above-ground biomass, residue on the soil surface, and the minimum C factor of the plant (Neitsch et al., 2005).

$$A = R \times K \times LS \times C \times P \qquad \text{Eq. 3-17}$$

$$Y = 11.8\left(Q \times q_p\right)^{0.56} \times K \times C \times P \times LS \qquad \text{Eq. 3-18}$$

The fate and transport of nutrients in a watershed depend on the transformations the compounds undergo in the soil environment. SWAT models the complete nutrient cycle for nitrogen and phosphorus for each HRU in the watershed. Nitrogen may be added to the soil as fertilizer, manure, or residue, through fixation by symbiotic or non-symbiotic bacteria, and in rain. Nitrogen is removed from the soil by plant uptake, leaching, volatilization, de-nitrification, and erosion. Phosphorus may be added to the soil as fertilizer, manure, or residue application and removed from the soil by plant uptake and erosion. Except for plant uptake, nutrients may be flushed into the main channel and transported downstream through surface runoff, lateral flow, or percolation. The primary forms of nitrogen in SWAT simulation are usually nitrate (NO^{-3}) and organic nitrogen; phosphorus may be soluble, organic, and mineral. In this study, total nitrogen (TN) included both nitrate and organic nitrogen; total phosphorus (TP) included all the soluble, organic, and mineral phosphorus.

The total mass of nitrate lost from the soil layer is obtained through the concentration of nitrate in the mobile water and the volume of water moving in each pathway (Neitsch et al., 2005). Most organic nitrogen attaches to soil particles and is transported to the main channel with soil erosion (sediment). The amount of organic nitrogen transported with sediment to the stream is calculated with a loading function developed by McElroy et al. in 1976 and modified by Williams and Hann in 1978 (Neitsch et al., 2005). The loading function estimates the daily organic nitrogen runoff loss based on the concentration of organic nitrogen in the top soil layer, the sediment yield from the HRU, and the enrichment ratio.

Usually the phosphorus was generalized and simply stated as an immobile nutrient. The chemical form of P in fertilizer materials is phosphate ($H_2PO_4^-$, HPO_4^{-2} or PO_4^{-3}). When applied to the soil, the precipitation occurs rapidly and, therefore, phosphate tends to move very little. This phosphorus precipitation or availability is affected by soil pH. The loss of phosphate (fixation) through precipitation is actually of less concern in alkaline than in acid soils. As a result of precipitation, phosphate does not leach very much. The amount of soluble phosphorus transported in surface runoff is estimated with phosphorus concentration in the top 10 mm of soil layer, runoff volume, and a partitioning factor (Neitsch et al., 2005). Organic phosphorus and mineral phosphorus also attach to soil particles and are transported by surface runoff to the main channel. The amount of phosphorus load transported with sediment is simulated using a loading function similar to organic N transport and developed by McElroy et al. and modified by Williams and Hann (Neitsch et al., 2005).

Therefore, SWAT model was selected to simulate water-quality outcomes of WQT trades in this study. SWAT can simulate an extensive set of agricultural BMPs, ranging from changes in crop types, tillage practices, fertilizer management, and edge-of field conservation practices (Gassman et al., 2007). SWAT has also been applied in Kansas itself (Tuppad et al., 2003) and is well suited for investigating the long-term impact of watershed-process variability in Kansas.

3.3 Study Watershed Description

The Lower Kansas watershed (HUC8: 10270104; Figure 3-2) encompasses portions of eleven Kansas counties (Atchison, Douglas, Jefferson, Johnson, Leavenworth, Osage, Shawnee, Wabaunsee, Wyandotte, and Wyandotte) and Jackson County, Missouri, near the northeastern Kansas-Missouri border, and covers approximately 429,000 ha (1,656 mi^2). The watershed has 99.6% of its area in Kansas with 0.4%

in Missouri. This watershed area is identified by Kansas state agencies as a high priority for NPS nutrient abatement and also a potential TN pollution WQT pilot study area (KDHE, 2004; Leatherman et al., 2005). SWAT modeling requires geospatial referenced data which describe topography, landuse/landcover, soil types and attributes, and climate, all of which are available for the Lower Kansas watershed area. Digital stream network information, historical stream discharge of available gauging stations within the watershed, and upstream ponds and reservoirs storage data were collected and manipulated for stream network analysis. Potential land management practices, plant/crop growing information, field operations, and fertilizer applications were collected from watershed specialists and professionals in the Kansas State University Extension Service as well as from literature reviews, USDA NRCS field offices, and the USDA NRCS electronic field office technical guides (eFOTGs) website (Barnes, 2006; Boyer, 2006; KSU, 2006; Maddux, 2006; NRCS-Kansas, 2006; NRCS, 2008e). This information was used to design the potential alternative land management practices and its inputs for the model. Geospatial referenced digital data were reprojected to a Universal Transverse Mercator (UTM) coordinate system (NAD, 1983; UTM Zone 15N [spheroid = GRS80, NAD 1983]). Throughout the following description and discussion, metric measurement units were used other than some common usage in both metric and English units.

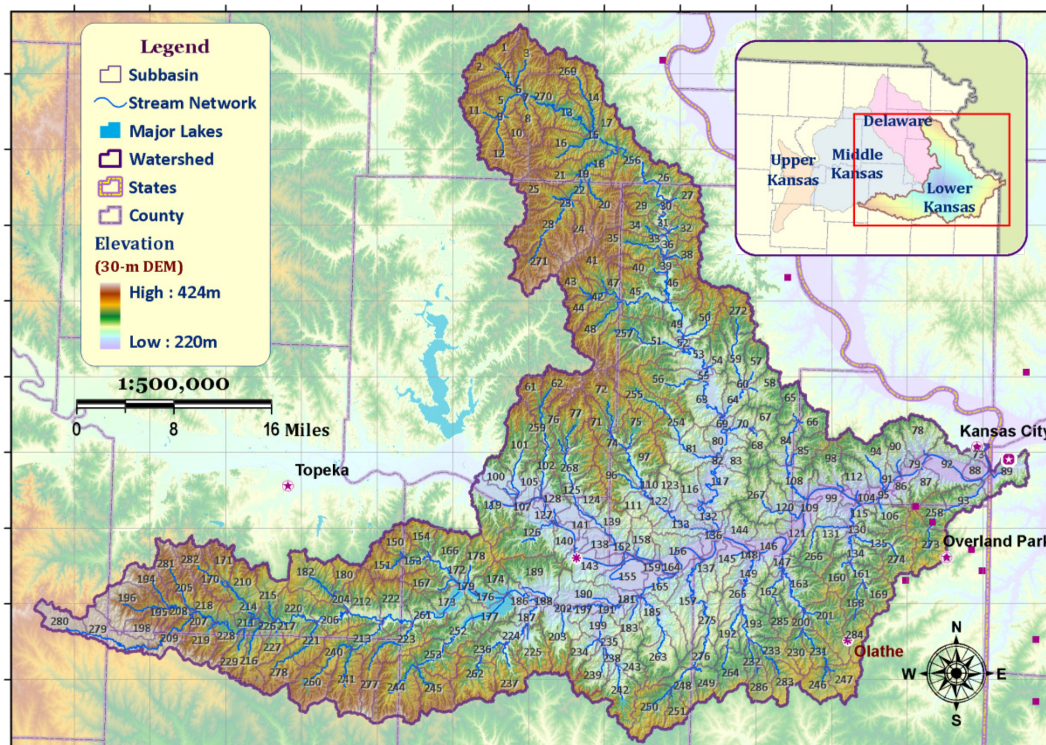


Figure 3-2 Elevation and Subbasin Delineation in Lower Kansas Watershed (10270104)

3.3.1 Elevation and Watershed Delineation

USGS National Elevation Dataset (NED) provided a seamless digital elevation model (DEM) for the entire study watershed at 30-m resolution (USGS, 2006). Figure 3-2 illustrates the terrain of the study watershed where the elevation ranges from 220 m to 424 m with an average 301 m, and the surface slopes (not displayed) range from 0% to 63%. The study watershed boundary and subbasin boundaries were generated from this digital elevation layer and burn-in streams of the high resolution National Hydrography Dataset (NHD) using a watershed delineation tool built into AVSWAT-X, one of the SWAT version 2005 interfaces.

The Federal Geographic Data Committee (FGDC) released the Federal Standard for Delineation of Hydrologic Unit Boundaries in October 2004 to delineate hydrologic unit boundaries consistently, modify existing hydrologic units, and establish a national watershed boundary dataset (WBD) (FGDC, 2004). This guideline provides the criteria and methods for hydrologic unit selection and boundary delineation to develop standardized hydrologic units (FGDC, 2004). Based on this guideline and WBD layers downloaded from USDA Geospatial Data Gateway (USDA, 2008), these boundaries were used as a template for the boundaries generated from the digital elevation. In addition to watershed delineation, the additional geoprocessing functions, such as calculating flow direction and accumulation, longest flow path, or topographic characteristics for each defined subbasin in the watershed, were also based on this digital elevation data.

According to the Kansas 2002 Census of Agriculture report from USDA National Agricultural Statistics Service (NASS), the average farm size in Kansas is approximately 296.6 ha (733 ac), and the weighted average is 130 ha (322 ac) with a median of 52 ha (129 ac) for the study watershed (NASS, 2004). To delineate the study watershed to fit the NASS census results and maintain subbasin in a hydrology-reasonable shape, 990 ha (2450 ac) were set as the stream definition threshold area in the automatic watershed delineation function of AVSWAT-X. With manual adjustments of subbasin shapes and outlets, each area was less than 4000 ha, stream lengths less than 8000 m. A total of 286 subbasins were then delineated with areas ranging from 250 ha to 4000 ha and an average of 1500 ha, about five times the average farm size in Kansas or eleven and half times the size of the watershed average.

3.3.2 Landuse/Landcover

USGS National Land Cover Data (NLCD) developed from Landsat Thematic Mapper (TM) imagery, was acquired at 30-meter resolution (USGS, 1999; Yang et al., 2001; MRLC, 2008). To standardize the process of acquiring WQT data and maintain sufficient data quality, this study first used the NLCD 1992

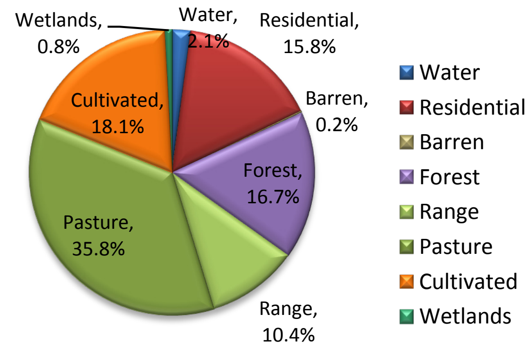
(1992 National Land Cover Data) dataset, and after the new version became available, switched to the NLCD 2001 (2001 National Land Cover Data) dataset. The classification system used for NLCD 2001/NLCD 1992 was modified from the Anderson land-use and land-cover classification system (USGS, 1999). To use the NLCD as the SWAT model landuse dataset, descriptive classes in the NLCD were renamed and/or aggregated with a lookup table to match landuse categories within the internal SWAT landuse/landcover database. Descriptive classes in the coverage were renamed as necessary and/or aggregated to match landuse categories within the internal SWAT landuse/landcover database. Table 3-1 shows the classification and description of the lookup table for both SWAT and NLCD 2001. Based on the classification of SWAT, winter pasture (WPAS) (fescue [FESC]) is the major landuse, occupying 35.83% of the total watershed area. Moreover, agricultural land/row crops (AGRR) occupies 18.10% of the area, forest totals 16.71%, residential urban area 15.84%, range-grasses land 10.41%, water 2.11%, and other minor landuses less than 1% (Table 3-2).

Table 3-1 Landuse Classification, Code and Description for SWAT and NLCD 2001

Code	SWAT Landuse Description	Land Cover Class	NLCD Classification / Description
WATR	Water	Water	11. Open Water
			12. Perennial Ice/Snow
URLD	Residential-Low Density	Developed	21. Developed, Open Space
URMD	Residential-Medium Density		22. Developed, Low Intensity
URHD	Residential-High Density		23. Developed, Medium Intensity
UIDU	Industrial		24. Developed, High Intensity
UINS	Institutional	Barren	31. Barren Land (Rock/Sand/Clay)
FRSD	Forest-Deciduous	Forested Upland	41. Deciduous Forest
FRSE	Forest-Evergreen		42. Evergreen Forest
FRST	Forest-Mixed		43. Mixed Forest
RNGB	Range-Brush	Scrubland	52. Shrub/Scrub
RNGE	Range-Grasses	Herbaceous Upland Natural/Semi-natural Vegetation	71. Grassland/Herbaceous
WPAS	Winter Pasture (Fescue)	Herbaceous Planted/Cultivated	81. Pasture/Hay
AGRR	Agricultural Land-Row Crops		82. Cultivated Crops
WETF	Wetlands-Forested	Wetlands	90. Woody Wetlands
WETL	Wetlands-Mixed		95. Emergent Herbaceous Wetlands

Table 3-2 Landuse Classification for SWAT Model Simulation

Code	Classification	Code	Classification
WATR	Water	RNGB	Range
URLD	Residential	RNGE	
URMD		FESC	Pasture
URHD		AGRR	Cultivated
UIDU		WETF	Wetlands
UINS	Barren	WETL	
FRSD	Forest		
FRSE			
FRST			



In our WQT pilot study, only agricultural landuse would be eligible for trades, and thus only subbasins/HRUs with AGRR landuse provided useful load reduction information. To simplify SWAT modeling and statistical analysis as well as estimating the potential load reduction over the entire study watershed, we first considered the whole watershed, other than water body (WATR), as AGRR. Then, we modeled each alternative land management scenario in every subbasin and HRU with AGRR or WATR landuse to estimate its potential pollutant load. Based on this loading information in every scenario, the pollutant load difference in between any two land management scenarios can be calculated and extracted to create a database for queries. These processes provide a broader scope and a faster way for stakeholders to compare and assess the potential benefits of several methods as well as the spatiotemporal variation within the watershed. Figure 3-3 illustrates the landuse classification and geospatial distribution of NLCD 2001 dataset in study watershed. Figure 3-3 displays the original landuse of NLCD 2001 with SWAT classification method. Figure 3-4 illustrates the simplified landuse for modeling simulation in this study; it includes only AGRR and WATR.

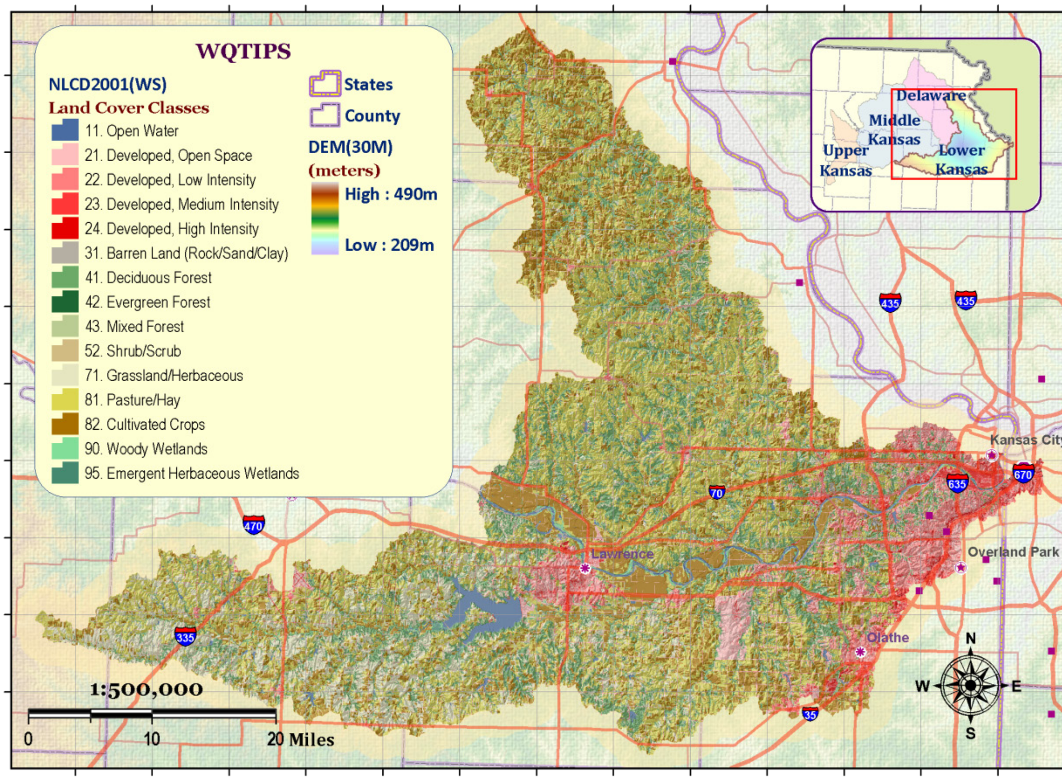


Figure 3-3 Watershed Landuse Based on NLCD 2001 Classification

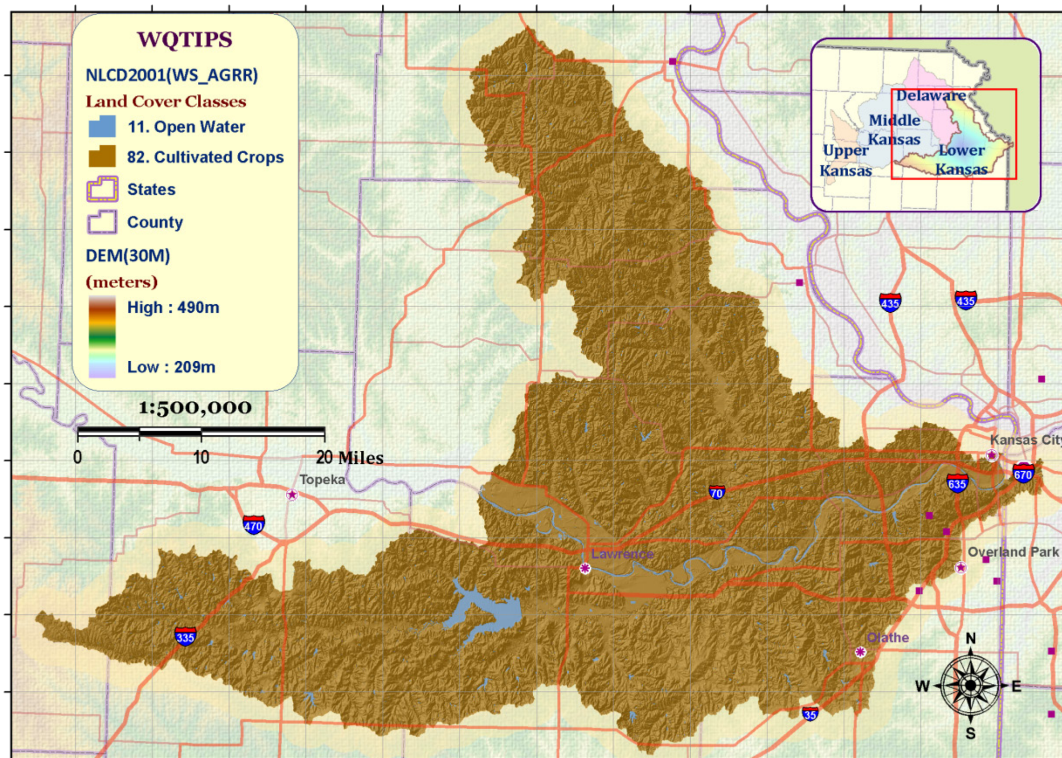


Figure 3-4 Simplified Watershed Landuse with Only WATR and AGRR for Modeling

3.3.3 Soil Data Preparation

The most widely used soil survey databases available in Lower Kansas watershed are the 1:250,000 State Soil Geographic Database (STATSGO) and the 1:24,000 Soil Survey Geographic Database (SSURGO) (NRCS, 1997; NRCS, 2008b; NRCS, 2008d). STATSGO is the default dataset of AVSWAT-X for preparing the basic soil information for the SWAT model (Di Luzio et al., 2002). STATSGO is a spatially explicit database consisting of a broadly based inventory of soils and non-soil areas that occur in landscape (NRCS, 1995). It was created by generalizing more detailed SSURGO maps in 1- by 2-degree topographic quadrangle units, and its attributes were determined by expanding the data statistics of whole map unit (NRCS, 2008d). Thus, STATSGO is the generalized version of detailed soil survey maps, whereas SSURGO used field mapping based on national standards as the source for detailed soil information (NRCS, 2007b). SSURGO is the most detailed level of soil mapping done by the NRCS (2007).

NRCS originally created SSURGO for smaller scale studies in townships or counties (NRCS, 2007b). In contrast, STATSGO is better for broader scale resource planning, management, and monitoring (NRCS, 1995). However, the more detailed resolution in soil survey maps is needed because higher resolution soils maps are more accurate for models of hydrologic and water quality parameters. Prior research has noted that using SSURGO as soil data source with watershed water quality models would allow more precise estimates of soil erosion or pollutant loads than STATSGO (Anderson et al., 2006; Peschel et al., 2006; Wang and Melesse, 2006; Williamson and Odom, 2007). However, other research indicates the difference between STATSGO and SSURGO is not significant or that STATSGO is even superior to SSURGO in estimating nutrient loads (Grove et al., 2001; Peschel et al., 2003; Di Luzio et al., 2004; Gowda and Mulla, 2005; Heathman and Larose, 2006; Geza and McCray, 2007; Ghidey et al., 2007). In this study, we first used STATSGO and then SSURGO for the SWAT soil database to simulate the pollutant load within the study watershed.

To use SSURGO as the SWAT soil dataset, research has developed an optional extension in AVSWAT-X to automatically create a custom soil dataset as the modeling soil data source (Peschel et al., 2003; Di Luzio et al., 2004). However, there are several issues in using this SWAT-SSURGO extension: the version of SSURGO data, the changes in SSURGO map unit boundary, and the unexpected missing or blank attributes in custom soil datasets. To fix these issues, we developed a set of VBA scripts in a Microsoft Access project .mdb file. Detailed descriptions can be found in Appendix B.5 Soil.

3.3.4 Climate Data Preparation

The five basic climate data categories in SWAT weather data definition dialog are precipitation, temperature, solar radiation, wind speed, and relative humidity (Neitsch et al., 2004). The default SWAT modeling methods require historical daily surface precipitation and minimum/maximum temperatures for computing the daily water budget in each HRU; the others are optional (Neitsch et al., 2005). In this study, runoff, infiltration, and peak runoff rate was computed using the NRCS runoff curve number method (NRCS, 2004; Neitsch et al., 2005); potential evapotranspiration (PET) was estimated using Hargreaves' method (Hargreaves and Samani, 1985); sub-surface flow was computed using a kinematic storage model (Sloan et al., 1983; Sloan and Moore, 1984); and water transmission losses were estimated using the ephemeral procedure described in Chapter 19 of Part 630 Hydrology of USDA NRCS National Engineering Handbook (NRCS, 2007a). The National Environmental Satellite, Data and Information Service (NESDIS) of National Oceanic and Atmospheric Administration (NOAA) and National Climatic Data Center (NCDC) of US Department of Commerce provided several meteorological elements including daily surface precipitation, maximum and minimum temperatures, and other indicators for more than 10,000 stations across the United States (NCDC, 2009). Quality climate data source for SWAT could possibly be acquired directly online.

To use this climate database, the daily climate dataset included all available cooperative weather stations across the watershed with a twenty-mile buffer in both Kansas and Missouri, downloaded in ASCII format from NCDC Climate Data Online (CDO), Daily Surface Data website (NCDC, 2009) for January 1, 1960, through December 31, 2006. However, the field definitions in NCDC are quite different to the definitions in SWAT. Moreover, every weather station must be filtered to prevent significant gaps in the data. Therefore, a set of VBA scripts were developed to arrange and transform that database into the SWAT weather dataset. The detailed methods are in Appendix B.6 Climate. Weather data for each station were extracted for the longest possible coincident period of record (1971-2006) and formatted for input into SWAT. Data gaps in precipitation and/or temperature at each station were filled using the SWAT internal weather generator and built-in database. The weather generator uses the weather statistics from the nearest USGS weather station to estimate daily precipitation and temperatures as well as optional daily solar radiation, relative humidity, and wind speed if needed.

SWAT does not use any interpolation method, like Thiessen's Polygon Method, to estimate surface precipitation or temperature. Instead, SWAT uses the nearest weather station for each subbasin (Neitsch et al., 2005). SWAT will automatically search for the nearest station for each subbasin based on the distance between the stations to the centroid of subbasin (Neitsch et al., 2005). That means several subbasins may share identical weather data from the same weather station. Using the site-selection criteria described above, we found 41 precipitation gauges and 20 temperature stations that had no significant data gaps within 20 miles of the study watershed. However, the SWAT default only uses at most 18 weather stations for each climate category in a simulation. Figure 3-5 shows the 18 precipitation gauges and 13 temperature stations used in this study.

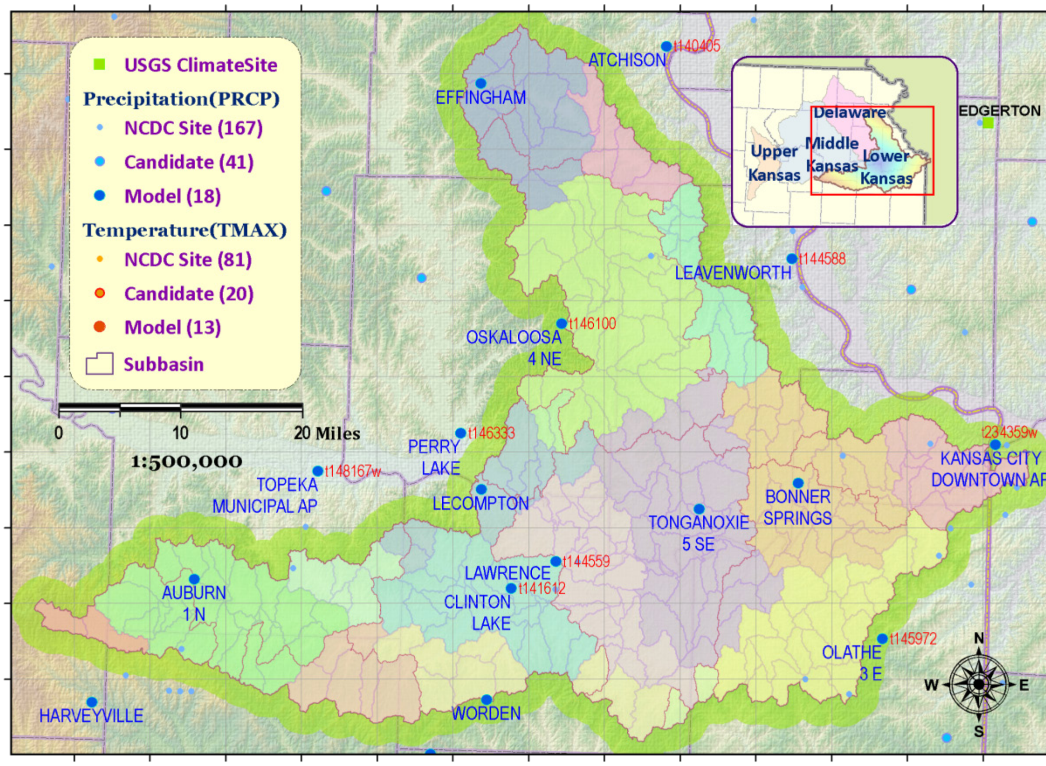


Figure 3-5 Modeling Weather Station in Study Watershed

3.3.5 Multiple HRUs Generalization

To characterize site specific effects on a geospatial scale, this study defined a watershed as several subbasins based on topography and divided each subbasin into one to several hydrologic response units (HRUs) based on the soil and landuse types within the subbasin. Each subbasin was simulated as a homogeneous area in terms of climatic conditions and topography; each HRU represents a unique land cover, soil, and management combination within a subbasin and is assumed to be distributed uniformly and to inherit the geospatial properties of that subbasin. Hence, SWAT predicts surface runoff and chemical movement of each HRU separately for overland processes at each time step. SWAT then aggregated the weighted outputs for each subbasin to represent the potential surface runoff and chemical load that may occur at the edge of field. Eventually, SWAT routed pollutants along the stream network to the watershed outlet and modeled the pollutant attenuation during the channeling process.

Theoretically, a set of HRUs should include all kinds of landuse and soil combinations within a subbasin. However, too many HRUs will increase the complexity of the model and data analyses, consuming enormous computing resources and becoming too time consuming. Therefore, we generalized landuse and soil types to create an adequate number of HRUs to represent the major characteristics of the subbasin while maintaining acceptable modeling performance.

To create the set of multiple HRUs, only an area of landuse higher than 4% in each subbasin and soil-class area more than 7% in each selected landuse were considered as an HRU. Using these criteria, we delineated 286 subbasins and 1294 HRUs in Lower Kansas watershed (USGS HUC8: 10270104) with NLCD 2001 and SSURGO dataset. As previously noted, this study simplified landuse classes to include only AGRR and WATR.

3.4 Alternative Management Scenario Design

Efforts to alleviate the impact of agriculture on water quality have focused primarily on the abatement of soil erosion and proper management of chemical fertilizers. The broader designs of agricultural BMPs demonstrably provided alternative management for croplands to reduce in-field pollutant load and stream contaminant levels.

Inspired by prior research results in a pilot study of the Lower Kansas watershed using SWAT to estimate the potential pollutant load, load reduction, and other indicators, a broader set of alternative scenarios were then developed. Referring to SWAT documents (Neitsch et al., 2004; Neitsch et al., 2005), four categories and balanced scenario designs were chosen for the different scenarios in this study: crop type (CROP), tillage system (TILL), edge-of-field BMP (BMPS), and fertilizer application (FERT). By changing one of these four categories at a time, a balanced alternative management scenario can be implemented. The major advantage of the balanced scenario design is it could minimize cross effects from other static variable categories and provide a clearer comparison at the dynamic variable category levels. The detail levels of crop types and other categories are in Table 3-3.

Table 3-3 Variables and Levels for Alternative Management Scenario Design

Variable	Attribute	Level
CROP[1]	Growing crops or rotation	BBLS, SWCH, FESC, CORN, GRSG, SOYB, WWHT, WWHT-SOYB, CORN-SOYB, GRGS-SOYB, WWHT-FALW, WWHT-(FALW)-CORN, WWHT-(FALW)-GRSG, WWHT-GRSG-SOYB
TILL[2]	Tillage system on field	NT, OT, RT, MT, CT
BMPS[3]	Edge-of-field BMPs	Blank, FS
FERT[4]	Fertilizer application method	SB, DB

Note: **1.** BBLS: big bluestem, used to simulate native prairie grass with SWAT default Big Bluestem parameters; SWCH: switchgrass, used to simulate alternative energy source (bio-fuel) with SWAT default Alamo Switchgrass parameters; FESC: tall fescue, used to simulate a Kansas cool season grass for vegetative filter strip with SWAT default Tall Fescue parameters; CORN: continuous corn; GRSG: continuous grain sorghum; SOYB: continuous soybean; WWHT: continuous winter wheat; WWHT-SOYB: 1-year winter wheat-soybean double crops; CORN-SOYB: 2-year corn-soybean rotation; GRGS-SOYB: 2-year grain sorghum-soybean rotation; WWHT-FALW: 2-year winter wheat-fallow rotation; WWHT-(FALW)-CORN: 3-year winter wheat-fallow-corn rotation; WWHT-(FALW)-GRSG: 3-year winter wheat-fallow-grain sorghum rotation; WWHT-GRSG-SOYB: 3-year winter wheat-grain sorghum-soybean rotation. **2.** NT: no-till; OT: rotational tillage, which is a tillage system with halftime no-till (NT) and halftime minimum tillage (MT); RT: reduced tillage; MT: minimum tillage; CT: conventional tillage. **3.** Blank: without any BMP; FS: with VFS. **4.** SB: general surface fertilizer application; DB: general sub-surface fertilizer application.

3.4.1 Crop Type and Rotation

According to the field technical notes from NRCS field office and the interviews with several watershed specialist and professionals (Barnes, 2006; Boyer, 2006; KSU, 2006; Maddux, 2006; NRCS-Kansas, 2006), the design of the alternative management scenarios in SWAT covered most common crop types and rotations in the Lower Kansas watershed. Corn, soybean, grain sorghum, and winter wheat are common food or feed crops. Big bluestem is one of the native grasses in the tall grass prairie of Great Plains (Ohlenbusch et al., 1983; Ohlenbusch, 1997). Tall fescue is a commonly planted cool season grass for vegetative filter strip (VFS) in northeastern Kansas (Harner et al., 2000; NRCS-Kansas, 2002; NRCS-Kansas, 2003). Moreover, bio-energy, an alternative energy source, uses biological material like corn, soybean, or non-food crops, and is frequently studied because of the high price of fossil fuels (Nelson et al., 2006; Babcock et al., 2007). Switchgrass is one source of bio-energy and is also a common native prairie grass in the Great Plains (Babcock et al., 2007). Therefore, we classified crop types into fourteen categories with seven plants and three crop rotation periods. More details of crop season and crop rotation are in Appendix A.2.1.

3.4.2 Tillage System

Farmers usually till before planting crops. Tilling removes weeds, mixes fertilizers with soil, shapes rows for crop plants, and creates furrows for irrigation. However, tilling may lead to soil compaction, loss of soil moisture, degradation of soil aggregates, and potential soil erosion (Whitney et al., 1999; Staggenborg et al., 2004). The tillage system usually involves multiple cultivating operations with implements such as a mold board plow, disk, or chisel plow. Traditional intensive tillage systems, often called conventional tillage, leave less than 15% crop residue cover or 560 kg/ha (500 lb/ac) of small grain residue. In contrast, conservation tillage leaves at least 30% crop residue on the soil surface or 1,120 kg/ha (1,000 lb/ac) of small grain residue on the surface during the critical soil erosion periods. In conservation tillage, surface residue slows runoff, reduces rain drop energy, and minimizes potential soil erosion. Better stream water quality, higher soil moisture, and less soil compaction as well as savings in labor or fuel are additional benefits.

Several potential tillage systems are used in the Lower Kansas watershed. After reviewing crop handbooks and interviewing field professionals and watershed specialists, five tillage systems (no-till, rotational tillage, reduced tillage, minimum tillage, and conventional tillage) were selected as alternative tillage methods for SWAT scenario design (Fjell et al., 1997; Shroyer et al., 1997; Fjell et al., 1998; Barnes, 2006; Boyer, 2006; Maddux, 2006; KSU, 2006; NRCS-Kansas, 2006; Fjell et al., 2007; NRCS, 2008a). The definitions of each tillage system are in Table 3-4. To balance the design for modeling and later statistical analyses, these five tillage systems were modeled with eleven common food crop rotations, two edge-of-field BMP selections, and two fertilizer application methods. Although some of these scenarios would not be suggested in practice, they can still be modeled and analyzed for the statistical comparison. The detailed schedule of each cultivating operation in tillage systems and crop rotations is in Appendix A.2.2.

Table 3-4 Definition of Tillage Systems Applied in This Study

Tillage System	Description
Conventional tillage	Includes intensive tillage and cultivating activities before planting. Usually, less than 15% crop residue cover will remain on the field.
Minimum tillage	A system somewhere between 100% no-till and 100% conventional tillage, and much closer to conventional tillage. This system typically reduces fall and early spring cultivation and consists of a combination of disking, chiseling, and field cultivating before planting. Crop residue at planting should be around 15% to 30%.
Reduced tillage	A tillage system somewhere between 100% no-till and 100% conventional tillage, but much closer to no till side. This system typically eliminates fall and early spring cultivation and cultivates fields only before planting. Reduced tillage is conservation tillage and crop residue is more than 30%.
Rotational tillage	Also known as rotational no-till, this a 50% no-till and 50% minimum tillage mixed tillage system. For corn-soybean crop rotation, corn is planted into existing soybean stubble without tilling whereas minimum tillage takes place after the corn harvest in preparation for soybean planting. For single cropping, no-till and minimum tillage would alternate years.
No-till	Does not disturb the soil through tillage. At least 30% crop residue remains on soil surface.

3.4.3 Edge-of-Field BMP

Storm water runoff from agricultural fields often carries pollutants, such as soil sediments, nutrients, and other chemicals, that affect water quality. One way to minimize pollution is to build an edge-of-field BMP that reduces the total amount of runoff, slows down runoff velocity, and/or filters the particles carried by the runoff. VFSs are one of these BMPs. The vegetation can reduce sediments, nutrients, and chemicals carried in surface runoff and remove nutrients through plant up-take. It is easy to establish, environmentally friendly, and economically preferable to most other BMPs. VFSs are also called grass-waterways, filter strip terraces, buffer strips, riparian strips, and settling basins (Regehr et al., 1996). In this study, the scenarios designated to implement VFSs were defined as the buffer strips:

an area at the edge of the field along a ditch, gully, or stream that is covered permanently by tall fescue *(Festuca arundinacea)* (Regehr et al., 1996; Harner et al., 2000).

The efficiency of VFSs in trapping pollutants relates to the local topography, soil property, climate condition, and management. Studies have shown no simple answer for estimating removal efficiency of VFSs. Some studies suggested the long-term trapping efficiency might be from 55% to 95% of annual soil loss (Schauder and Auerswald, 1992; Coyne et al., 1997; Cooprider and Coyne, 1999; NRCS-Kansas, 2002). For the efficiency to reduce sediment concentrations in runoff, the number could be from 50% to 92% (Coyne et al., 1997; Devlin et al., 2003; Blanco-Canqui et al., 2004). For the nutrient reductions such as TN or TP in runoff, the efficiency could be from 35% to 50% (Devlin et al., 2003). Mankin et al. (2006, 2007) indicated the VFS has a potential 66% of total nutrient and 77% of fecal coliform concentration reductions, and the grass-shrub riparian buffer system (RBS) has 85% TP load reduction in Kansas. Furthermore, several researchers report that different width of VFSs could produce different load reduction effectiveness from 51% to 92% with 2 m to 10 m long filters (Blanco-Canqui et al., 2004; Abu-Zreig et al., 2001; Shiono et al., 2004; Mankin et al., 2006; Mankin et al., 2007). However, Gharabaghi et al. (2001) found that increasing the width of VFS may not also increase trapping efficiency for sediment when VFS beyond 10 m.

SWAT 2005 cannot directly simulate landscape components processes and VFS systems geospatially either in the complex watershed and/or subbasin (Bosch et al., 2007); SWAT simply uses an empirical equation (Eq. 3-19) developed by Moore et al. (1988) to simulate the VFS trapping efficiency for sediment and nutrient yield (Neitsch et al., 2005). In this study, following the VFS instructions published by the NRCS Kansas subdivision (NRCS-Kansas, 2003), a uniform, 20 m wide VFS was applied as an edge-of-field BMP for scenarios that simulate VFSs as a management operation. The calculated global VFS trapping efficiency ($E(t)_{nutrient}$) in this study would be around 90%, which is close to what the literature and previous field experience reveals (Barnes, 2006).

$$E(t)_{nutrient} = 0.367 \times w^{0.2967} \qquad \text{Eq. 3-19}$$

The potential issue of VFSs is the removal rate of dissolved nitrates from surface runoff. Some nutrients that are strongly adsorbed by soils are transported and deposited with sediments. As long as soil particles are trapped, these nutrients are removed. However, nitrates (NO_3^-) are not strongly adsorbed to soils and may be dissolved in runoff. To remove dissolved pollutants in runoff water requires that the water infiltrate the underlying soil in the VFSs. If the soil is dry, infiltration may occur and reduce the dissolved herbicide or nitrate leaving the field. In contrast, if the soil is already saturated during runoff, little further infiltration will occur. For a minor storm water runoff event, the removal rate may reach 100% when all the water infiltrates the soil. However, Regehr et al. (1996) indicated that only about 25% of dissolved Atrazine can be removed by VFSs. Nothing further has been published on dissolved nitrate, but the removal rate should be less than the estimate from Eq. 3-19.

Eq. 3-19 implies that SWAT model VFSs are well designed, maintained, and effective at all times in trapping and removing soil sediments from surface runoff as well as infiltrating runoff water into the soil. However, these assumptions may not hold in practice given such field circumstances as soil saturation under VFSs. Without any other tool to modify SWAT, Eq. 3-19 remains a useful way to estimate the trapping efficiency of VFSs in this study. However, the equation still needs further research. More details for modeling VFSs with SWAT are in Appendix A.2.3

3.4.4 Fertilizer Application

Effective placement and timing of fertilizers can maximize crop yield. In this study, using an earlier study in northeastern Kansas, fertilizer application methods were simply classified as "surface broadcast" and "deep band application" to represent the surface and sub-surface fertilizer (Maski et al., 2007). Surface broadcast means a uniform application across the field surface, and deep band means fertilizer applied at least 100 mm (4 in) below the soil surface (Jones and Jacobsen, 2003). The broadcast fertilizer operations are designed to incorporate with cultivating operation. Some liquid fertilizer, such as anhydrous ammonia and urea-ammonium nitrate solutions (UAN), were designed to be band applied through knives in the soil sub-surface.

Fertilizer application rates are tied to yield goals for crops. Appropriate yield goals fall between the average yield obtained in a field over the past 3 to 5 years and the highest yield ever obtained in a particular field (Leikam et al., 2003). After a review of crop planting handbooks and several research reports, we have summarized in Table 3-5 the estimated yield and fertilizer requirement as TN and TP for each crop in this study (Whitney et al., 1991; Kilgore and Brazle, 1994; Blackmer et al., 1997; Fjell et al., 1997; Shroyer et al., 1997; Fjell et al., 1998; Leikam et al., 2003; Staggenborg et al., 2004; Claassen, 2005; Fjell et al., 2007). A detailed discussion of both N and P fertilizers, application schedules, and fertilizer amount recommendations for each crop as well as both application methods can be found in Appendix A.2.4.

Table 3-5 Crop Fertilizer Requirements for Estimated Yield

Crop Rotation	**Est. Yield** (bushel/acre)	**Req. N** (kg/ha)	**Req. P** (kg/ha)
Continuous corn	100	140	36.986
Continuous grain sorghum	80	76.22	35.866
Continuous soybean	40	n/a	35.866
Winter wheat (WWHT) [Rotated/Continuous]	40	57.16	22.416
Winter wheat (WWHT) [Double Crop]	40	90.784	22.416

3.4.5 Model Simulation

The environmental benefit of WQT focuses largely on load reduction at the watershed outlet. Pollutant load reduction in nutrient (TN and TP) loads leaving the edge of field and entering the stream network to the watershed main outlet were determined for the cropland acreage with different crop rotation scenarios in study area. A total of 225 scenarios from 1968 to 2006 (or 39 years) were modeled with SWAT, with the analysis based on the 1971 to 2006 (36 years) modeling period. Table A-20 lists the simulation series number and brief descriptions for all 225 potential alternative scenarios.

Annual values were simulated for pollutant load and load reduction for both TN and TP at a daily time step. Of the 286 subbasins and 1294 HRUs in study area, only 285 subbasins and 1206 HRUs are classified as cropland area. The others were classified as waterbodies. Each simulation was calculated for all HRUs in every subbasin. However, only cropland areas were subjected to changing land management practices, making them the only HRUs able to produce load reduction between two alternative cases. The subbasin level outputs were adjusted using area weighted values of each cropland HRU within each subbasin. Hence, the overall watershed level information was calculated as the average of all subbasin level outputs in study watershed for later comparisons.

To analyze site-specific temporal effects within the WQT, monthly values with the same settings as annual ones were also simulated for pollutant load and load reduction for both TN and TP at daily time steps. These scenarios are mainly continuous corn, soybean, and two-year corn-soybean rotation management with different tillage, fertilizer application, and edge-of-field BMP options. For each scenario, the modeling processes are identical to the annual ones, except the final outputs were given by the month (over 12 months) instead of annually. Therefore, each scenario provided 432 monthly observations for analysis, compared to the 36 yearly observations in the yearly study. Brief descriptions of each scenario for analyzing temporal effects are in Table A-21.

3.4.6 Adjustment for Model Parameters

In this study, SWAT was used to obtain the annual and monthly nutrient loads associated with the designed scenarios. The characteristics of the watershed model and the properties of the study watershed made it necessary to ensure that SWAT would reasonably predict pollutant load in the Lower Kansas watershed. Therefore, a set of calibrated and verified SWAT parameters were needed.

Maski et al. (2007; 2008) calibrated and validated SWAT with measured data from field plots in the sorghum-soybean cropping sequence from 2001 to 2004 in northeastern Kansas. These WQT parameters, including USLE crop and cover management (C) factors, runoff curve numbers for moisture condition II (CN2), and soil saturated hydraulic conductivity (K_{SAT}), were modified for all annual and monthly scenarios. Moreover, Parajuli (2007) calibrated and validated flow, sediment with SWAT near Clinton Lake in study area. Three SWAT modeling parameters including CN2, soil evaporation compensation coefficient (ESCO), and USLE C factors, were selected (Parajuli, 2007). Therefore, the modeling CN2 and USLE C parameters were adjusted based on both Maski et al. and Parajuli studies, and ESCO were fine-tuned as 0.50 for all scenarios (Parajuli, 2007).

Furthermore, in default, SWAT uses a single roughness coefficient (Manning's n) for overland flow on the same type of surface coverage plant, and a single Manning's n for the channel flow along the whole stream network. These defaults may not be reasonable for modeling a huge watershed like the Lower Kansas watershed. Therefore, surface Manning's n for overland flow was adjusted to account for surface impermeability due to different tillage systems (Neitsch et al., 2005). Manning's n for the channel flow was also adjusted for channel conditions in the study watershed using prior research (Wanielista et al., 1997; Neitsch et al., 2005).

In addition, different tillage systems have specific cultivating operation dates as well as the type of fertilizer application chemicals, amount, application dates, and application methods. These parameters were also adjusted to take into account the watershed specialist's experience and reports from the NRCS field office (Whitney et al., 1991; Fjell et al., 1997; Whitney et al., 1999; Leikam et al., 2003; Fjell et al., 2007). The SWAT default VFS trapping efficiency was modified using USDA NRCS technical notes and several literature reviews (NRCS-Kansas, 2003; Neitsch et al., 2005; Mankin et al., 2006).

The methods for major adjusted parameters are discussed in following sections. Table 3-6 provides the major adjusted parameters of SWAT and the brief planting/harvesting dates used in this study. Each scenario required some fine-tuning. More detailed discussion of these parameters can be found in Appendix A.3.

3.4.6.1 *USLE Crop and Cover Management (C) Factor*

The USLE crop and cover management (USLE-C) factor is a ratio of soil loss from land cropping under specified conditions to the corresponding loss from clean-tilled, continuous fallow (Neitsch et al., 2005). The factor is determined by the crop canopy protection offered, the crop growing stage, or the residue cover on the ground. As the amount of residue cover on the soil increases, the C factor decreases. Bingner et al. (1989) indicated the C factor is a critical input for sediment loss predictions. SWAT calculates the actual C factor based on the amount of soil cover and the minimum C factor determined for the plant/land cover (Neitsch et al., 2005). Continuous row crops (soybean, corn, or grain sorghum) produce a larger C factor than small grains (winter wheat) in rotation with row crops. Certain tillage operations also modify the C factor. Prior research shows that the C factor of no-till with deep band fertilizer application method is similar to the textbook definition (Maski et al, 2008). Other research shows no-till might decrease the textbook C factor by 30% and ridge-till by 25% (Whitney et al., 1999). However, spring plowing would increase the standard C factor by 50%, and fall plowing by 70% (Whitney et al., 1999). Based on these conclusions, crop and cover management factor for each scenario was adjusted according to its crop type and tillage system. We increased the USLE C factor for conventional tillage while decreasing it for no-till.

3.4.6.2 *Runoff Curve Number for Moisture Condition II (CN2)*

SWAT provides both curve number (CN) or Green and Ampt methods for calculating the infiltration and surface runoff during a precipitation event (Neitsch et al., 2005). It uses by default the CN method and requires the curve numbers for “moisture condition II” (CN2) or antecedent moisture condition II (AMC II) (Neitsch et al., 2004). The NRCS runoff CN is an empirical parameter in the NRCS runoff equation that is widely used to determine the approximate amount of direct surface runoff from a rainfall event in a particular area (SCS, 1972; NRCS, 2004). The curve number method is described detail in the National Engineering Handbook (NEH): Section 4 - Hydrology (now NEH, Part 630: Hydrology) (Kent, K.M., 1972; SCS, 1972; NRCS, 2004; NRCS, 2007c).

SWAT adjusts the entered CN daily to reflect changes in ground soil moisture, water content, or plant evapotranspiration. Maski et al. (2008) suggested increasing CN2 by one hydrologic soil group when simulating no-till systems in northeastern Kansas. In other words, if the SWAT default CN2 of corn crop is 67, 77, 83, 87 for hydrologic soil groups A, B, C, D, to compensate for no-till, these CN2 must be increased to 77, 83, 87, 89 for hydrologic soil groups A, B, C, D, respectively. Based on this suggestion and HRU’s hydrologic soil group, CN2 was adjusted by promoting one group of the stocked CN2 value for no-till. For simulating rotational tillage, the adjusted no-till values and original SWAT defaults of the other rotated tillage method (e.g., minimum tillage) were averaged for rotational tillage's CN2.

3.4.6.3 *Saturated Hydraulic Conductivity*

Hydraulic conductivity (K) is defined by Darcy's law and is a measure of the soil's ability to transmit water on a hydraulic gradient. The saturated hydraulic conductivity (K_{SAT}) is the same quantitative measure but for a saturated soil, or the ease with which pores of a saturated soil permit water movement. In Darcy's law, K_{SAT} is a constant (or proportionality constant) affected by soil pore geometry as well as the fluid viscosity and density. In SWAT, the K_{SAT} parameter is used to estimate the time in which percolation drains water in excess of field capacity to the next soil layer; if percolation time for a layer exceeds 24 hours, soil water in excess of field capacity is carried forward to the next day (Neitsch et al., 2005). Maski et al. (2008) suggested doubling the K_{SAT} value to compensate for the consolidated soil surface effects due to no-till. Based on this suggestion, when modeling no-till, the K_{SAT} for each soil type was doubled. For modeling rotational tillage, the K_{SAT} of each soil type was roughly multiplied by 1.5 to compensate for half of the no-till effect.

3.4.6.4 *Roughness Coefficient (in Manning's Equation)*

SWAT uses Manning's equation to define the rate and velocity of either channel flow or overland flow (Neitsch et al., 2005). The roughness coefficient of Manning's equation represents the resistance to flow in surface, channels, and flood plains. It often denoted as "n" or "Manning's n". Manning's n values vary greatly in natural stream channels and will even vary in a given reach of a channel at different stages of flow. SWAT's default assigns Manning's roughness coefficient a value of 0.14 for overland flow on a row crop surface and 0.014 for channel flow in the whole stream network (Neitsch et al., 2005). However, this assumption may be suitable only for some types of tillage systems and channel conditions. The SWAT theory document (Neitsch et al., 2005) and other research (Wanielista et al., 1997) provide suggestions for Manning's n, tabulated according to factors that affect surface and channel roughness. Based on this research, the overland flow Manning's n is fine-tuned according to tillage system and crop rotation. Therefore, Manning's n of overland flow was increased for no-till due to the impermeability of the surface. Moreover, channel flow Manning's n was calculated with the channel conditional n equations provided by Wanielista et al. (1997). Hence, the global channel roughness coefficient is 0.05 for a tributary and 0.025 for the main channel.

Table 3-6 List and Major Adjusted SWAT Parameters for Alternative Scenarios

Crop Rotation	Till[1]	Abbrev.[2]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[3]				Manning's n	K_{SAT}
						A	B	C	D		
Big bluestem		BBLS	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
Switchgrass		SWCH	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
Fescue		FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
Fescue	FS GZ	FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
	NT	C1			0.13	77	83	87	89	0.3	2x
	OT	C2			0.22	72	80	85	88	0.22	1.5x
CORN (1-yr)	RT	C3	05/01/01	09/15/01						0.14	
	MT	C4			0.31	67	77	83	87	0.12	---
	CT	C5								0.09	
	NT	G1			0.13	77	83	87	89	0.3	2x
	OT	G2			0.22	72	80	85	88	0.22	1.5x
GRSG (1-yr)	RT	G3	06/01/01	10/15/01						0.14	
	MT	G4			0.31	67	77	83	87	0.12	---
	CT	G5								0.09	
	NT	W1			0.03	73	81	84	86	0.2	2x
	OT	W2			0.03	68	77	82	85	0.17	1.5x
WWHT (1-yr)	RT	W3	09/15/01	06/15/02						0.15	
	MT	W4			0.03	62	73	81	84	0.14	---
	CT	W5								0.12	
	NT	S1			0.11	78	85	89	91	0.19	2x
	OT	S2			0.17	72	81	87	90	0.16	1.5x
SOYB (1-yr)	RT	S3	05/15/01	10/07/01						0.14	
	MT	S4			0.23	67	78	85	89	0.12	---
	CT	S5								0.09	
	NT	WS1			0.07	75	83	86	88	0.2	2x
	OT	WS2			0.1	70	79	84	87	0.17	1.5x
WWHT-SOYB (1-yr) (Double Crop)	RT	WS3	W: 10/01/01 S: 06/01/01	W: 05/22/01 S: 09/15/01						0.15	
	MT	WS4			0.13	65	76	83	87	0.13	---
	CT	WS5								0.11	
	NT	CS1			0.12	77	84	88	90	0.24	2x
	OT	CS2			0.2	72	80	86	89	0.18	1.5x
CORN-SOYB (2-yr)	RT	CS3	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02						0.14	
	MT	CS4			0.27	67	77	84	88	0.12	---
	CT	CS5								0.09	
	NT	GS1			0.12	77	84	88	90	0.24	2x
	OT	GS2			0.2	72	80	86	89	0.18	1.5x
GRGS-SOYB (2-yr)	RT	GS3	G: 06/01/01 S: 05/15/02	G: 10/15/01 S: 10/07/02						0.14	
	MT	GS4			0.27	67	77	84	88	0.12	---
	CT	GS5								0.09	
	NT	WF1			0.03	73	81	84	86	0.2	2x
	OT	WF2			0.03	68	77	82	85	0.17	1.5x
WWHT-FALW (2-yr)	RT	WF3	W: 09/15/01	W: 06/15/02						0.15	
	MT	WF4			0.03	62	73	81	84	0.14	---
	CT	WF5								0.12	
	NT	WC1			0.08	75	82	85	87	0.25	2x
	OT	WC2			0.12	70	79	84	86	0.2	1.5x
WWHT-CORN (3-yr)	RT	WC3	W: 09/15/03 C: 05/01/02	W: 06/15/01 C: 09/15/02						0.15	
	MT	WC4			0.17	64	75	82	85	0.13	---
	CT	WC5								0.1	
	NT	WG1			0.08	75	82	85	87	0.25	2x
	OT	WG2			0.12	70	79	84	86	0.2	1.5x
WWHT-GRSG (3-yr)	RT	WG3	W: 09/15/03 G: 06/01/02	W: 06/15/01 G: 10/15/02						0.15	
	MT	WG4			0.17	64	75	82	85	0.13	---
	CT	WG5								0.1	

Crop Rotation	Till[1]	Abbrev.[2]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[3] A	B	C	D	Manning's n	K_{SAT}
WWHT-GRSG-SOYB (3-yr)	NT	WGS1	W:10/01/03 G: 06/01/02 S:05/15/03	W: 06/15/01 G: 10/15/02 S: 09/15/03	0.1	76	83	86	88	0.25	2x
	OT	WGS2			0.16	71	79	84	87	0.2	1.25x
	RT	WGS3			0.22	66	76	83	87	0.15	---
	MT	WGS4								0.13	
	CT	WGS5								0.1	

Note: 1. NT: no-till; OT: rotational till (50% no-till and 50% minimum till); RT: reduced till; MT: minimum till; CT: conventional till. **2.** C: corn; S: soybean; G: grain sorghum; W: winter wheat; WS: 1-yr winter wheat-soybean double crop; CS: 2-yr corn-soybean rotation; GS: 2-yr grain sorghum-soybean rotation; WF: 2-yr winter wheat-fallow rotation; WC: 3-yr winter wheat-fallow-corn rotation; WG: 3-yr winter wheat-fallow-grain sorghum rotation; WGS: 3-yr winter wheat-grain sorghum-soybean rotation; BBLS: big bluestem; SWCH: switchgrass; FESC: tall fescue. **3.** CN2: curve number for moisture condition II; HSG: hydrologic soil group.

3.4.7 Scenario Trends Analysis

To find the general trends of potential load and load reduction among 220 alternative scenarios, the analysis of variance (ANOVA) method was applied in the four major scenario design variables in Table 3-3. For each design variable (crop, tillage, fertilizer, or edge-of-field BMP), the watershed level annual TN and TP loads for 220 alternative scenarios were analyzed. Similarly, the watershed level annual TN and TP load reductions for 48400 scenario pairs were also analyzed. For both ANOVA analyses, the major grass scenarios such as BBLS, SWCH, or FESC were excluded. For the ANOVA for nutrient load, the factorial design with three way interactions was tested with SAS 9.1. In contrast, the ANOVA for nutrient load reduction also used factorial design but only tested main effect with SAS 9.1. From this ANOVA test, the trend of load or load reduction trends for each design variable can be seen.

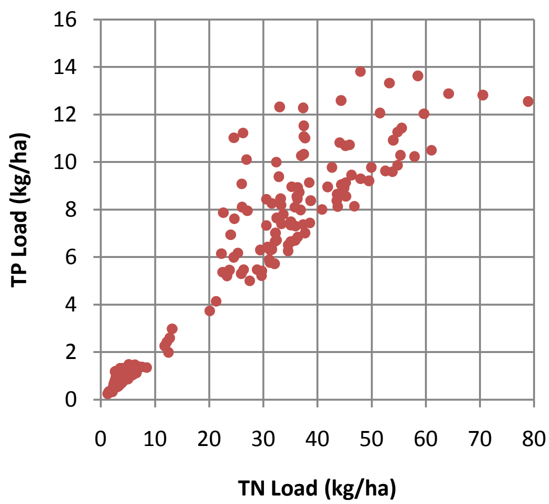
ANOVA provides a quick way to tell if an effect is statistically significant or not by calculating the p-value for each testing model. For those effects where the p-values are less than 0.05, the differences among tested scenarios are statistically significant. However, ANOVA only provides a trend direction for nutrient load or load reduction for each variable effect or interaction. It does not provide specifics about differences between any two levels of variables or pair comparisons.

Therefore, to find similarities between any two class levels of each design variable, Fisher's Least-Significant-Difference (LSD) was used for pairwise comparison of the levels' means. Fisher's LSD is a two-step testing procedure for pair-wise comparisons of several treatment groups (SAS Institute Inc., 2004). In the first step of the procedure, a global test checks the null hypothesis that all population means are equal (the omnibus null hypothesis) with an ANOVA. If the first global test of the main effect of ANOVA is not significant, then the omnibus null hypothesis and any other null hypotheses about differences among means can be rejected. If the main effect of ANOVA is significant at a specified level, then the second step of the procedure calls for pair-wise comparisons at the same level of significance. Fisher's LSD method can answer questions like "Which scenarios are similar to each other?" or "What is the priority among these variable levels?"

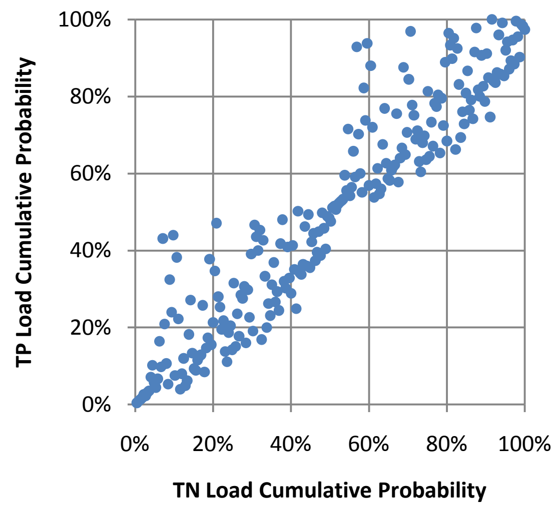
3.5 Results and Discussion

3.5.1 Potential Nutrient Load

We analyzed nutrient loads from 1971 to 2006 for 286 subbasins and 1294 HRUs using 225 different scenarios. Because 285 out of 286 subbasins and 1206 out of 1294 HRUs were classified as cropland and the others were water, this analysis mainly focused on scenarios for agricultural cropland. Figure 3-6 presents the watershed scale annual nutrient loads, the area of cropland weighted average of 286 subbasins. In Figure 3-6 (a), scenarios with higher TN loads also tend to produce a higher TP load. This trend is clear in the cumulative probability in Figure 3-6 (b). For more detailed statistics and loading data of TN and TP loads, see Appendix C.1 and C.2.



(a) Potential Nutrient Load



(b) Cumulative Probability of Nutrient Load

Figure 3-6 Annual Watershed Level TN-TP Loads of Each Scenario

Figure 3-7 presents the annual TN and TP loads for several selected scenarios from first 60 scenarios and the other five major grass scenarios at the watershed level. In Figure 3-7, the major grass scenarios like native grasses big bluestem (S221) and switchgrass (S222), or VFS grass tall fescue (S223) have the lowest TN and TP loads. These scenarios were ranked by their nutrient loads and assigned a cumulative probability for every scenario, and Figure 3-8 illustrates the percentile of several selected scenarios. From the percentiles in Figure 3-8, switchgrass (S222) has the lowest TN load while big bluestem (S221) has the lowest TP load. For the other scenarios with the same crop rotations, the scenarios with the highest TN load amounts use surface fertilizer application and conventional tillage without edge-of-field VFS (S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean). The loading yields would decrease if the tillage system changed to no-till with surface fertilizer application and without edge-of-field VFS (S17: 2-yr corn-soybean, S37: cont. corn, and S57: cont. soybean). For the same tillage, sub-surface fertilizer scenarios tend to have a smaller TN load than surface fertilizer scenarios (S1 versus S3, and S17versus S19).

Furthermore, no-till scenarios with surface fertilizer application and no VFS (S17, S37, and S57) tend to produce a higher TP load. These values are sometimes higher than conventional tillage scenarios. In contrast, the scenarios with no-till and sub-surface fertilizer application without edge-of-field VFS (S19: 2-yr corn-soybean, S39: cont. corn, and S59: cont. soybean) have the lowest TP load. Scenarios with surface fertilizer application tend to show an increase in the TP load when surface cover percentage increases (from conventional tillage to no-till). However, for scenarios with sub-surface fertilizer application, the TP loading trend is just like the TN load: no-tillage has the lowest load. Thus, these phenomena show that increasing surface coverage percentages also increases the amount of surface runoff. Surface fertilizer application deploys fertilizer directly on the surface where it is easily flushed away after a precipitation event.

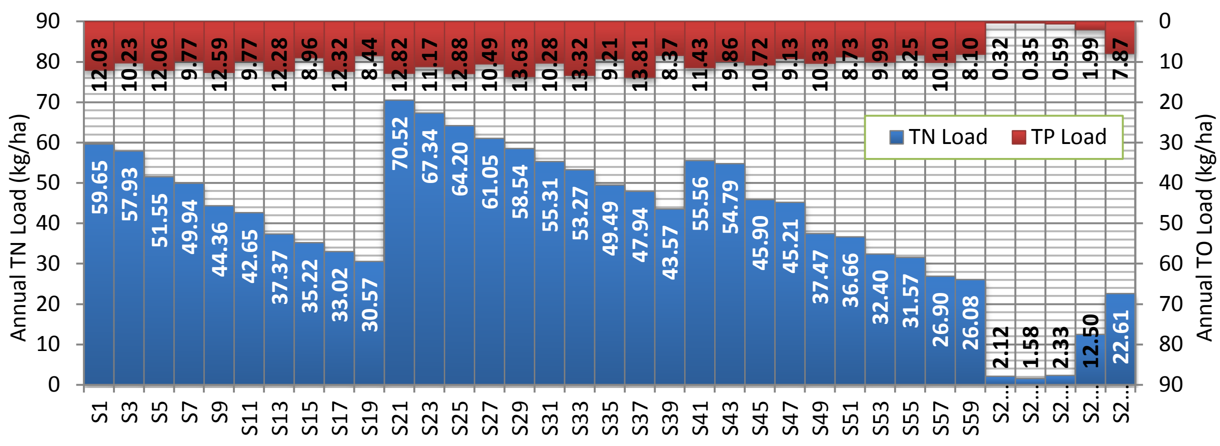


Figure 3-7 Watershed Level Annual Nutrient Load (kg/ha) for Selected Scenarios

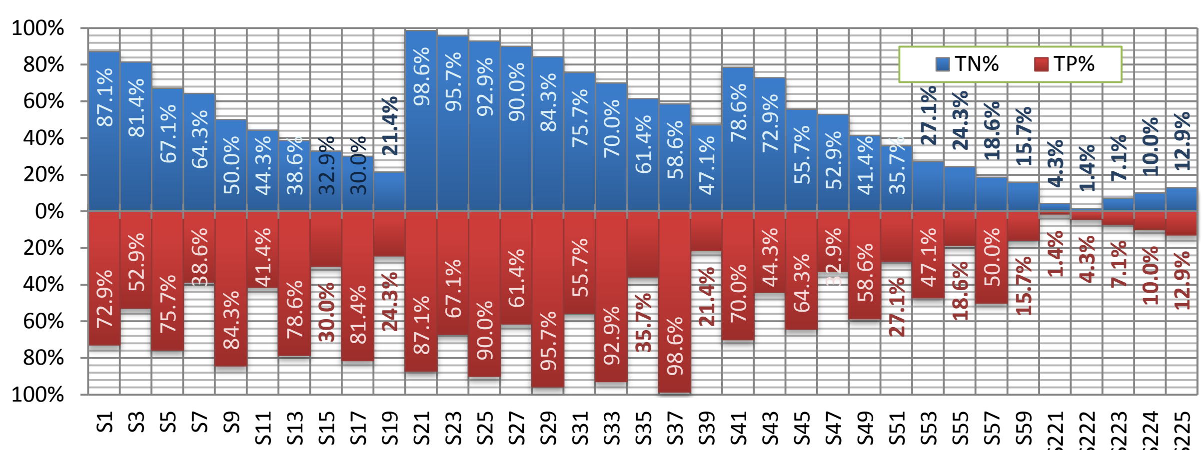


Figure 3-8 Percentile of Annual Nutrient Load for Selected Scenarios

3.5.1.1 *Scenario Trend of Nutrient Load*

To examine the similarity of the means of nutrient loads for the design variables listed in Table 3-3, the means of 220 potential alternative scenarios (excluded major grasses), ANOVA was applied. For those main effects or cross effects (interactions) with p-values less than 0.05, the loads were significantly different among the scenarios. Conversely, for the main effects or interactions with p-values more than 0.05, the differences among the scenarios were not significant. Therefore, we can use the p-value to judge whether the design variables differed significantly. Within the ANOVA statistics, the p-values for the overall ANOVA of TN and TP loads are less than 0.0001, which means all scenarios differ significantly. For the model ANOVA statistics, most of the model (sources) effects have p-values less than 0.0001 other than some cross effects (interactions) like CROP*FERT (Pr=0.8376), TILL*FERT (Pr=0.124), CROP*FERT*BMPS (Pr=0.9556), TILL*FERT*BMPS (Pr=0.3037), and CROP*TILL*FERT (Pr=0.0886) for TN loads as well as CROP*TILL*FERT (Pr=0.0886) for TP loads. The main effects for four variables are illustrated in Figure 3-9.

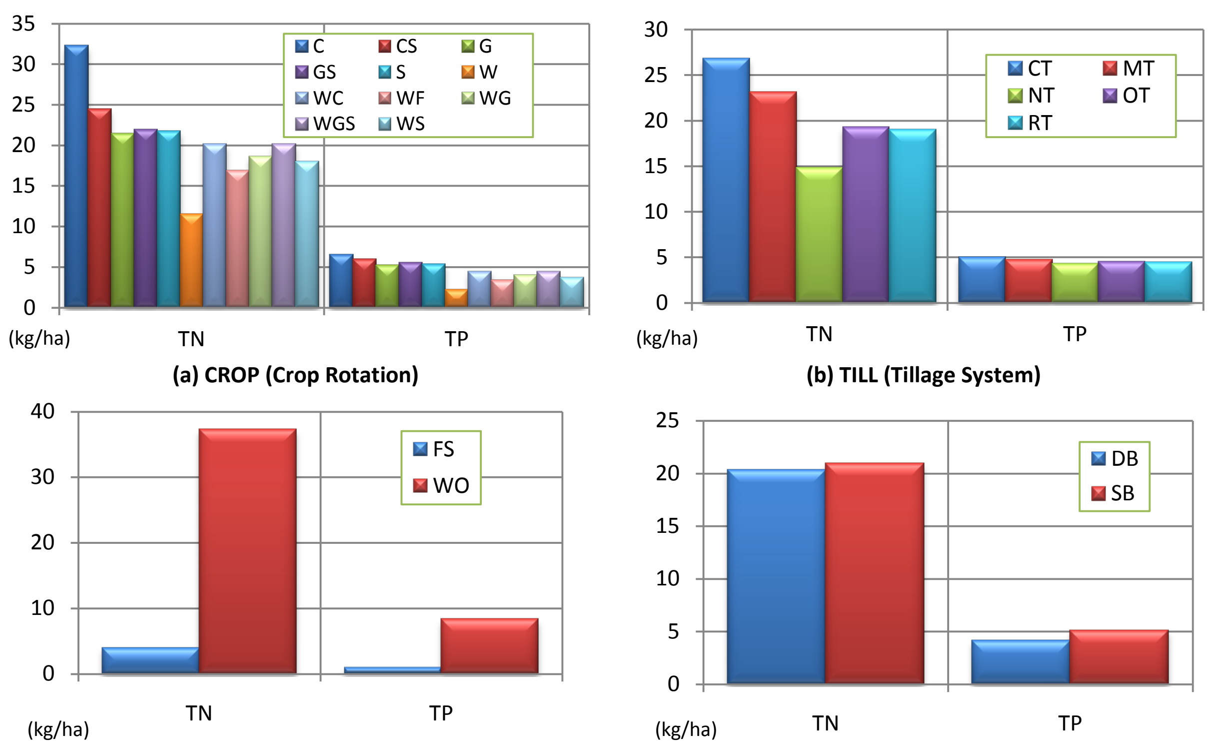
For the nutrient loads of different crop types in Figure 3-9 (a), corn (C) tends to produce higher TN and TP loads than any other crop while winter wheat (W) has lower loads of both TN and TP. This indicates that changing the crop rotation from corn to winter wheat might reduce the maximum TN load. However, native grasses or VFS grass in study watershed (not shown in Figure 3-9) like big bluestem (BBLS), switchgrass (SWCH), and tall fescue (FESC) have a very low nutrient loads. Therefore, the best option for maximizing load reduction would be to restore cropland to original prairie.

For tillage system analyses, illustrated in Figure 3-9 (b), the conventional tillage (CT) provided the highest TN loads while no-till (NT) system has the lowest TN loads. Minimum tillage (MT) has second highest loadings, but the difference between rotational tillage (OT) and reduced tillage (RT) is not statistical significant. The trends for the TP load of each tillage system seem relatively flat. That means the changes in management in tillage system would not make much difference in TP load.

For implementing edge-of-field VFSs, the nutrient loads of scenarios with VFSs were approximately 90% of scenarios without VFSs. SWAT uses the empirical equation to estimate VFS efficiency, which explains this strong load difference, seen in Figure 3-9 (c). Some research supports this number, but it would be hard to duplicate in the field. Analysis of fertilizer loads is in Figure 3-9 (d). For either TN or TP, surface fertilizer application tends to have a slightly higher load than sub-surface fertilizer application. This phenomenon is because the surface broadcast fertilizers tend to be easily flushed by storm water, especially for storms that occur soon after an application event.

The overall trends for nutrient loads show the scenarios without VFSs will produce higher nutrient loads than any other design variable; corn has dramatically high TN loads compared to the other crops. Therefore, applying edge-of-field VFSs, implementing winter wheat on the field, or changing tillage system to no-till would be higher priority. However, this conclusion uses watershed level nutrient loads. Slight differences in magnitude and/or trends in these analyses may differ at the subbasin level.

To explain the similarities among class levels of each design variable, LSD was used to compare the means of nutrient loads between levels. LSD was applied to four design variables, crop type (CROP), tillage system (TILL), edge-of-field BMP (BMPS), and fertilizer application (FERT), for TN and TP loads. The levels of grain sorghum (G), soybean (S), and grain sorghum-soybean rotation (GS) in crop rotation (CROP) variable are not significantly different in TN load. Moreover, winter wheat-corn (WC) rotation and winter wheat-grain sorghum-soybean (WGS) rotation are also not significantly different in TN load. However, these crop rotations have similar TP loads. For the tillage system (TILL) analysis, the TN and TP loads of rotational tillage (OT) and reduced tillage (RT) systems are not significantly different. For FERT and BMPS, there are only two levels for each variable. These two levels are in different groups, so their means are significantly different. Therefore, using the results in scenario trend analysis, potential nutrient loads in evaluating the alternative scenarios becomes easy to prioritize.



(a) CROP (Crop Rotation)

(b) TILL (Tillage System)

(c) BMPS (Edge-of-Field VFS)

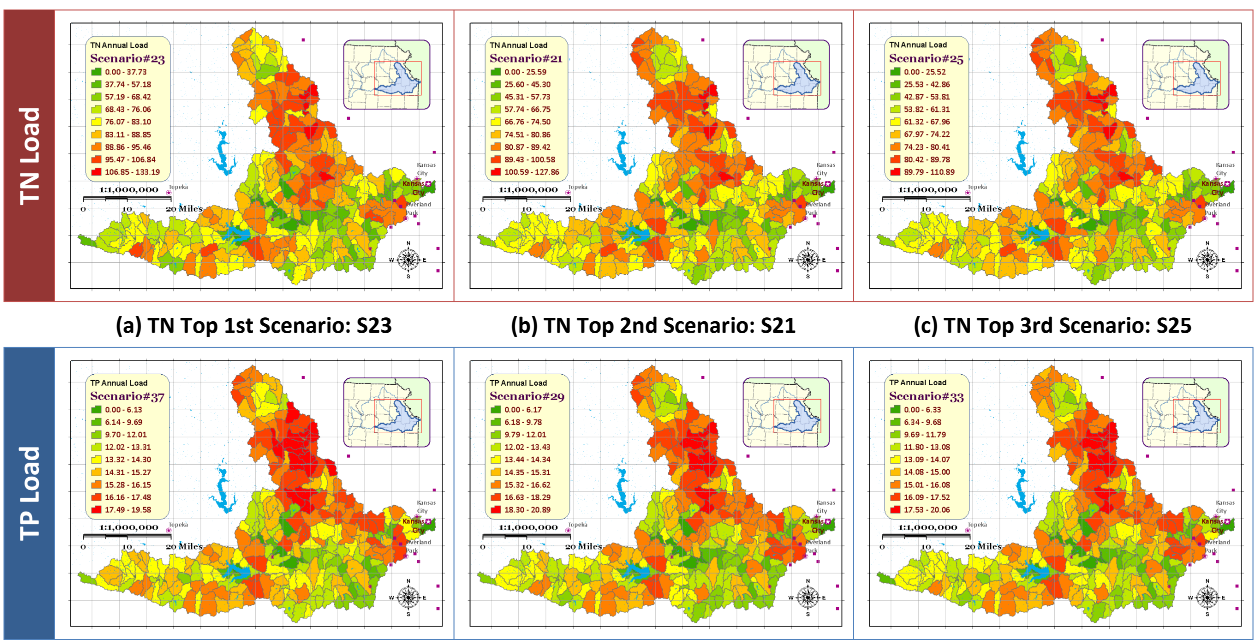
(d) FERT (Fertilizer Application Method)

Figure 3-9 Nutrient Load ANOVA Main Effects

3.5.1.2 *Geospatial Site-Specific Effect*

The watershed level annual nutrient loads only provide simple loading information for each scenario in the study watershed. To understand the pattern of potential nutrient load distribution among subbasins in the study watershed, the loading yields were visualized with GIS software, ESRI ArcGIS 9.2, to show the trends of nutrient loads in a two dimensional, geospatial scale. Figure 3-10 illustrates both annual TN and TP loads of each subbasin for the top three scenarios. In Figure 3-10, the green blocks represent the lower nutrient loads while the red blocks show the higher loads. Similarly, Figure 3-11 display annual TN and TP loads of each subbasin for the lowest three scenarios.

From these maps, the site-specific effect is clear. With the same land management practice in different subbasins, nutrient load yields are dramatically different. That shows watershed heterogeneity in soil types, topographic properties, and/or micro climate might cause distinct hydrology responses as well as pollutant loads. Moreover, different scenarios produce different loads and patterns in the study watershed. This implies a potential difference between the nutrient loads of any two scenarios.

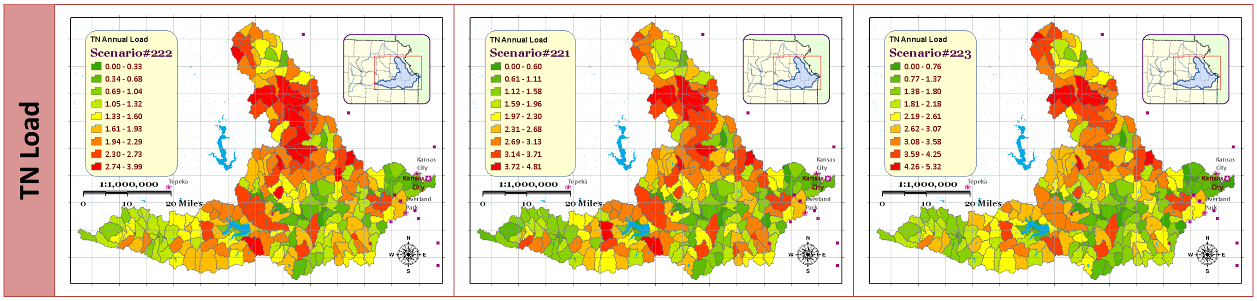


(a) TN Top 1st Scenario: S23 **(b) TN Top 2nd Scenario: S21** **(c) TN Top 3rd Scenario: S25**

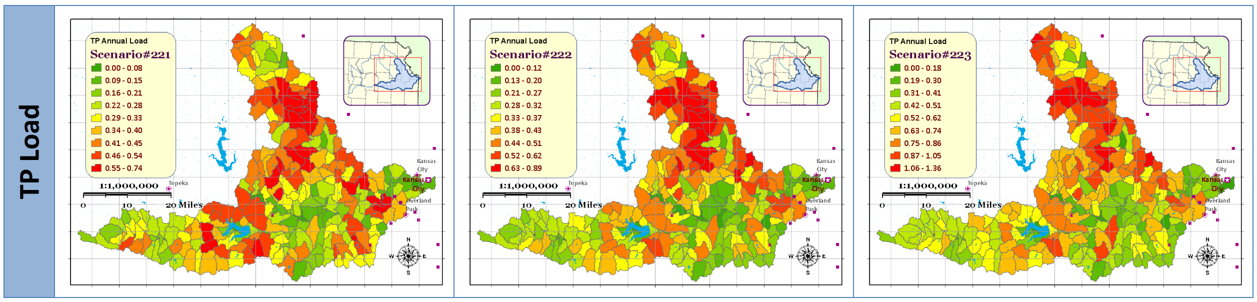
(d) TP Top 1st Scenario: S37 **(e) TP Top 2nd Scenario: S29** **(f) TP Top 3rd Scenario: S33**

Note: S21: cont. corn, conventional till, surface fertilizer, no VFS; S23: cont. corn, conventional till, sub-surface fertilizer, no VFS; S25: cont. corn, minimum till, surface fertilizer, no VFS; S29: cont. corn, reduced till, surface fertilizer, no VFS; S33: cont. corn, rotational till, surface fertilizer, no VFS; S37: cont. corn, no-till, surface fertilizer, no VFS;

Figure 3-10 Annual Nutrient Loads of Each Subbasin for Top 3 Scenarios



(a) TN Bottom 1st Scenario: S222 **(b) TN Bottom 2nd Scenario: S221** **(c) TN Bottom 3rd Scenario: S223**



(d) TP Bottom 1st Scenario: S221 **(e) TP Bottom 2nd Scenario: S222** **(f) TP Bottom 3rd Scenario: S223**

Note: S221: native grass, big bluestem; S222: native grass, switchgrass; S223: VFS grass, tall fescue;

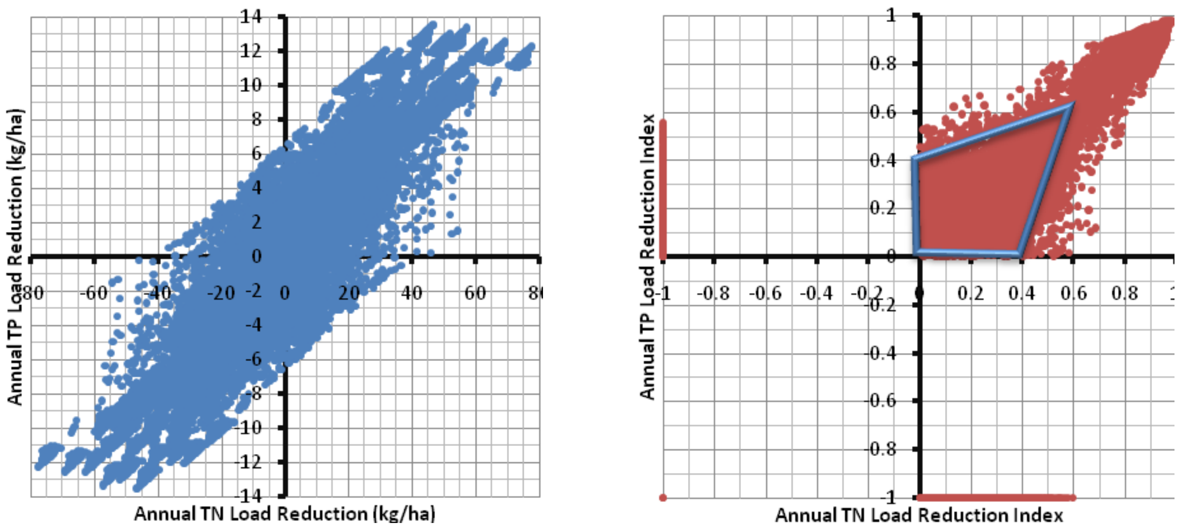
Figure 3-11 Annual Nutrient Loads of Each Subbasin for Bottom 3 Scenarios

3.5.2 Potential Load Reduction

To determine the pollutant load reduction between current and alternative management practices, the subbasin level nutrient load reduction of each of the 224 scenarios is given as the current in-field load subtract the load of each of the other scenarios. Based on the pollutant load reduction equation in Eq. 3-7, the set of watershed and subbasin level annual TN and TP load reductions can be calculated from SWAT outputs. As described previously, only cropland produces a meaningful load reduction for WQT. Therefore, the following analyses will focus on the cropland subset. Furthermore, the 36-year average annual nutrient load reduction was calculated for each of the 286 subbasins and for the entire watershed. Following Eq. 3-8, the relative pollutant load reduction index, or BMP reduction efficiency factor ($BMP_{R(1-2)}$) can also be calculated.

Figure 3-12 (a) illustrates the potential watershed level nutrient load reduction for 225x225 scenario pairs. Each dot in Figure 3-12 (a) represents a scenario pair and the intersection of its potential TN load reduction (X-axis) and potential TP load reduction (Y-axis). The distribution of these dots presents a strong NE-SW trend that indicates most scenario pairs tend to behave similarly in TN and TP load reductions. In other words, when a scenario pair has a positive TN load reduction, it usually will also have a positive TP load reduction.

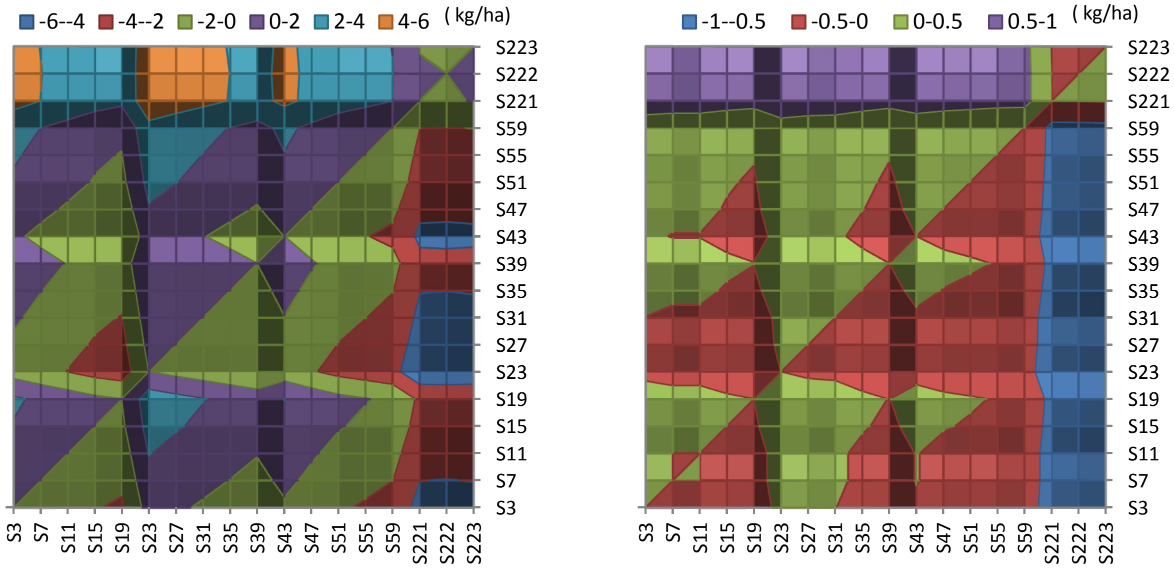
Similarly, Figure 3-12 (b) displays the distribution of relative load reduction index for all scenario pairs. For those dots line-up at the bottom or left end of the figure and at point of (-1, -1) represent that scenario pairs with a negative potential load reduction. Looking at the distribution of those dots with positive load reduction index, they show an obvious 45 degree trend. However, looking at the detail of Figure 3-12 (b), for the block enclosing values from 0 to 0.6 along both axes in the first quadrant, the dots appear to show a random distribution in a kite shaped area. Extending the kite shape to the (1, 1) point includes most of the load-reduction pairs. Moreover, for dots with either TN or TP load reduction index equal to 0, the other load reduction will not exceed 0.6, a mysterious phenomenon that is still being researched.



(a) Potential Annual Nutrient Load Reduction
(b) Potential Annual Nutrient Load Reduction Index

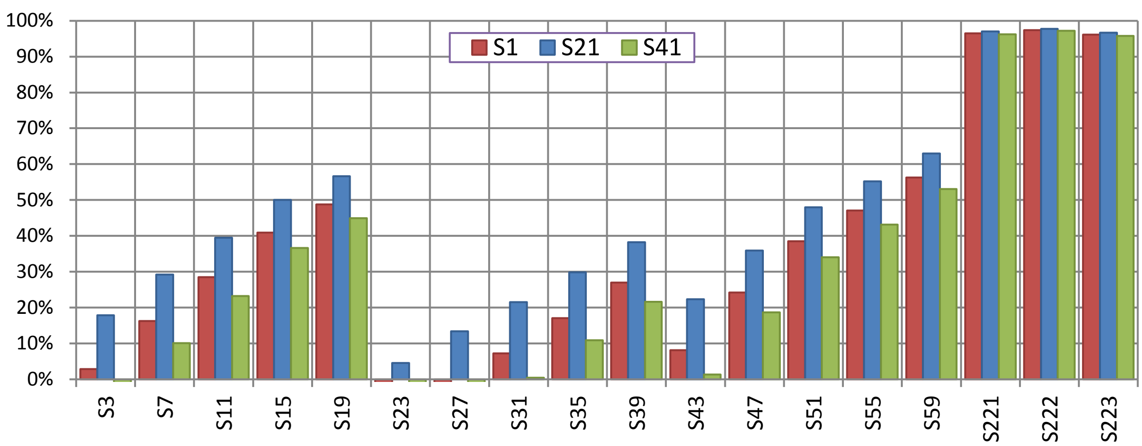
Figure 3-12 Potential Load Reduction and Reduction Index for All Scenario Pairs

Figure 3-13 (a) and (b) display the TN and TP load reduction among several selected scenarios. In Figure 3-13 (a), the highest TN load reduction occurs in the grasses section (S221: big bluestem, S222: switchgrass, and S223: tall fescue, in orange), but the other crop rotations also have some high reduction alternative scenarios (in cyan). Similarly, the major grasses (S221, S222, and S223 in purple) show the highest TP load reduction in Figure 3-13 (b). Both Figure 3-14 and Figure 3-15 illustrate the nutrient load reduction index for three scenarios with conservation till and surface fertilizer: S1 (2-yr corn-soybean), S21 (cont. corn), and S41 (cont. soybean) to the other scenarios within five tillage systems and sub-surface fertilizer application. For the TN load reduction indexes in Figure 3-14 and TP in Figure 3-15, the pattern of the load reduction indexes are similar: scenarios with conventional tillage, sub-surface fertilizer, and no VFS (S3: 2-yr corn-soybean, S23: cont. corn, or S43: cont. soybean) usually have a lower load reduction index while scenarios with no-till (S19: 2-yr corn-soybean, S39: cont. corn, or S59: cont. soybean) have higher ones.



(a) TN Load Reduction **(b) TP Load Reduction**

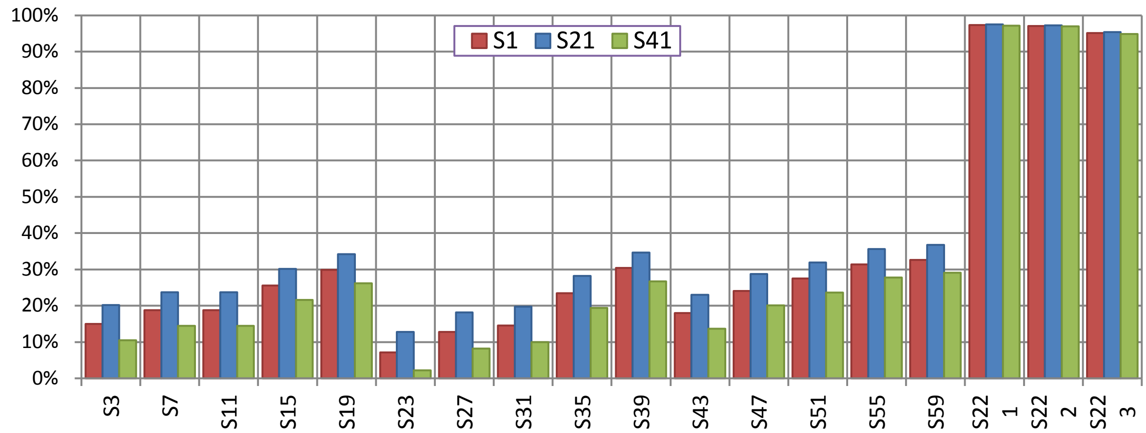
Figure 3-13 Potential Annual Nutrient Load Reduction between Selected Scenarios



Above chart shows the TN load reduction indexes for three conservation tillage scenarios with surface fertilizer and no VFS: S1, S21, and S41 to the other tillage system scenarios with sub-surface fertilizer.

Note: Selected current scenarios: conservation till with surface fertilizer and no VFS: S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean. Alternative scenarios with sub-surface fertilizer and no VFS: S3, S23, and S43: conventional till; S7, S27, and S47: minimum till; S11, S31, and S51: reduced till; S15, S35, and S55: rotational till; S19, S39, and S59: no-till. Native prairie grasses: S221: big bluestem, S222: switchgrass, and S223: tall fescue.

Figure 3-14 TN Load Reduction Index for S1, S21, and S41



Above chart shows TP load reduction indexes for three conservation tillage scenarios with surface fertilizer and no VFS: S1, S21, and S41 to the other tillage system scenarios with sub-surface fertilizer.

Note: Selected current scenarios: conservation till with surface fertilizer and no VFS: S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean. Alternative scenarios with sub-surface fertilizer and no VFS: S3, S23, and S43: conventional till; S7, S27, and S47: minimum till; S11, S31, and S51: reduced till; S15, S35, and S55: rotational till; S19, S39, and S59: no-till. Native prairie grasses: S221: big bluestem, S222: switchgrass, and S223: tall fescue.

Figure 3-15 TP Load Reduction Index for Three S1, S21, and S41

3.5.2.1 *Load Reduction and Reduction Index Ranks*

By sorting and ranking the nutrient load reduction and reduction indexes of all scenarios, we found the maximum nutrient load reductions, reduction indexes, and top 20 scenarios for each nutrient load (see Table 3-7 and Table 3-8). The overall trends in Table 3-7 and Table 3-8 show most of the current corn scenarios will generate the maximum TN and TP load reductions when the alternative scenarios are native prairie grass (C-BBLS, C-SWCH, C-FESC). The corn to winter wheat (C-W) scenarios also produced a higher TN load reduction. Similarly, corn to native prairie grass (C-BBLS, C-SWCH, C-FESC) scenarios produced higher TN load reduction indexes (TNRI) or TP load reduction indexes (TPRI), but corn-soybean (CS) or grain sorghum-soybean (GS) to native prairie grasses scenarios also rank highly in the TNRI and TPRI statistics. Therefore, for the modeling scenarios in this study, corn has a higher potential to produce more nutrient loads than other crops, and native prairie grasses (BBLS, SWCH, and FESC) tend to yield lower loads than other crops. In addition to the native prairie grasses, winter wheat (W) was another option with the potential to yield lower nutrient loads than other crops. Moreover, some corn-soybean (CS) to major grass scenario pairs were more highly ranked in nutrient load reduction, especially if the alternative was switchgrass (SWCH).

While the absolute nutrient load reduction might vary from one location to another, the load reduction index provides a relatively stable indicator by using the load reduction divided by current load, which is a standardized parameter in percentage scale and also a relative BMP efficiency index.

Although the trades in WQT programs focus mainly on maximizing mass load reductions (rather than percentage reductions), the load reduction index allows farmers to evaluate globally the overall reduction efficiency of the potential alternative scenarios. Therefore, the load reduction index is also an important indicator for comparing potential load reduction for given current-alternative scenario pair.

Table 3-7 Top 20 Scenarios for TN Load Reduction and Reduction Index

(a) Ranking with TN Load Reduction

Scenario		Scenario Variable (Current-Alternative)				Rank
CUR	ALT	CROP[1]	TILL[2]	FERT[3]	BMPS[4]	TN
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	1
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	2
23	223	C-FESC	CT-NP	DB-NA	WO-WO	3
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	4
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	5
21	223	C-FESC	CT-NP	SB-NA	WO-WO	6
23	91	C-W	CT-RT	DB-DB	WO-WO	7
23	99	C-W	CT-NT	DB-DB	WO-WO	8
23	224	C-FESC	CT-MO	DB-NA	WO-WO	9
23	89	C-W	CT-RT	DB-SB	WO-WO	10
23	97	C-W	CT-NT	DB-SB	WO-WO	11
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	12
25	221	C-BBLS	MT-NP	SB-NA	WO-WO	13
25	223	C-FESC	MT-NP	SB-NA	WO-WO	14
27	222	C-SWCH	MT-NP	DB-NA	WO-WO	15
27	221	C-BBLS	MT-NP	DB-NA	WO-WO	16
23	95	C-W	CT-OT	DB-DB	WO-WO	17
21	91	C-W	CT-RT	SB-DB	WO-WO	18
27	223	C-FESC	MT-NP	DB-NA	WO-WO	19
21	99	C-W	CT-NT	SB-DB	WO-WO	20

(b) Ranking with TN Load Reduction Index

Scenario		Scenario Variable (Current-Alternative)				Rank
CUR	ALT	CROP[1]	TILL[2]	FERT[3]	BMPS[4]	TNRI
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	1
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	2
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	3
27	222	C-SWCH	MT-NP	DB-NA	WO-WO	4
1	222	CS-SWCH	CT-NP	SB-NA	WO-WO	5
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	6
29	222	C-SWCH	RT-NP	SB-NA	WO-WO	7
3	222	CS-SWCH	CT-NP	DB-NA	WO-WO	8
41	222	S-SWCH	CT-NP	SB-NA	WO-WO	9
31	222	C-SWCH	RT-NP	DB-NA	WO-WO	10
43	222	S-SWCH	CT-NP	DB-NA	WO-WO	11
121	222	GS-SWCH	CT-NP	SB-NA	WO-WO	12
61	222	G-SWCH	CT-NP	SB-NA	WO-WO	13
123	222	GS-SWCH	CT-NP	DB-NA	WO-WO	14
23	223	C-FESC	CT-NP	DB-NA	WO-WO	15
33	222	C-SWCH	OT-NP	SB-NA	WO-WO	16
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	17
63	222	G-SWCH	CT-NP	DB-NA	WO-WO	18
5	222	CS-SWCH	MT-NP	SB-NA	WO-WO	19
7	222	CS-SWCH	MT-NP	DB-NA	WO-WO	20

Table 3-8 Top 20 Scenarios for TP Load Reduction and Reduction Index

(c) Ranking with TP Load Reduction

Scenario		Scenario Variable (Current-Alternative)				Rank
CUR	ALT	CROP[1]	TILL[2]	FERT[3]	BMPS[4]	TP
37	221	C-BBLS	NT-NP	SB-NA	WO-WO	1
37	222	C-SWCH	NT-NP	SB-NA	WO-WO	2
29	221	C-BBLS	RT-NP	SB-NA	WO-WO	3
29	222	C-SWCH	RT-NP	SB-NA	WO-WO	4
37	223	C-FESC	NT-NP	SB-NA	WO-WO	5
29	223	C-FESC	RT-NP	SB-NA	WO-WO	6
33	221	C-BBLS	OT-NP	SB-NA	WO-WO	7
33	222	C-SWCH	OT-NP	SB-NA	WO-WO	8
33	223	C-FESC	OT-NP	SB-NA	WO-WO	9
25	221	C-BBLS	MT-NP	SB-NA	WO-WO	10
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	11
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	12
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	13
25	223	C-FESC	MT-NP	SB-NA	WO-WO	14
9	221	CS-BBLS	RT-NP	SB-NA	WO-WO	15
9	222	CS-SWCH	RT-NP	SB-NA	WO-WO	16
21	223	C-FESC	CT-NP	SB-NA	WO-WO	17
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	18
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	19
9	223	CS-FESC	RT-NP	SB-NA	WO-WO	20

(d) Ranking with TP Load Reduction Index

Scenario		Scenario Variable (Current-Alternative)				Rank
CUR	ALT	CROP[1]	TILL[2]	FERT[3]	BMPS[4]	TPRI
37	221	C-BBLS	NT-NP	SB-NA	WO-WO	1
29	221	C-BBLS	RT-NP	SB-NA	WO-WO	2
33	221	C-BBLS	OT-NP	SB-NA	WO-WO	3
25	221	C-BBLS	MT-NP	SB-NA	WO-WO	4
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	5
37	222	C-SWCH	NT-NP	SB-NA	WO-WO	6
29	222	C-SWCH	RT-NP	SB-NA	WO-WO	7
9	221	CS-BBLS	RT-NP	SB-NA	WO-WO	8
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	9
33	222	C-SWCH	OT-NP	SB-NA	WO-WO	10
17	221	CS-BBLS	NT-NP	SB-NA	WO-WO	11
13	221	CS-BBLS	OT-NP	SB-NA	WO-WO	12
5	221	CS-BBLS	MT-NP	SB-NA	WO-WO	13
1	221	CS-BBLS	CT-NP	SB-NA	WO-WO	14
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	15
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	16
9	222	CS-SWCH	RT-NP	SB-NA	WO-WO	17
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	18
129	221	GS-BBLS	RT-NP	SB-NA	WO-WO	19
41	221	S-BBLS	CT-NP	SB-NA	WO-WO	20

Note: **1. CROP**: crop rotation; C: continuous corn; S: continuous soybean; G: continuous grain sorghum; W: continuous winter wheat; CS: 2-yr corn-soybean rotation; GS: 2-yr grain sorghum-soybean rotation; BBLS: big bluestem, native prairie grass; SWCH: switchgrass, alternative energy source (bio-fuel); FESC: general VFS cover plant (for Kansas cool season grass). **2. TILL**: tillage system; NT: no-till; OT: rotational tillage, which is a tillage system with halftime no-till (NT) and halftime minimum tillage (MT); RT: reduced tillage; MT: minimum tillage; CT: conventional tillage; NP: native prairie grass/no practice. **3. FERT**: fertilizer application method; SB: general surface fertilizer (surface broadcast); DB: general sub-surface fertilizer (deep band); NA: not apply. **4. BMPS**: edge-of-field BMPs; WO: without edge-of-field BMPs; FS: with edge-of-field VFS.

3.5.2.2 *Scenario Trend of Nutrient Load Reduction*

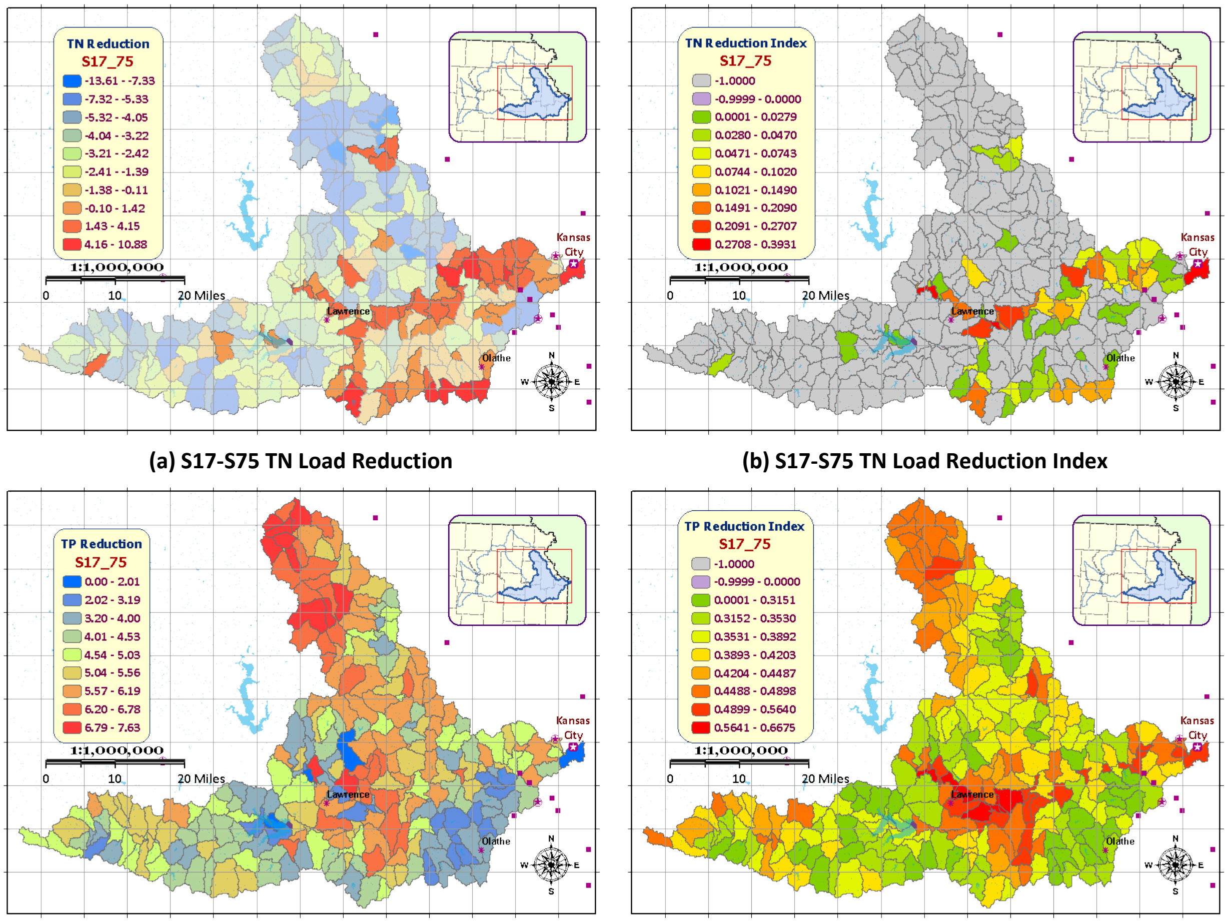
To understand the similarity of the means of nutrient load reductions among alternative scenario pairs, the means of nutrient loads of 48400 potential alternative scenario pairs (excluding grass scenarios) were tested with the factorial ANOVA method. Within the ANOVA statistics, the p-value for the overall ANOVA of both TN and TP load reductions are less than 0.0001, which indicates significant differences in the means of load reduction among all scenarios. For the model ANOVA of load reduction, most design variables (model sources) have a p-value less than 0.0001 except CROP*FERT (Pr=1.0) for TN load reduction. This implies an overall trend that all scenarios tend to generate significant differences in nutrient load reduction. However, this conclusion is based on the watershed level nutrient load reductions. The magnitude and/or trends of these analyses may differ slightly at the subbasin level.

To understand the similarities of load reductions among class levels of each design variable, LSD was used to compare the level means of nutrient load reductions, with four design variables, CROP, TILL, FERT, and BMPS, applied for the t-test of TN and TP load reductions for each level. The original 121 classes of alternative crop rotations (CROP) were divided into 69 groups for TN and 66 groups for TP. Most classes of alternative tillage systems (TILL) were significantly different in load reduction except minimum tillage to reduced tillage (MT-RT) versus reduced tillage to no-till (RT-NT) for TN as well as minimum tillage to reduced tillage (MT-RT) versus rotational tillage to no-till (OT-NT) and minimum tillage to rotational tillage (MT-OT) versus reduced tillage to no-till (RT-NT) for TP. For the other two alternative scenario variables, FERT and BMPS, we have only three levels for each variable. Other than levels with means equal to 0, all other levels are in different groups with significantly different nutrient load reductions. These results provide a great guidance for stakeholders in choosing potential alternatives for maximizing load reduction.

3.5.2.3 *Geospatial Site-Specific Effect*

The test of geospatial site-specific effects on the annual nutrient loads in each subbasin revealed a further research question: Is the geospatial site-specific effect also significant in load reduction and the reduction index. To understand the pattern of potential nutrient load reductions and reduction indexes for each subbasin, we used GIS software to render subbasin level information from several scenario pairs. Figure 3-16 (a) and (b) illustrate the TN load reduction and reduction index of each subbasin when current scenario #17 (S17: 2-yr corn-soybean, no-till, surface fertilizer, no VFS) changed to alternative scenario #75 (S75: cont. grain sorghum, rotational till, sub-surface fertilizer, no VFS). The watershed level average of TN load reduction for S17-S75 is -2.05 kg/ha, while the TN load reduction index is in grey, which suggests this scenario pair should not be applied for trading. However, looking at Figure 3-16 (a), some areas would still have positive TN load reductions (orange to red) as high as 10 kg/ha. The reduction indexes in Figure 3-16 (b) also show a similar trend (yellow to red) where the subbasins show an index with a maximum 0.4. Conversely, the watershed level average of TP load reduction for S17-S75 is 4.84 kg/ha while the TP reduction index would reach 39.25%. Interestingly enough, S17-S75 tended to yield more TP than TN in the upper stream subbasins, but the maximum TP load reduction index occurred in the middle part of watershed (Figure 3-16 (c) and (d)). These phenomena provide solid evidence that geospatial site-specific effect continued in load reductions and reduction indexes.

Following the above processes, we analyzed the potential nutrient load reductions and reduction indices for six selected alternative scenario pairs in Appendix E.1.2 and illustrated load reductions and reduction indices for every subbasin in Figure E-4 through Figure E-7. In comparing Figure E-4 through Figure E-7, different scenarios have different distribution patterns for each nutrient load reduction or reduction index, but the higher and lower values tend to cluster at specific areas. In other words, the overall trends for load reduction or reduction index for each alternative scenario pair are similar. The northern subbasins in the watershed tended to produce more TN load reduction, but the higher reduction index occurred in the middle part of watershed, downstream. TP load reductions showed similar trends, but TP load reduction indexes had a maximum value at the low end of the watershed.



(a) S17-S75 TN Load Reduction **(b) S17-S75 TN Load Reduction Index**

(c) S17-S75 TP Load Reduction **(d) S17-S75 TP Load Reduction Index**

Note: S17: 2-yr corn-soybean, no-till, surface fertilizer, no VFS; S75: cont. grain sorghum, rotational till, sub-surface fertilizer, no VFS;

Figure 3-16 Subbasin Nutrient Load Reduction and Reduction Index for S17-S75

3.5.3 Uncertainty Ratio

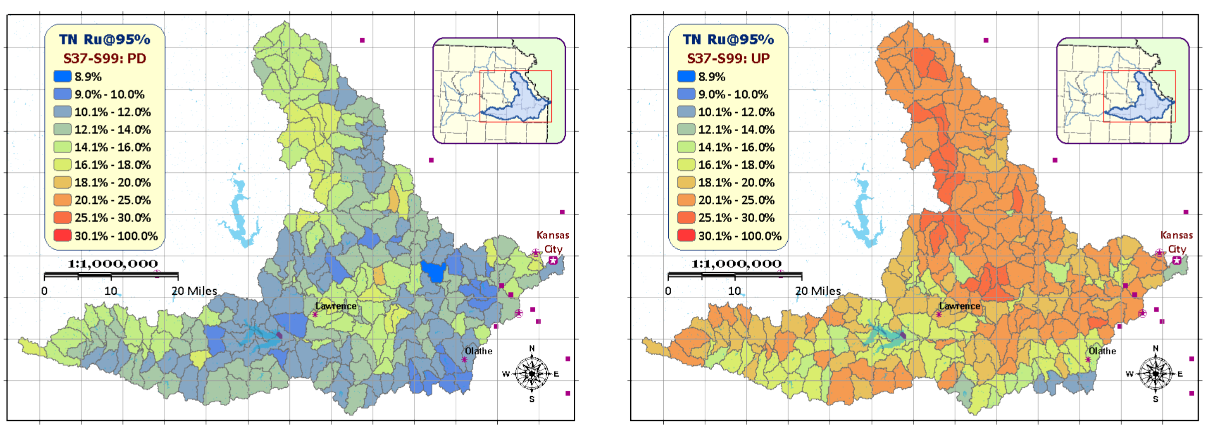
The normal range of R_U is zero (0) to one (1). When R_U equaled 0 there was no uncertainty or potential variation among all the nutrient load reduction records of that alternative scenario pair, so an R_U of 0 in a 36 year simulation gives a statistically insignificant annual load reduction difference. As R_U approached to 1, the TR approached infinity. To quantify the uncertainty of potential load reduction, we applied both paired (PD) and unpaired (UP) load reduction uncertainty ratios in Eq. 3-4 through Eq. 3-14. Thus, all 225 scenarios to its 224 alternative scenario pairs were first tested for the statistical significance of load reduction (difference) with a t-test at 90%, 95%, and 97.5% confidence level. For those pairs with insignificant load reductions or negative load reductions, the R_U is assigned as 1, representing a very high uncertainty, which makes a trade unviable. Otherwise, the R_U was calculated with Eq. 3-13 for paired and Eq. 3-14 for unpaired analysis.

3.5.3.1 *Paired and Unpaired Analysis*

In comparing R_U for the same alternative scenarios with either PD or UP analysis at three different confidence levels, approximately 80% of all 50400 cases have similar R_U (difference < 0.01). For the other 20%, the UP analysis produced a larger R_U. Moreover, only 3% of all cases have differences larger than 0.1. However, no (0%) alternative scenarios had a lower R_U when analyzed using the UP analysis rather than the PD analysis.

Figure 3-17 shows the subbasin level TN load reduction R_U for scenario #37 (S37: cont. corn, no-till, surface fertilizer, no VFS) to scenario #99 (S99: cont. winter wheat, no-till, sub-surface fertilizer, no VFS) at a 95% confidence level. In comparing Figure 3-17 (a) and Figure 3-17 (b), we see that most subbasins tend to produce higher R_U with UP analysis than PD analysis. This indicates that UP analysis estimated a higher uncertainty of the TN load reduction than PD analysis for these S37-S99 alternative scenario pairs. The UP analysis is much more aggressive than PD analysis in estimating nutrient load reduction uncertainty. Moreover, the subbasin level R_U differences between PD and UP analyses ranged from 0.0% to -13.33% across the watershed while the watershed average is -0.5%. These phenomena suggest geospatial site-specific effects also apply to the load reduction R_U.

Although the UP and PD analyses differ in calculating uncertainty ratio of nutrient load reduction, deciding which method is superior remains difficult. UP and PD analyses are based on different statistical assumptions; their observations are either independent or dependent. Therefore, because we assume each nutrient load observation in this study is independent, we chose UP analysis.



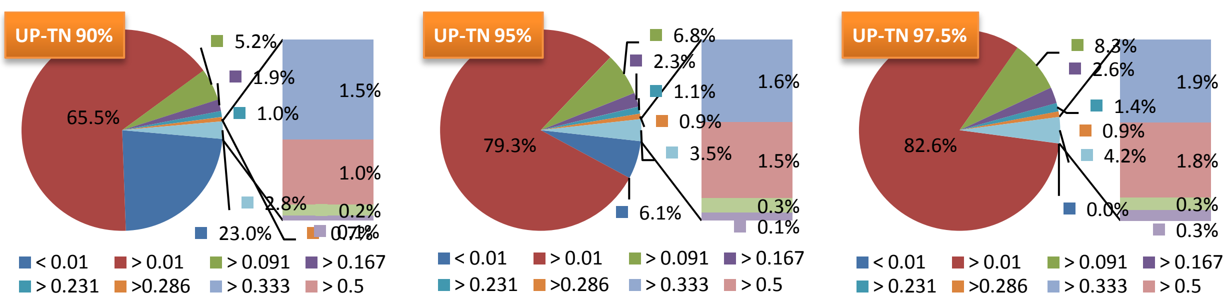
(a) Paired (PD) Analysis **(b) Unpaired (UP) Analysis**

Note: S37: cont. corn, no-till, surface fertilizer, no VFS; S99: cont. winter wheat, no-till, sub-surface fertilizer, no VFS

Figure 3-17 Subbasin TN Load Reduction Uncertainty Ratio for S37-S99 with PD and UP Analyses

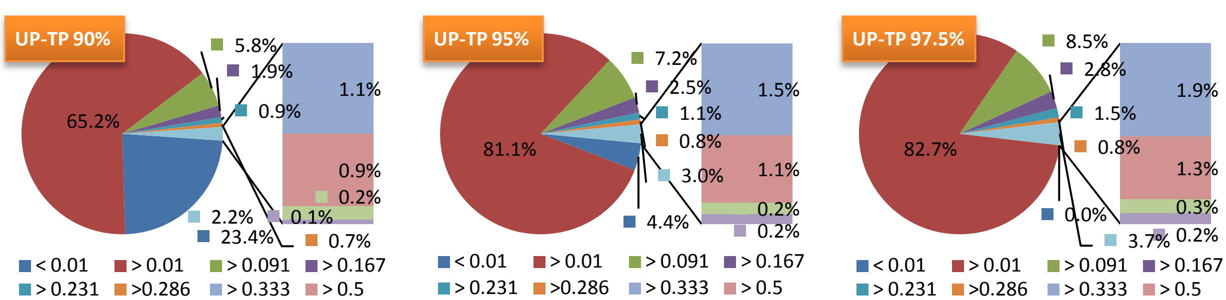
3.5.3.2 *Confidence Level of Uncertainty Ratio*

Figure 3-18 and Figure 3-19 illustrate TN and TP load reduction uncertainty ratio statistics for the UP analysis at 90%, 95% and 97.5% confidence levels. In these charts, the blue blocks represent an R_U value less than 0.01, which means all the observations of load reduction in the alternative scenarios in this category have an almost constant load reduction. The red block means R_U value is greater than 0.01 but less than 0.091, and so on. For these confidence levels (CL), 23% of alternative scenarios at 90% CL have an R_U almost equal to zero while 65.5% scenarios at this CL have an R_U between 0.01 and 0.1. At other confidence levels, the percentage of red blocks increased as the CL increased. In contrast, the percentage of blue blocks decreased as CL increased. Thus, the higher CL means the higher uncertainty should be applied to keep the same load reduction. The higher R_U also means a higher TR and trading cost for credit buyers. Therefore, selecting the confidence level of the R_U for WQT is critical. In a real WQT system, the selection of this level would be a policy decision. In this study, the 95% confidence level was considered a good option to maintain a balance between high security of potential load reduction and trading cost.



(a) TN R_U at 90% CL (b) TN R_U at 95% CL (c) TN R_U at 97.5% CL

Figure 3-18 Statistics of TN Load Reduction Uncertainty Ratio with UP Analysis



(a) TP R_U at 90% CL (b) TP R_U at 95% CL (c) TP R_U at 97.5% CL

Figure 3-19 Statistics of TP Load Reduction Uncertainty Ratio with UP Analysis

3.5.3.3 *Uncertainty Ratio Matrix*

The R_Us for the entire watershed, each individual subbasin, and each HRU were calculated based on Eq. 3-13 and Eq. 3-14. The R_Us for each category were originally listed in several 225x225 matrices at specific confidence levels (90%, 95%, and 97.5%). In these matrices, the first (top) row presents current scenarios and the first column contains potential alternative scenarios. Both current scenario columns and alternative scenario rows ranged from S1 to S225 to represent scenarios #1 to #225 as described in Table 3-6 and Table A-20. Therefore, in each column, we have 225 potential R_Us for each specific current scenario in changing to alternative scenarios. Conversely, each row contains 225 potential R_Us for each specific alternative scenario as it changed from the current scenario. The cell value in each column and row intersection is the potential nutrient load reduction R_U if the management practice changed from the selected current scenario to the alternative one. Table 3-9 lists 20 selected alternative scenarios and 5 major grass scenarios from the original R_U matrix for demonstration and discussion.

In Table 3-9, different colored cells represent a different magnitude for R_U. For example, the greenish block represents an R_U greater than 0.01, which might provide a significant load reduction between current and alternative scenarios. For values greater than 0.333, the bluish blocks represent an R_U between 0.333 and 0.5, reddish blocks represent an R_U between 0.5 and 0.8, and the red blocks an R_U from 0.8 to 0.9. The black blocks indicate an R_U value greater than 0.9 but less than 1.0. In extreme cases, R_U values were assigned a value of 1, and those blocks are white.

In Table 3-9, scenario #221 (S221) to scenario #225 (S225) are the major grass scenarios. The R_U values for grasses changing to other crop rotations equal 1, showing the potential load reductions of these cases are negative. Conversely, the R_U values for changing major crop rotations to grass are greater than 0, but none of them is greater than 0.1, so load reductions in these cases are positive, while the uncertainties of those load reductions are very small. In contrast, scenario #121 (S221: big bluestem) to scenario #61 (S61: cont. grain sorghum, conventional till, surface fertilizer, no VFS) have the highest uncertainty ratios (R_U = 0.982) and scenario #41 (S41: cont. soybean, conventional till, surface fertilizer, no VFS) to scenario #121 (S121: 2-yr grain sorghum-soybean, conventional till, surface fertilizer, no VFS) have the second high R_U value (0.968), indicating the uncertainty in these two trades is very high. Although the potential load reduction between current and alternative scenarios in each trade is still positive, the costs are huge. More detailed R_U statistics can be found in Appendix C.3.

Table 3-9 Selected TN Load Reduction Uncertainty Ratio with UP Analysis at 95% CL

SCEN	S1	S21	S23	S25	S27	S29	S31	S33	S35	S37	S41	S61	S81	S101	S121	S141	S161	S181	S201	S221	S222	S223	S224	S225
S1		0.085	0.049	0.186	0.591	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S21	1		0.125	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S23	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S25	1	0.151	0.066		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S27	1	0.100	0.054	0.275		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S29	0.725	0.077	0.046	0.149	0.328		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S31	0.182	0.060	0.039	0.093	0.141	0.244		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S33	0.117	0.051	0.035	0.072	0.099	0.141	0.356		1	1	0.316	1	1	1	0.483	1	1	1	1	1	1	1	1	1
S35	0.072	0.041	0.030	0.053	0.065	0.080	0.122	0.175		1	0.117	0.161	1	1	0.134	1	1	1	1	1	1	1	1	1
S37	0.061	0.037	0.028	0.046	0.056	0.067	0.094	0.121	0.404		0.091	0.117	1	1	0.101	1	1	1	1	1	1	1	1	1
S39	0.043	0.031	0.024	0.036	0.041	0.046	0.057	0.064	0.102	0.134	0.056	0.066	1	1	0.060	1	0.272	0.551	0.174	1	1	1	1	1
S41	0.193	0.061	0.040	0.096	0.147	0.263	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
S61	0.141	0.055	0.038	0.082	0.116	0.175	0.585	1	1	1	0.492		1	1	0.982	1	1	1	1	1	1	1	1	1
S81	0.024	0.021	0.018	0.022	0.024	0.025	0.027	0.028	0.032	0.034	0.027	0.029		0.106	0.028	0.102	0.045	0.048	0.042	1	1	1	1	1
S101	0.034	0.027	0.022	0.030	0.033	0.036	0.041	0.043	0.055	0.060	0.040	0.045	1		0.042	1	0.082	0.094	0.073	1	1	1	1	1
S121	0.161	0.058	0.038	0.088	0.129	0.208	1	1	1	1	0.968	1	1	1		1	1	1	1	1	1	1	1	1
S141	0.035	0.027	0.022	0.031	0.034	0.037	0.042	0.045	0.057	0.063	0.042	0.046	1	1	0.043		0.086	0.099	0.076	1	1	1	1	1
S161	0.063	0.039	0.030	0.049	0.058	0.068	0.091	0.111	0.237	0.446	0.088	0.108	1	1	0.096	1		1	0.526	1	1	1	1	1
S181	0.056	0.037	0.028	0.045	0.053	0.060	0.078	0.092	0.164	0.241	0.076	0.090	1	1	0.082	1	0.622		0.288	1	1	1	1	1
S201	0.074	0.043	0.032	0.056	0.068	0.082	0.116	0.153	0.522	1	0.112	0.143	1	1	0.125	1	1	1		1	1	1	1	1
S221	0.01	0.011	0.01	0.010	0.010	0.010	0.010	0.01	0.01	0.01	0.010	0.011	0.018	0.017	0.010	0.017	0.014	0.014	0.014		1	0.193	0.014	0.016
S222	0.01	0.011	0.01	0.01	0.010	0.01	0.010	0.01	0.01	0.01	0.010	0.011	0.018	0.017	0.010	0.017	0.014	0.014	0.014	0.069		0.049	0.013	0.015
S223	0.01	0.011	0.01	0.010	0.010	0.010	0.010	0.01	0.01	0.01	0.010	0.011	0.018	0.017	0.010	0.017	0.014	0.014	0.014	1	1		0.014	0.016
S224	0.012	0.013	0.011	0.012	0.013	0.013	0.013	0.012	0.013	0.013	0.013	0.014	0.031	0.025	0.013	0.025	0.019	0.019	0.019	1	1	1		0.035
S225	0.018	0.017	0.014	0.017	0.018	0.018	0.019	0.019	0.021	0.021	0.019	0.021	0.093	0.050	0.020	0.049	0.029	0.031	0.029	1	1	1	1	

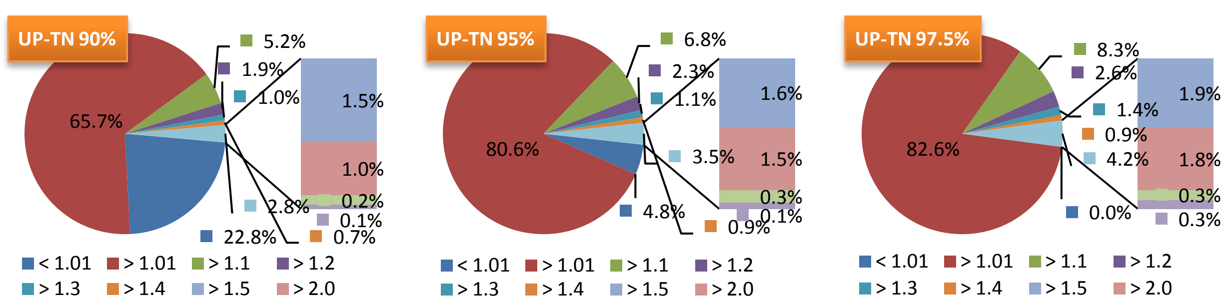
3.5.4 In-Field Trading Ratio

The normal TR is more than one (1). When TRs equal 1, we have a 1:1 trade, which means a stakeholder can buy a unit nutrient load reduction to replace one unit of reduction requirement. For TRs greater than 1, some degree of load reduction uncertainty (or delivery inefficiency) remains in the alternative scenario pair. As the TR becomes larger, uncertainty also becomes higher. Therefore, a TR approaching infinity gives us a highly uncertain situation, and its corresponding R_U will approach 1.

As for the R_U analyzed previously, all the scenario pairs of 225 scenarios to the other 224 alternative scenarios were tested to see if their load reductions were statistically significant using t-tests at 90%, 95%, and 97.5% CL. For pairs with non-significant load reductions or negative load reductions, the R_U is assigned 1 to represent a very high uncertainty, which would not be amenable to trade. Otherwise, R_U is calculated with Eq. 3-13 for paired and Eq. 3-14 for unpaired analysis. Based on Eq. 3-3, if we neglect delivery effects and only focus on the in-field load processes, the equation for calculating TR can be rewritten as Eq. 3-15 where the TR is equal to the inverse of the 1 minus R_U value. For special cases, where the R_U value equals 1, the TR value will be infinite according to Eq. 3-15. Therefore, the TR for those cases is assigned a 0, indicating they may not be profitable for trading. Following these steps, the TRs for 50400 alternative scenario pairs were calculated.

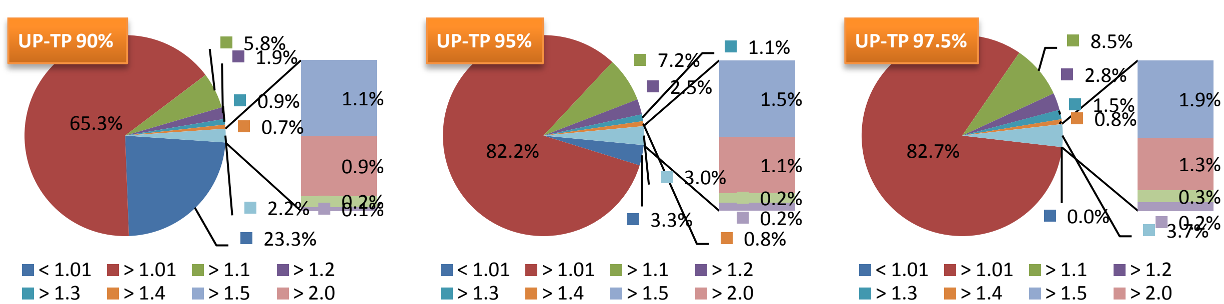
3.5.4.1 *Analysis of Trading Ratio*

As with both UP and PD analysis of the R_U for the alternative scenario pairs, we applied UP analysis with three different CLs for calculating TR. An increasing CL means a decreasing tolerance for failed expected load reductions, so the TR will increase as the confidence level increases. Figure 3-20 and Figure 3-21 illustrate TN and TP load reduction TR statistics with UP analysis at 90%, 95%, and 97.5% confidence levels. In these charts, the blue blocks represent a TR value less than 1.01, which means the load reductions of these alternative scenario pairs show very little difference, or almost constant. The red blocks in the charts mean TR is greater than 1.01 but less than 1.1, and 10% extra load reduction purchasing is advisable. Among these three CLs, 22.8% of alternative scenario pairs at 90% CL have a TR almost equal to 1, while only 4.8% at 95% CL have a TR almost equal to 1, with 0% at 97.5% CL. In contrast, the TR value of the blue blocks ranges from 1.01 to 1.1, with 65.7% at 90% CL, 80.6% at 95% CL, and 82.6% at 97.5% CL. These indicate a higher confidence level leads to increased TR to compensate for the risk of failure of expected load reduction. The higher TR also means higher trading costs for load reduction credits. Therefore, selecting the CL is critical. In this study, a 95% CL was suggested for estimating WQT parameters.



(a) TN TR at 90% CL (b) TN TR at 95% CL (c) TN TR at 97.5% CL

Figure 3-20 Statistics of TN Load Reduction TR with UP Analysis

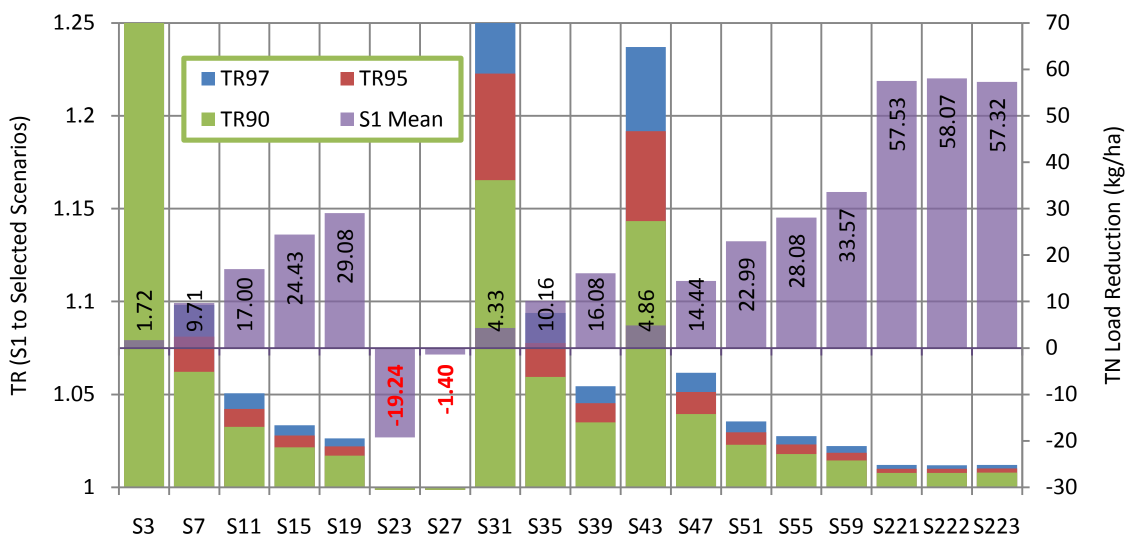


(a) TP TR at 90% CL (b) TP TR at 95% CL (c) TP TR at 97.5% CL

Figure 3-21 Statistics of TP Load Reduction TR with UP Analysis

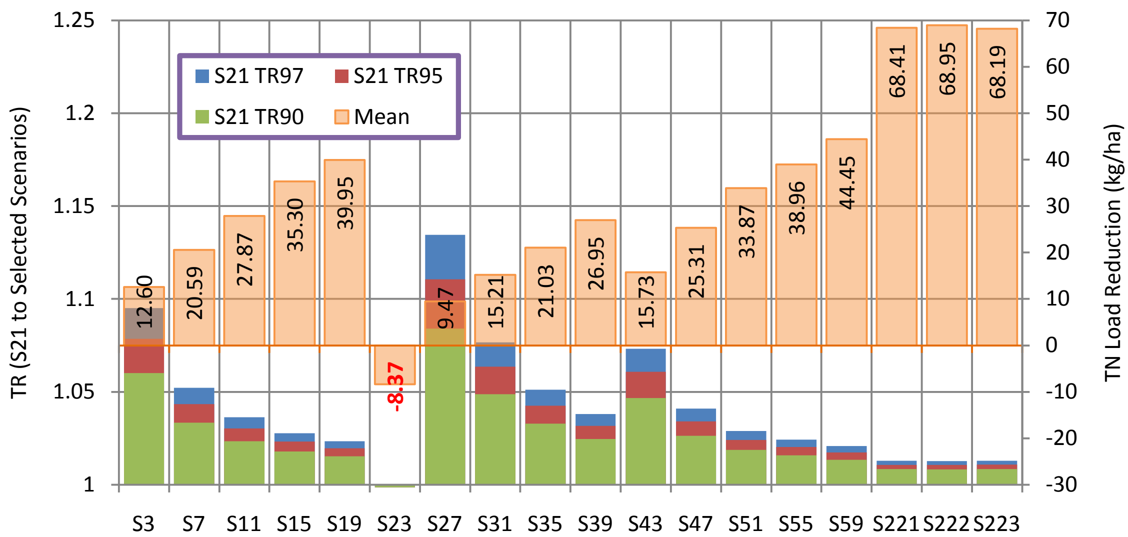
3.5.4.2 *Scenario Comparison*

Following Figure 3-14, Figure 3-22 illustrates the means of potential annual TN load reductions and TRs at 97.5%, 95%, and 90% CLs for scenario #1 to selected alternative scenarios. Similarly, Figure 3-23 is for scenario #21 and Figure 3-24 is for scenario #41 to the same selected alternative scenarios in Figure 3-22. In these figures, look at the load reduction and its TR together, it seems that TR and load reduction are highly correlated in these three cases: the cases with higher load reductions also had lower TRs. However, this trend may only be true for specific alternative scenario pairs, which are based on the same baseline. For example, the potential TN load reduction of S1-S39 is larger than S1-S47 in Figure 3-22, and their TRs have an inverse trend. However, S21-S43 and S21-S31 in Figure 3-23 have the load reduction in between S1-S39 and S1-S47 in Figure 3-22, but their TRs are higher than the later scenario pairs'. Likewise, S21-S3 in Figure 3-23 and S41-S11 in Figure 3-24 have similar load reductions (12.60 versus 12.91)and both are higher than S41-S39's in Figure 3-24, but the TR of S41-S39 is in between the other two's. Therefore, both potential load reduction and TR are the important indicators for WQT assessment. We cannot simply use one's value to estimate another one's.



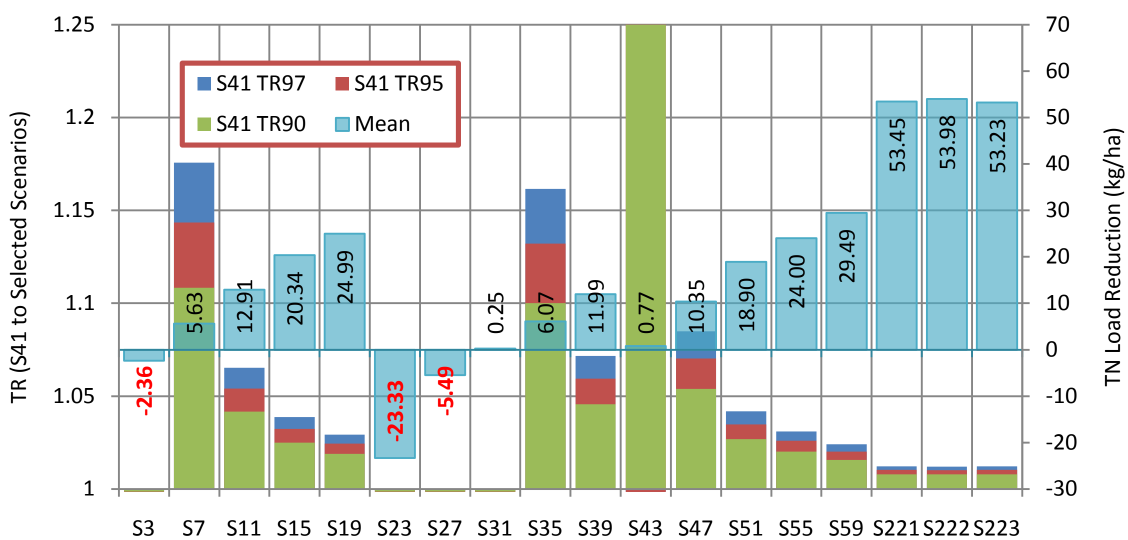
Note: selected current scenarios: conservation till with surface fertilizer and no VFS: S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean. Alternative scenarios with sub-surface fertilizer and no VFS: S3, S23, and S43: conventional till; S7, S27, and S47: minimum till; S11, S31, and S51: reduced till; S15, S35, and S55: rotational till; S19, S39, and S59: no-till. Native prairie grasses: S221: big bluestem, S222: switchgrass, and S223: tall fescue.

Figure 3-22 Annual TN Load Reduction and TR at Three CLs for S1 to Selected Scenarios



Note: selected current scenarios: conservation till with surface fertilizer and no VFS: S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean. Alternative scenarios with sub-surface fertilizer and no VFS: S3, S23, and S43: conventional till; S7, S27, and S47: minimum till; S11, S31, and S51: reduced till; S15, S35, and S55: rotational till; S19, S39, and S59: no-till. Native prairie grasses: S221: big bluestem, S222: switchgrass, and S223: tall fescue.

Figure 3-23 Annual TN Load Reduction and TR at Three CLs for S21 to Selected Scenarios



Note: selected current scenarios: conservation till with surface fertilizer and no VFS: S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean. Alternative scenarios with sub-surface fertilizer and no VFS: S3, S23, and S43: conventional till; S7, S27, and S47: minimum till; S11, S31, and S51: reduced till; S15, S35, and S55: rotational till; S19, S39, and S59: no-till. Native prairie grasses: S221: big bluestem, S222: switchgrass, and S223: tall fescue.

Figure 3-24 Annual TN Load Reduction and TR at Three CLs for S41 to Selected Scenarios

3.5.4.3 *Trading Ratio Matrix*

The TR for the entire watershed, each individual subbasin, and each HRU were calculated using Eq. 3-15. The results of TRs for each category were originally listed in several 225x225 matrices at specific confidence levels (90%, 95%, and 97.5%). In these matrices, the first row lists the current management scenarios and the first column provides the potential alternatives. Both current scenario column and alternative scenario row ranged from S1 to S225 as described in Table 3-6 and Table A-20. Thus, in each column, we had 225 potential TRs for each specific current scenario changing to other scenarios. Each row contained 225 potential TRs for each alternative scenario changing from current scenarios. The cell value for each column and row intersection is the potential nutrient load reduction TR for land management practice as it changed from the selected current scenario to the chosen alternative one. Table 3-10 lists 20 selected alternative scenarios with major crop rotation and 5 major grass alternative scenarios from the original TR matrix.

In Table 3-10, different colors in the cells represent the different magnitudes in TRs. For example, the greenish block shows the value of TR is more than 1.01, which indicates the alternative scenario pair might produce a significant load reduction over the current scenario. For cell values greater than 1.5, the bluish blocks represent a TR between 1.5 and 2.0, reddish blocks represent a TR between 2.0 and 5.0, and the red blocks a TR from 5.0 to 10. For the black block, the TR value is greater than 10 and represents an extremely high TR. For other cases where the potential load reduction was negative, the TR values were assigned a 0, and the table shows them as a white cell.

In Table 3-10, the grass scenarios (S221 to S225) show similar trends in R_U: the TR values for major grasses compared to other crop rotations are equal to 0, showing the potential load reductions in these cases were negative. Conversely, the TR values for major crop rotations compared to grass scenarios are greater than 1, but none is greater than 1.1. Thus, these load reductions were positive, and the uncertainties ratios were very small. In contrast, scenarios #121 (S121: 2-yr grain sorghum-soybean, conventional till, surface fertilizer, no VFS) to #61 (S61: cont. grain sorghum, conventional till, surface fertilizer, no VFS) had the highest R_U (0.982) and the highest TR of 57; scenarios #41 (S41: cont. soybean, conventional till, surface fertilizer, no VFS) to #121 (S121) had the second highest R_U value (0.968) and a TR of 31.1. The uncertainties of these two trades were very high: although the potential load reductions between the trades were still positive (0.8 kg/ha), the costs to gain those load reductions and compensate for the risk of the failure in expected load reduction were huge. In other words, a large TR or high uncertainty only indicates a highly risk of failure within a trade; it doesn't represent the amount of potential load reduction. Therefore, to assess a WQT trade, both potential load reduction and TR are important indicators. In practice, a TR larger than 10 is not a practical trading scenario. More details about TR statistics and analysis can be found in Appendix C.4.

Table 3-10 Selected TN Load Reduction TR with UP Analysis at 95% CL

SCEN	S1	S21	S23	S25	S27	S29	S31	S33	S35	S37	S41	S61	S81	S101	S121	S141	S161	S181	S201	S221	S222	S223	S224	S225
S1		1.093	1.051	1.228	2.447	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S21	0		1.142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S23	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S25	0	1.178	1.071		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S27	0	1.111	1.057	1.378		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	3.630	1.083	1.048	1.175	1.489		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S31	1.223	1.063	1.041	1.103	1.165	1.322		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S33	1.133	1.053	1.036	1.078	1.110	1.164	1.553		0	0	1.463	0	0	0	1.935	0	0	0	0	0	0	0	0	0
S35	1.078	1.043	1.031	1.055	1.070	1.087	1.139	1.213		0	1.132	1.192	0	0	1.155	0	0	0	0	0	0	0	0	0
S37	1.065	1.039	1.029	1.049	1.060	1.072	1.104	1.137	1.678		1.100	1.132	0	0	1.112	0	0	0	0	0	0	0	0	0
S39	1.045	1.032	1.025	1.037	1.043	1.049	1.061	1.069	1.114	1.154	1.059	1.071	0	0	1.064	0	1.374	2.228	1.211	0	0	0	0	0
S41	1.239	1.064	1.041	1.106	1.173	1.357	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
S61	1.164	1.059	1.039	1.089	1.131	1.212	2.410	0	0	0	1.968		0	0	57	0	0	0	0	0	0	0	0	0
S81	1.025	1.021	1.018	1.023	1.025	1.026	1.028	1.029	1.033	1.035	1.028	1.030		1.119	1.029	1.113	1.047	1.051	1.044	0	0	0	0	0
S101	1.036	1.028	1.023	1.031	1.034	1.037	1.043	1.045	1.058	1.064	1.042	1.047	0		1.044	0	1.089	1.103	1.078	0	0	0	0	0
S121	1.193	1.061	1.040	1.096	1.148	1.263	0	0	0	0	31.1	0	0	0		0	0	0	0	0	0	0	0	0
S141	1.037	1.028	1.023	1.032	1.035	1.038	1.044	1.047	1.060	1.067	1.043	1.048	0	0	1.045		1.094	1.110	1.082	0	0	0	0	0
S161	1.067	1.041	1.031	1.051	1.062	1.073	1.100	1.125	1.311	1.804	1.097	1.121	0	0	1.106	0		0	2.111	0	0	0	0	0
S181	1.060	1.038	1.029	1.047	1.055	1.064	1.084	1.101	1.196	1.318	1.082	1.099	0	0	1.089	0	2.647		1.404	0	0	0	0	0
S201	1.080	1.045	1.033	1.059	1.073	1.089	1.131	1.180	2.093	0	1.126	1.167	0	0	1.142	0	0	0		0	0	0	0	0
S221	1.010	1.011	1.01	1.010	1.010	1.010	1.010	1.01	1.01	1.01	1.010	1.011	1.018	1.017	1.010	1.018	1.014	1.014	1.014		0	1.239	1.014	1.016
S222	1.01	1.011	1.01	1.010	1.010	1.010	1.010	1.01	1.01	1.01	1.010	1.011	1.018	1.017	1.010	1.017	1.014	1.014	1.014	1.074		1.052	1.013	1.016
S223	1.010	1.011	1.01	1.010	1.010	1.010	1.010	1.01	1.01	1.01	1.010	1.011	1.019	1.018	1.010	1.018	1.014	1.014	1.015	0	0		1.015	1.016
S224	1.013	1.013	1.012	1.013	1.013	1.013	1.013	1.012	1.013	1.013	1.013	1.014	1.032	1.026	1.013	1.026	1.019	1.019	1.019	0	0	0		1.036
S225	1.018	1.017	1.015	1.017	1.018	1.018	1.020	1.019	1.021	1.022	1.019	1.021	1.103	1.052	1.020	1.051	1.030	1.032	1.030	0	0	0	0	

3.5.5 Temporal Effect

As mentioned earlier, watershed heterogeneity might cause some site-specific effects within subbasins. Site-specific effects can be roughly categorized in geospatial (location) and temporal (modeling/observation duration) scales. Geospatial site-specific effects usually originate in the geophysical properties of individual subbasins or HRUs. Different subbasins or HRUs could have different soil types, land cover, or topography, such as slope, elevation, or latitude. In contrast, temporal site-specific effects usually originate in seasonal differences in modeling parameters, such as temperature, precipitation, or soil moisture. These differences will create differences in hydrologic responses and soil erosion, thus generating different pollutant loads. The seasonal variability in hydrology is significant In Kansas (Sophocleous, 1998). To address the magnitude of nutrient yields over monthly or seasonal periods, advanced modeling work in sub-annual time step is needed.

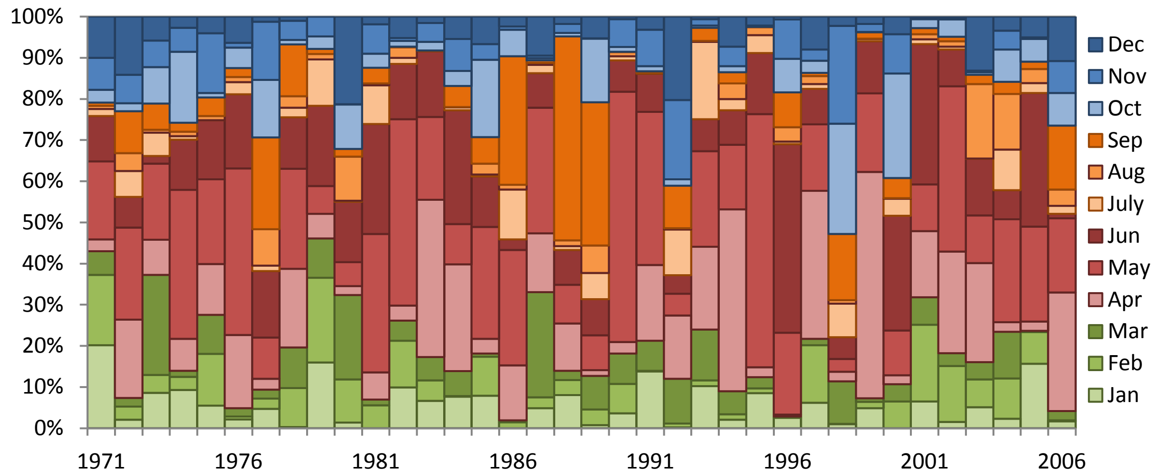
To characterize site-specific effects in a temporal scale, the first 60 scenarios and last 5 scenarios in Table A-20 (now listed in Table A-21) were simulated with SWAT in daily time step and aggregated in a monthly format. In other words, the modeling results for each simulated scenario in Table A-21 reflects a monthly basis, not the annual basis in Table A-20. Therefore, all the monthly WQT in-field parameters (nutrient loads, load reduction, reduction indexes, uncertainty ratios, and TRs) were prepared based on these simulations.

3.5.5.1 *Monthly Pollutant Load*

Both potential annual load reductions (AP_{NR}) in Section 3.5.2 and monthly load reductions (SP_{NR}) of the same alternative scenario pair in this section were calculated from SWAT daily loads. The CF for each month or season in a single year can be then calculated with Eq. 3-16. Figure 3-25 illustrates the monthly TN load CF of scenario #1 (S1: 2-yr corn-soybean, conventional tillage, surface fertilizer, no VFS) from 1972 to 2006. Figure 3-25 shows that the monthly CF for each year was dramatically different in some months, and some months, such as April to June of 1995 or April to June of 1999, might represent more than 80% of the total load in a year. However, in 1988 and 1989, the contribution of TN load from July to September had a higher TN load than any other season, in a period that usually produces very little TN load in other years.

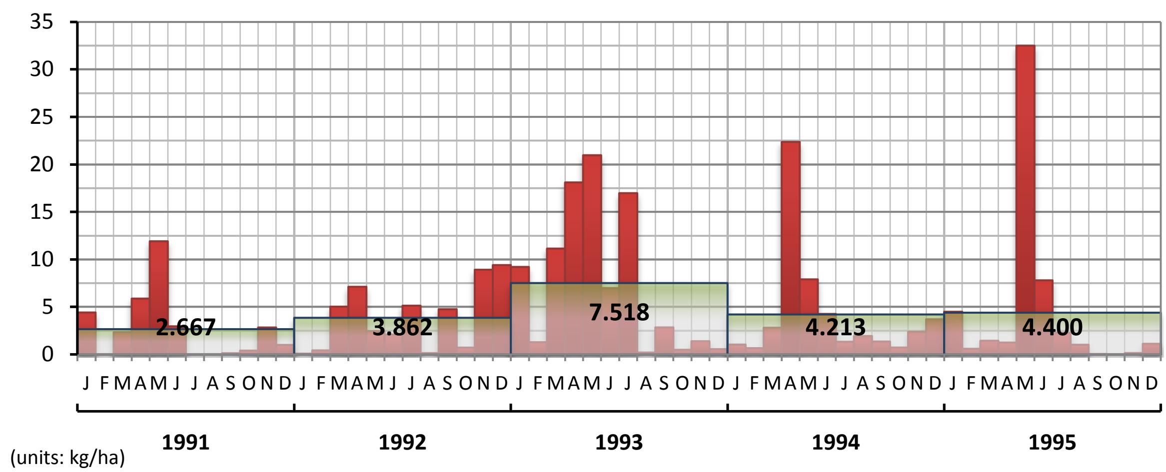
If we draw the individual monthly loads and its annual average load in the same chart, the trends of temporal effects in each individual month are clear. Figure 3-26 displays the average and individual monthly TN loads of S1 from 1991 to 1995. In each year, the monthly load distribution is unique. Even the difference of monthly load average among Years 1992, 1994, and 1995 are less than 15%, but the individual monthly loads differ strongly because about 75% of annual rainfall in Kansas occurs from April to September (Sophocleous, 1998). Therefore, the temporal site-specific effect is evident in the monthly nutrient loads.

Figure 3-27 illustrates the monthly TN load CF for selected scenarios. In Figure 3-27, April to June produces the largest 3-month portion of the annual load. July to September produces the smallest 3-month portion. For grass scenarios, especially tall fescue (S63), the monthly TN loads tend to be distributed evenly across the year. However, zooming into individual scenarios, like the example for S1 in Figure 3-25, shows considerable inconsistency in the monthly CF among years. The monthly CF for each individual year or scenario is so different that using the monthly CF may not be feasible for a WQT program.



Note: Scenario #1: 2-yr corn-soybean, conventional tillage, surface fertilizer, no VFS.

Figure 3-25 Monthly TN Load CF of Scenario #1 from 1972-2006



Note: Scenario #1: 2-yr corn-soybean, conventional tillage, surface fertilizer, no VFS.

Figure 3-26 Average and Individual Monthly TN Loads of Scenario #1 from 1991-1995

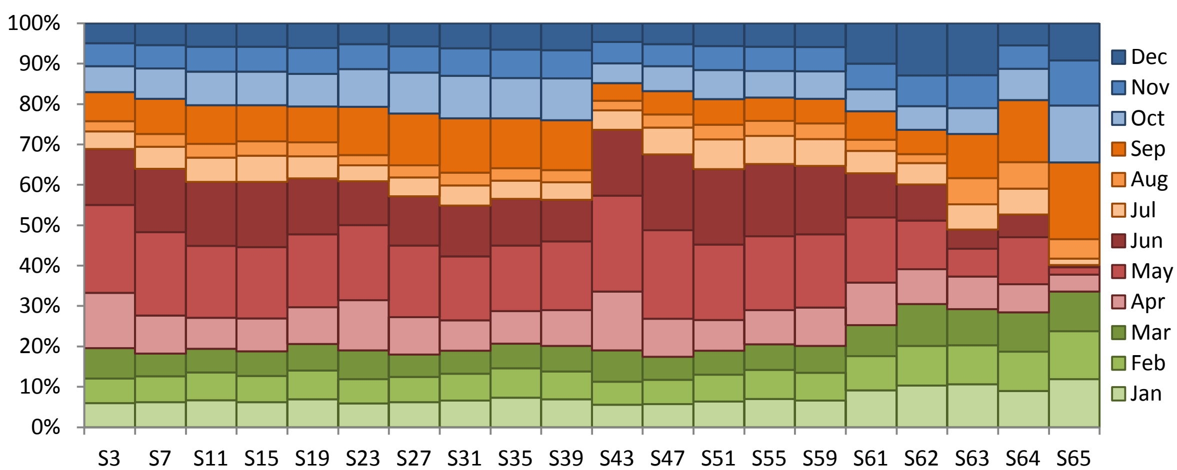


Figure 3-27 Monthly TN Load Contribution Percentage or CF for Selected Scenarios

Table 3-11 and Table 3-12 recorded the potential monthly CFs for TN and TP loads, as analyzed using Eq. 3-16, for several selected scenarios. Overall, for TN loads in a year, August tends to have the smallest CF and May the largest CF. Some scenarios have a second loading peak around September, possibly because harvest leaves fields without coverage. It seems a clear, regular trend for monthly nutrient load distribution in a year. However, the differences of CF among 12 months vary from scenario to scenario. For example, big bluestem (BBLS, S61) and switchgrass (SWCH, S62) have a minimum TN load at August and their loading peaks around May, but there is a second peak around December and January. Tall fescue (FESC, S63) has specific twin peaks of load distribution in September and December/January. Fescue with regular mowing event (S64: tall fescue, regular mowing) is similar to cont. corn with conventional till and no VFS scenarios (S21: surface fertilizer, and S31: sub-surface fertilizer), but its maximum TN load is in September, not May. Fescue with fall cattle grazing (S65: tall fescue, mowing and fall cattle grazing) generates its 90% TN load from September to the following March. The manure of grazing cattle is responsible for a large percentage of these loads. The monthly TP loads in Table 3-12 also show trends similar to TN, except the winter loading peak of grasses has disappeared. Therefore, the monthly nutrient loads for different scenarios may have different distributions. In other words, the patterns of monthly CFs or temporal effects among study scenarios may differ.

Table 3-11 Monthly TN Load CF for Selected Scenarios

Monthly TN Load											
MN	S1	S11	S21	S31	S41	S51	S61	S62	S63	S64	S65
1	6.0%	6.7%	5.8%	6.6%	5.8%	6.4%	9.1%	10.3%	10.6%	9.0%	11.9%
2	6.0%	6.9%	5.9%	6.7%	5.9%	6.6%	8.4%	9.9%	9.6%	9.8%	11.9%
3	7.5%	5.8%	6.9%	5.7%	7.8%	5.9%	7.7%	10.3%	9.0%	9.7%	9.8%
4	13.6%	7.7%	12.2%	7.5%	14.2%	7.6%	10.5%	8.6%	8.0%	6.9%	4.1%
5	22.7%	17.8%	20.5%	15.9%	23.7%	18.6%	16.2%	12.0%	6.9%	11.6%	1.8%
6	13.6%	15.8%	10.6%	12.6%	16.0%	18.7%	10.9%	9.0%	4.7%	5.6%	0.6%
7	4.2%	6.0%	3.8%	5.0%	4.7%	7.4%	5.6%	5.2%	6.3%	6.5%	1.6%
8	2.4%	3.5%	2.5%	3.2%	2.3%	3.6%	2.8%	2.3%	6.5%	6.5%	4.8%
9	7.0%	9.5%	11.6%	13.4%	4.3%	6.4%	7.0%	5.9%	10.9%	15.3%	19.0%
10	6.3%	8.3%	9.2%	10.5%	5.0%	7.2%	5.4%	5.9%	6.4%	7.8%	14.2%
11	5.8%	6.2%	6.1%	6.8%	5.5%	6.0%	6.3%	7.6%	8.1%	5.7%	11.1%
12	4.9%	5.8%	5.1%	6.2%	4.8%	5.6%	10.0%	12.9%	12.9%	5.5%	9.2%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Note: S1: 2-yr corn-soybean, conventional till, surface fertilizer, no VFS; S11: 2-yr corn-soybean, reduced till, sub-surface fertilizer, no VFS; S21: cont. corn, conventional till, surface fertilizer, no VFS; S31: cont. corn, reduced till, sub-surface fertilizer, no VFS; S41: cont. soybean, conventional till, surface fertilizer, no VFS; S51: cont. soybean, reduced till, sub-surface fertilizer, no VFS; S61: native grass, big bluestem; S62: native grass, switchgrass; S63: VFS grass, tall fescue; S64: tall fescue on VFS with regular mowing; S65: tall fescue on VFS with mowing and fall cattle grazing.

Table 3-12 Monthly TP Load CF for Selected Scenarios

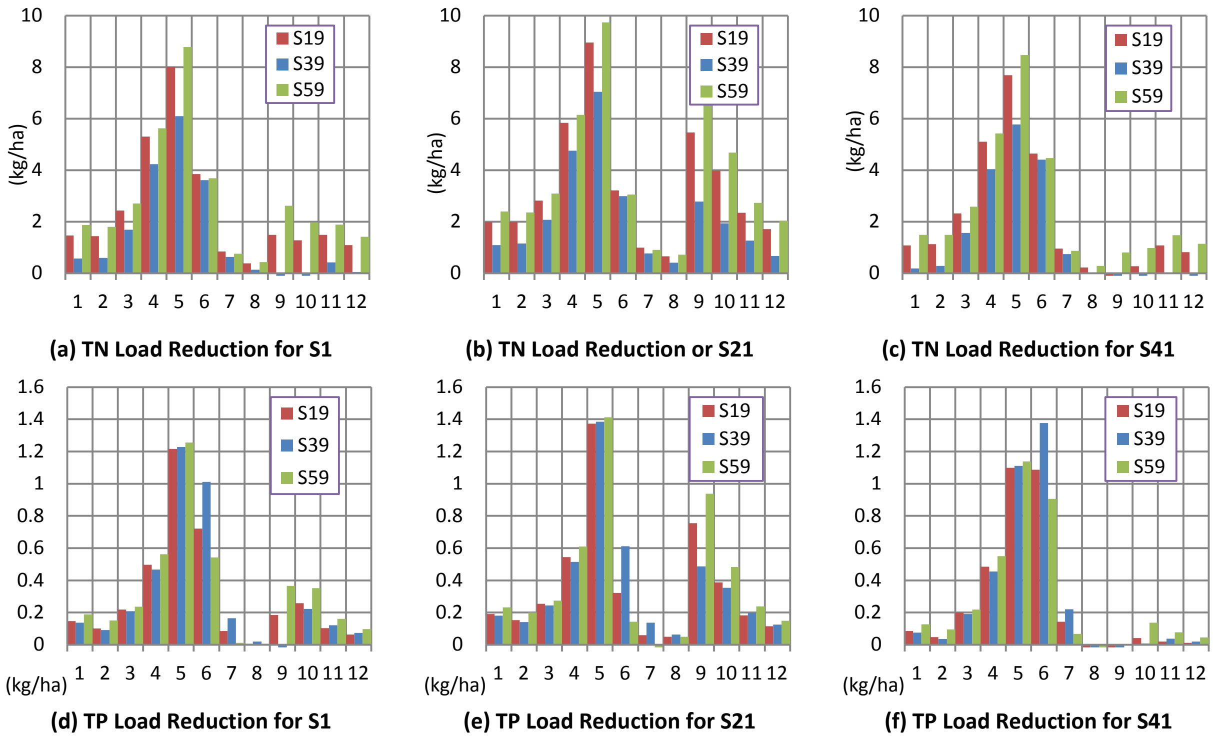
Monthly TP Load											
MN	S1	S11	S21	S31	S41	S51	S61	S62	S63	S64	S65
1	5.2%	6.4%	5.2%	6.4%	4.9%	6.1%	5.6%	6.5%	6.6%	9.0%	10.9%
2	5.3%	6.9%	5.3%	6.8%	5.0%	6.7%	7.0%	8.8%	8.0%	9.8%	11.2%
3	6.3%	6.3%	6.2%	6.2%	6.5%	6.5%	7.2%	9.7%	8.4%	9.8%	9.6%
4	10.9%	8.5%	10.6%	8.5%	11.4%	8.1%	11.7%	9.8%	9.5%	7.0%	4.2%
5	23.7%	18.1%	23.4%	16.9%	23.9%	18.9%	19.2%	15.6%	9.0%	11.6%	1.9%
6	17.1%	15.2%	12.9%	12.6%	21.2%	18.3%	13.8%	12.1%	6.3%	5.5%	0.7%
7	4.8%	5.1%	4.3%	4.6%	5.5%	6.6%	7.1%	7.1%	8.0%	6.4%	1.5%
8	2.5%	2.9%	2.7%	3.0%	2.3%	3.0%	3.4%	2.8%	8.4%	6.5%	4.4%
9	6.8%	8.0%	10.9%	12.4%	4.0%	5.3%	8.6%	7.2%	13.9%	15.3%	18.6%
10	7.7%	9.4%	8.3%	9.7%	6.3%	8.2%	6.7%	7.3%	8.3%	7.8%	14.6%
11	5.3%	6.9%	5.6%	6.7%	4.8%	6.3%	4.6%	5.5%	6.6%	5.7%	12.0%
12	4.5%	6.3%	4.6%	6.1%	4.2%	6.0%	5.2%	7.5%	7.2%	5.5%	10.3%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Note: S1: 2-yr corn-soybean, conventional till, surface fertilizer, no VFS; S11: 2-yr corn-soybean, reduced till, sub-surface fertilizer, no VFS; S21: cont. corn, conventional till, surface fertilizer, no VFS; S31: cont. corn, reduced till, sub-surface fertilizer, no VFS; S41: cont. soybean, conventional till, surface fertilizer, no VFS; S51: cont. soybean, reduced till, sub-surface fertilizer, no VFS; S61: native grass, big bluestem; S62: native grass, switchgrass; S63: VFS grass, tall fescue; S64: tall fescue on VFS with regular mowing; S65: tall fescue on VFS with mowing and fall cattle grazing.

3.5.5.2 *Monthly Load Reduction*

Although we have demonstrated the temporal site-specific effect is significant in the monthly nutrient load, another more important question for WQT is "does the temporal effects exist in load reduction?" According to the previous analyses, a higher reduction in nutrient load is not always associated with a scenario with higher nutrient yield. A load reduction index is a much more suitable indicator of the potential load reductions among alternative scenario pairs.

If we look at the monthly TN and TP load reduction for conventional till with surface fertilizer and, no VFS scenarios #1, #21, and #41 (S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean) to no-till with sub-surface fertilizer and no VFS scenarios #19, #39, and #59 (S19: 2-yr corn-soybean, S39: cont. corn, and S59: cont. soybean) in Figure 3-28 (a) through (f), the load reductions for each month are very different. While looking at the scenarios with same crop rotation, such as the two-year corn-soybean rotation in Figure 3-28 (a) and (d), we found a peak in load reduction in May for both TN and TP. For some scenarios, like continuous corn in Figure 3-28 (b) and (e), a second peak occurred in September. However, the August reduction tends to be the lowest in a year. Moreover, among different crop rotations, such as S19, S39 and S59, corn (S39) tends to have the least load reduction, and soybean (S59) has the most reduction, while corn-soybean rotation (S19) is in the middle, except from June to August, when the corn-soybean (S19) reduction is more than the soybean (S59) reduction for TN, and corn (S39) reduction is more than soybean (S59) reduction for TP.



Above charts show the individual monthly nutrient load reduction for conventional till with surface fertilizer scenarios (S1, S21, and S41) to no-till with sub-surface fertilizer scenarios (S19, 39, and S58)

Note: Conventional till, surface fertilizer, no VFS scenarios: S1: 2-yr corn-soybean, S21: cont. corn, and S41: cont. soybean. No-till, sub-surface fertilizer and no VFS scenarios: S19: 2-yr corn-soybean, S39: cont. corn, and S59: cont. soybean.

Figure 3-28 Individual Monthly Nutrient Load Reduction for Conventional Till to No-till

Table 3-13 and Table 3-14 tabulated the potential monthly TN and TP load reduction CFs calculated with Eq. 3-16. These potential monthly TN and TP load reductions come from selected scenarios to big bluestem (BBLS, S61). As with monthly nutrient loads, the common trends of TN and TP load reduction within a year show the minimum CF in August and maximum CF in May. For most of scenarios, a second load reduction peak might occur in September because of storm water flushing the bare ground after harvest. However, some scenarios such as native grasses, with a similar load, may have irregular load reduction patterns. For example, switchgrass (SWCH, S62) to big bluestem (BBLS, S61) has a minimum TN load reduction in August and strong load reductions from April to June, much like the other crop rotation scenarios. However, switchgrass (SWCH, S62) showed less TP load reduction than big bluestem (BBLS, S61) in some months, and even the overall annual TP load reduction remains positive. Tall fescue (FESC, S63) also has similar negative trend in both TN and TP load reductions.

Table 3-13 Monthly TN Load Reduction CF for Selected Scenarios to Big Bluestem (S61)

MN	S1	S11	S21	S23	S31	S41	S51	S62	S63	S64	S65
1	5.9%	6.6%	5.7%	5.8%	6.5%	5.6%	6.2%	5.7%	25.3%	9.0%	12.2%
2	5.9%	6.8%	5.8%	5.9%	6.6%	5.8%	6.5%	4.3%	21.3%	10.0%	12.2%
3	7.4%	5.7%	6.8%	7.1%	5.6%	7.8%	5.8%	0.2%	21.2%	10.1%	10.0%
4	13.7%	7.6%	12.3%	12.5%	7.4%	14.3%	7.5%	15.9%	-15.9%	6.2%	3.5%
5	22.9%	17.9%	20.6%	18.7%	15.8%	24.0%	18.8%	28.3%	-83.5%	10.7%	0.4%
6	13.7%	16.1%	10.6%	10.8%	12.7%	16.2%	19.1%	16.4%	-55.6%	4.5%	-0.5%
7	4.1%	6.0%	3.7%	3.9%	4.9%	4.7%	7.5%	6.6%	12.9%	6.6%	1.1%
8	2.4%	3.5%	2.4%	2.6%	3.2%	2.3%	3.7%	4.3%	42.9%	7.3%	5.0%
9	7.0%	9.6%	11.7%	12.1%	13.6%	4.2%	6.4%	10.2%	48.7%	17.0%	20.2%
10	6.3%	8.5%	9.3%	9.5%	10.7%	4.9%	7.3%	4.2%	16.0%	8.3%	15.1%
11	5.8%	6.2%	6.1%	6.2%	6.8%	5.4%	6.0%	2.5%	25.4%	5.6%	11.6%
12	4.8%	5.5%	4.9%	5.0%	6.0%	4.6%	5.3%	1.4%	41.3%	4.6%	9.1%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 3-14 Monthly TP Load Reduction CF for Selected Scenarios to Big Bluestem (S61)

MN	S1	S11	S21	S23	S31	S41	S51	S62	S63	S64	S65
1	5.1%	6.5%	5.2%	5.9%	6.4%	4.9%	6.1%	18.5%	7.8%	9.7%	11.2%
2	5.2%	6.9%	5.3%	6.1%	6.8%	5.0%	6.6%	32.4%	9.3%	10.4%	11.4%
3	6.3%	6.3%	6.2%	7.3%	6.2%	6.5%	6.5%	41.9%	9.9%	10.3%	9.7%
4	10.9%	8.4%	10.6%	12.9%	8.4%	11.4%	8.0%	-13.6%	6.8%	6.1%	3.9%
5	23.8%	18.1%	23.6%	19.3%	16.8%	24.0%	18.9%	-30.9%	-3.7%	10.1%	1.2%
6	17.1%	15.2%	12.9%	10.6%	12.6%	21.4%	18.5%	-9.1%	-3.0%	3.9%	0.1%
7	4.7%	5.1%	4.2%	3.6%	4.5%	5.5%	6.5%	6.4%	9.0%	6.2%	1.3%
8	2.5%	2.9%	2.7%	2.5%	3.0%	2.2%	3.0%	-4.8%	14.6%	7.1%	4.4%
9	6.8%	8.0%	10.9%	11.3%	12.6%	3.8%	5.2%	-10.7%	20.4%	16.6%	19.0%
10	7.8%	9.5%	8.3%	8.9%	9.8%	6.2%	8.3%	15.3%	10.2%	8.0%	15.0%
11	5.3%	7.0%	5.6%	6.3%	6.8%	4.8%	6.4%	17.4%	9.1%	6.0%	12.3%
12	4.4%	6.3%	4.6%	5.2%	6.1%	4.2%	6.0%	37.1%	9.6%	5.6%	10.5%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Note: S1: 2-yr corn-soybean, conventional till, surface fertilizer, no VFS; S11: 2-yr corn-soybean, reduced till, sub-surface fertilizer, no VFS; S21: cont. corn, conventional till, surface fertilizer, no VFS; S31: cont. corn, reduced till, sub-surface fertilizer, no VFS; S41: cont. soybean, conventional till, surface fertilizer, no VFS; S51: cont. soybean, reduced till, sub-surface fertilizer, no VFS; S61: native grass, big bluestem; S62: native grass, switchgrass; S63: VFS grass, tall fescue; S64: tall fescue on VFS with regular mowing; S65: tall fescue on VFS with mowing and fall cattle grazing.

3.5.5.3 *Strategy for WQT*

Addressing the temporal effects in WQT prove somewhat problematic. Increasing the intervals of modeling time step will generalize the modeling results and level the peaks of data distribution. Longer modeling time steps would shorten the modeling processes and simplify the WQT trading ratio system. Unfortunately, to clarify the question of the potential nutrient load or load reduction within a short period, we must address the temporal effects in WQT, which would require shorter modeling time steps.

As in previous annual load analyses, ANOVA and LSD methods were used to test the similarity of nutrient yields among the 12 months in each potential alternative scenarios and across all the scenarios.

ANOVA shows the p-value for the overall TN and TP loads are less than 0.0001. For the statistics of model ANOVA, both month and scenario effects have p-value less than 0.0001, showing a significant difference among all months and scenarios. In the pairwise comparison with LSD, the original 12 months were grouped into 7 subsets for TN load and 5 subsets for TP load (see Table 3-15). The annual time step might be too long to distinguish detail differences in nutrient loads, but the monthly time step is too short to provide clear and simple information about nutrient loads.

In compromise, developing a seasonal TR system, either four seasons (spring, summer, fall, and winter) or two seasons (wet and dry) might work to implement a WQT program. Therefore, the temporal site-specific effects are significant for either nutrient load or load reduction. To implement a WQT program in the study watershed, we recommend including the temporal effects in estimating environmental benefits. However, the monthly or seasonal basis trading policy would be more complex than annual ones. It would take more effort to address temporal effects in WQT.

Table 3-15 LSD Test for Monthly TN and TP Load

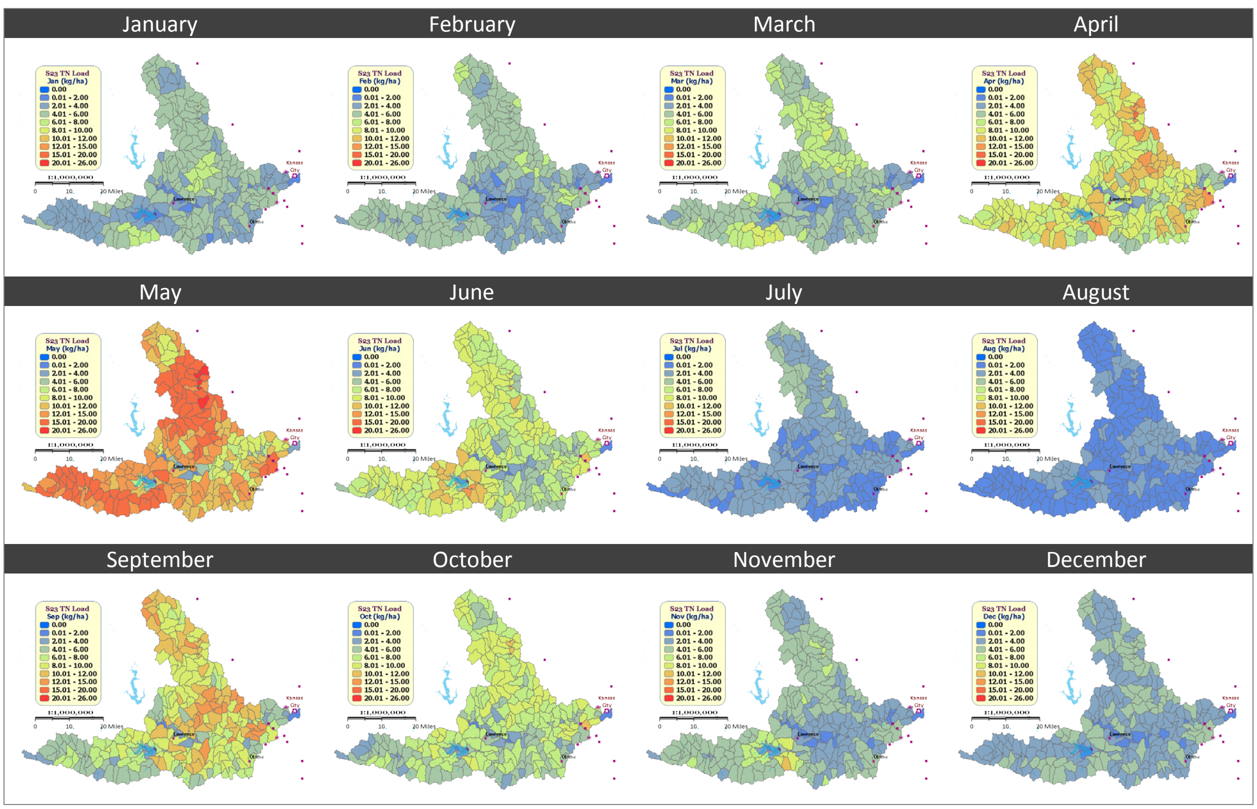
TN t Group		Mean	Month	TP t Group	Mean	Month
	A	5.179	5	A	1.212	5
	B	3.702	6	B	0.983	6
	C	2.551	4	C	0.544	4
D	C	2.368	9	C	0.485	9
D	E	2.091	10	C	0.473	10
F	E	1.658	2	D	0.361	3
F		1.633	1	D	0.354	2
F		1.620	3	D	0.349	11
F		1.585	11	D	0.336	7
F		1.438	12	D	0.330	1
F		1.338	7	D	0.314	12
	G	0.786	8	E	0.185	8

3.5.6 Overall Site-specific Effect

Given how we defined site-specific including geospatial and temporal aspects, neither subbasin location nor modeling time step can be neglected in estimating the environmental benefits of WQT. Figure 3-29 illustrates the twelve subbasin monthly TN loads for scenario #23 (S23: cont. corn, conventional till, sub-surface fertilizer, no VFS) and Figure 3-30 illustrates the TN loads for scenario #61 (S61: native grass, big bluestem). To see the potential difference among all subbasins and months,

Figure 3-31 portrays the twelve subbasin monthly potential TN load reductions for scenario #23 as it changes to alternative scenario #61. Likewise, Figure 3-32 portrays the TRs for scenario #23 as it changes to alternative scenario #61. The legend colors and classification ranges are fixed across these twelve figures. As the legend color varied from blue-greenish to red, the value of load, load reduction or TR became higher. It is thus easy to compare the differences of TRs among subbasins and months.

As we have said, the higher TR usually represents a higher trading risk, which means the effective load reduction of a scenario may vary from time to time. In other words, a higher TR describes a trade with higher uncertainty or more variability in its real load reduction. However, the trends for load reduction and variability might not be consistent.



Note: S23: cont. corn, conventional till, sub-surface fertilizer, no VFS

Figure 3-29 Subbasin Level Monthly TN Load for Scenario #23 in Study Watershed

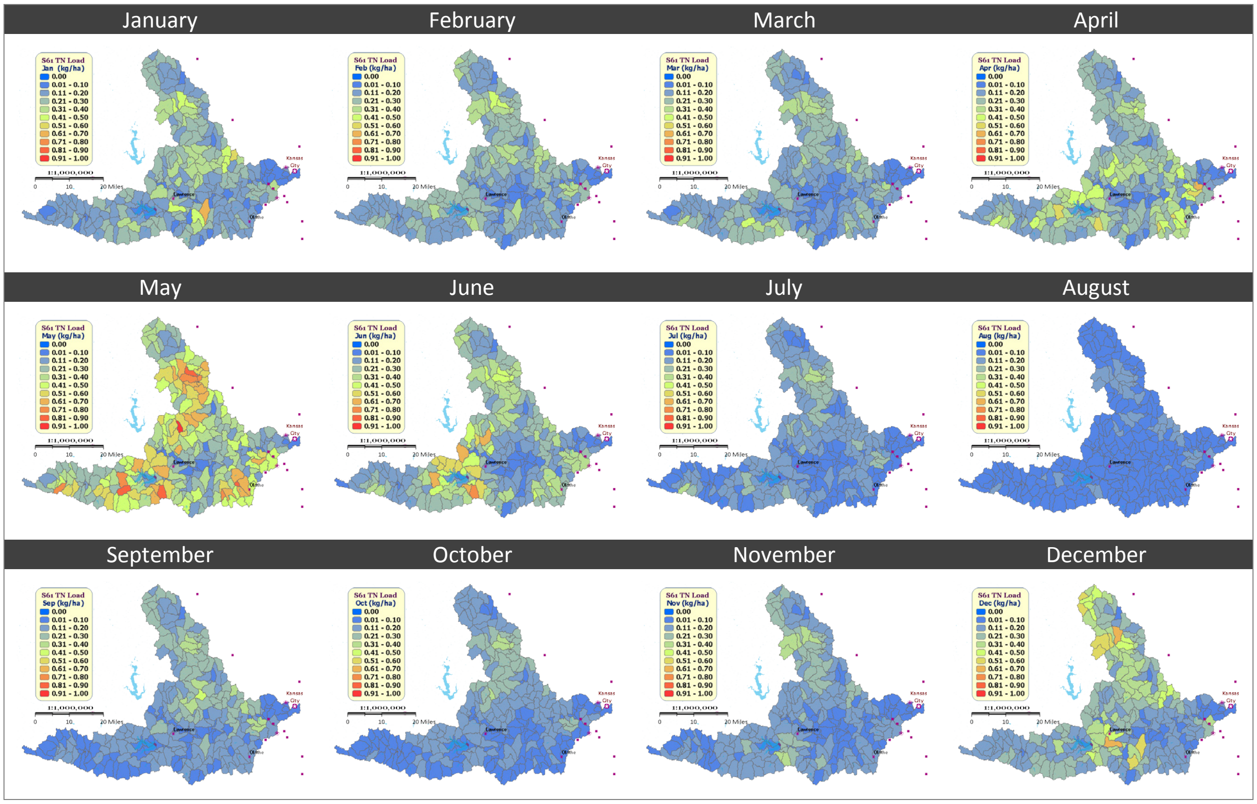
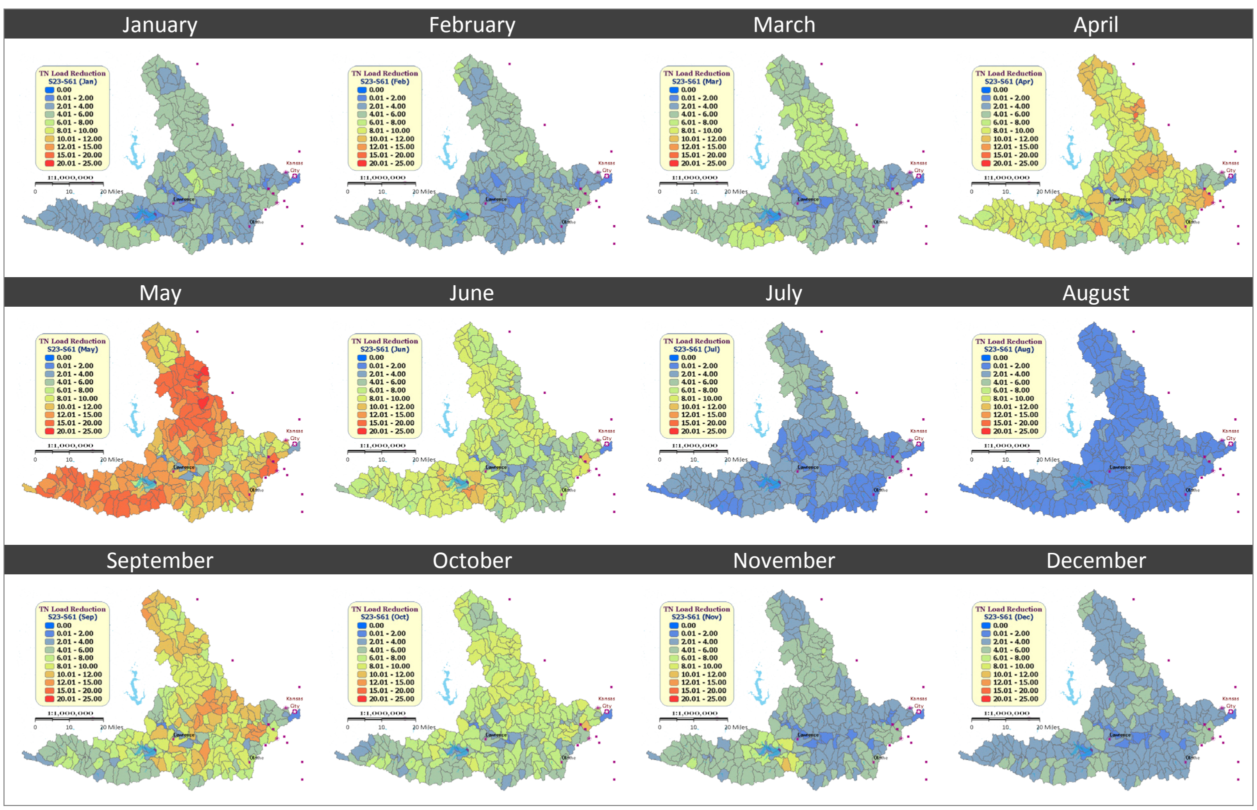
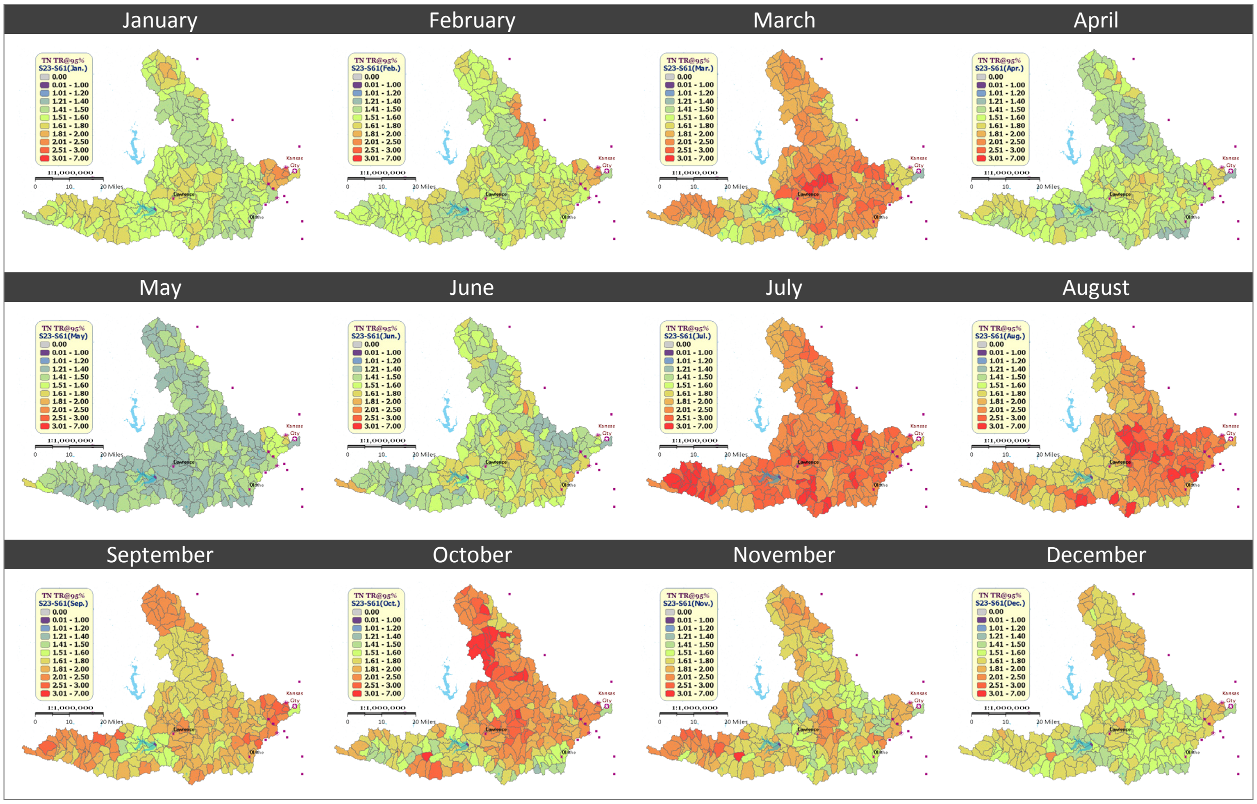


Figure 3-30 Subbasin Level Monthly TN Load for Scenario #61 in Study Watershed



Note: S23: cont. corn, conventional till, sub-surface fertilizer, no VFS; S61: native, grass, big bluestem.

Figure 3-31 Subbasin Level Monthly TN Load Reduction for S23-S61 in Study Watershed



Note: S23: cont. corn, conventional till, sub-surface fertilizer, no VFS; S61: native grass, big bluestem.

Figure 3-32 Subbasin Level Monthly TN Load Reduction TR for S23-S61 in Study Watershed

Figure 3-33 illustrates the TN load reductions over 12 months for scenario #23 (S23) changing to scenario #61 (S61). In Figure 3-33, the purple blocks represent the range from median to 75th percentile (P75), and the green blocks represent the range from 25th percentile (P25) to median. For each month, the blue bar shows the percentage of variability, defined as the larger inter-quartile range (IQR, P75-P25) divided by its median. Figure 3-34 illustrates the means of TN load reduction and TRs at three confidence levels over 12 months for S23-S61. In Figure 3-33, even though the maximum load reduction in May shows a large IQR, its variability is not the highest. Similarly, the minimum load reduction around August does not have the smallest variability. Likewise, in Figure 3-34, a month with a larger load reduction might have a lower TR. Moreover, in the TR in Figure 3-32, most subbasins have their highest TR in the month July, which is not the usual high load reduction month. In fact, most subbasins in the usual high load reduction May have lower TRs over a year. In other words, in some critical months, such as July or August, to purchase a load reduction in specific subbasins might pay more in its greater variability. Again, these trends for load reduction and TRs might not be consistent. In Figure 3-34, April and September have a similar load reduction, but their TRs are totally different.

Therefore, in the WQT program, the ability to actually reduce the load is what should concern the farmer and push implementation of alternative land management. The ability to produce higher load reductions means more tradable credits in hand. However, the trading risk, described by the TR, is also important. A higher TR means more risk in buying these credits. The final price for each credit and the economic benefits of the trade will depend on stakeholders in the market, whose concerns could be addressed with economic models (Smith, 2004; Peterson et al., 2007).

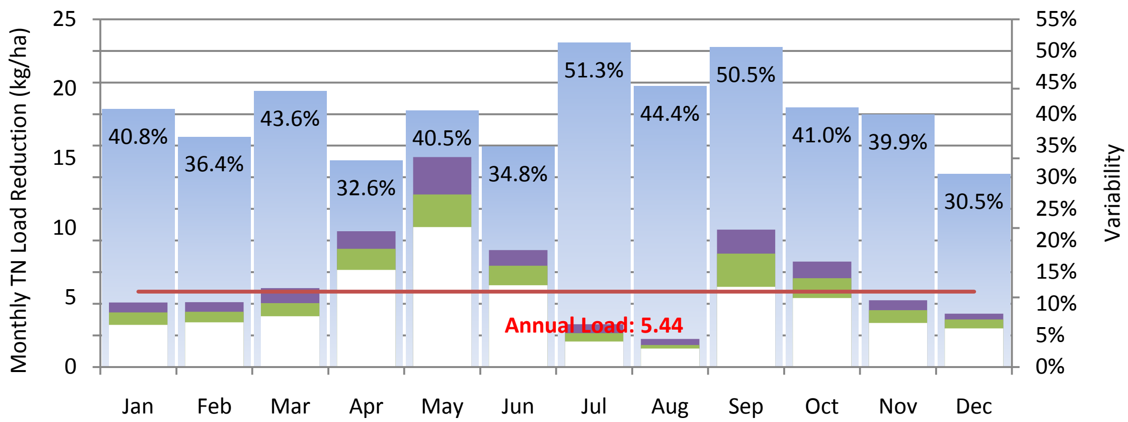


Figure 3-33 Monthly TN Load Reduction and Variability for S23-S61

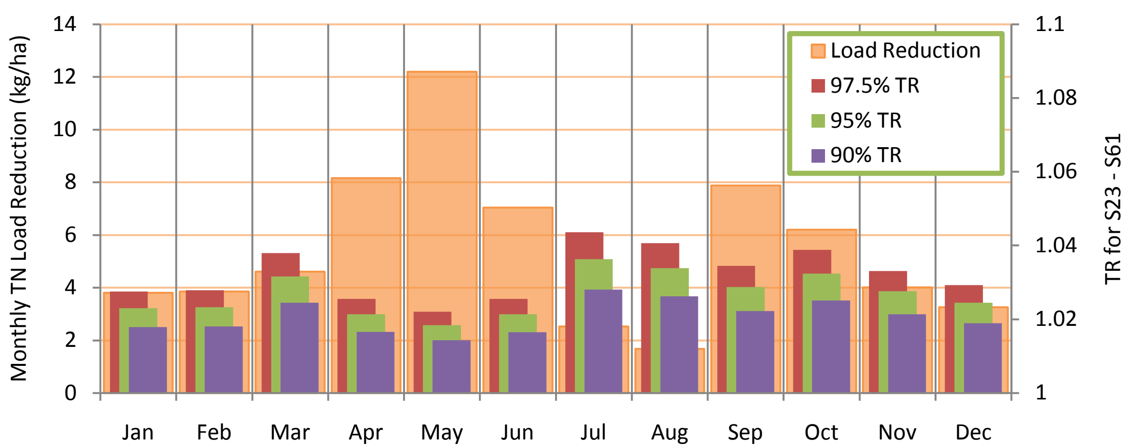
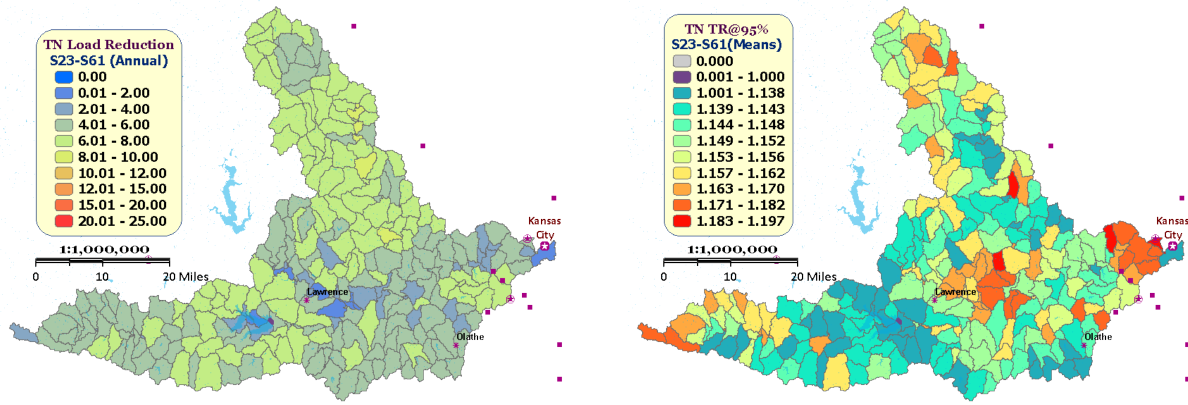


Figure 3-34 Monthly TN load Reductions and TRs at Different Confidence Levels for S23-S61

Figure 3-35 illustrates the annual TN load reductions and TRs for S23-S61. Comparing the load reductions and TRs in Figure 3-35 with the monthly parameters in Figure 3-31 and Figure 3-32, the temporal effects have been leveled for the annual calculations. Therefore, both geospatial and temporal site-specific effects will affect the potential load reductions and TRs while the trade occurred in between specific locations and/or at specific months in the study watershed.



(a) Annual TN Load Reduction **(b) Annual TN Load Reduction TR**

Figure 3-35 Subbasin Level Annual TN Load Reduction and TR for S23-S61 in Study Watershed

3.6 Conclusion

Based on previous WQT pilot studies, we developed a systematic method using SWAT model with 225 alternative scenarios to analyze potential nutrient load reductions, uncertainty, and the in-field TRs in the Lower Kansas watershed, Kansas. In this study, we developed scenarios of land management practice with combinations of crop rotations, tillage systems, fertilizer application methods, and edge-of-field BMPs to simulate the nutrient yield of the field, and then estimated the potential load reduction between any two alternative scenarios to quantify the environmental benefits of a WQT program.

Land management practice is a very complex umbrella term. It encompasses field operations like crop rotation, tillage system, fertilizer and chemical applications, planting and harvesting methods, irrigation, and drainage. For each field operation, land management might be affected by previous land cover, soil properties, and topography of the field, and may also be dramatically affected by the regional climate. Furthermore, the timing of field operations may produce significant differences in sediment or nutrient loads as well as crop production yields (Fjell et al., 1997; Shroyer et al., 1997; Fjell et al., 1998; Whitney et al., 1999; Fjell et al., 2007). Therefore, designing all-purpose land management practices that can lower nutrient pollution and provide higher crop yields for general use and apply across states would be a challenge. Hence, the land management practices modeled in this study merely provide a broad overview of the nutrient load differences among these field operations and some direction for selecting alternative management practices in the study watershed.

In this study, several approaches were applied to quantify the environmental benefits of WQT program. The uncertainty was used with pairwise comparisons and t-tests to estimate the potential NPS load reduction variation at several confidence levels. With the variations in potential nutrient load reduction, the R_U and TR were then calculated. The analyses of site-specific effects in both geospatial and temporal aspects were also applied to subbasin level WQT parameters in the study watershed. The results strongly supported that site-specific phenomena exist in the watershed. The advanced ANOVA analyses on alternative scenario design categories were applied. The main effects and cross effects showed significant differences among the design criteria. Moreover, advanced LSD statistics described the potential means for each level, allowing similar levels to be grouped.

The BMPS category of scenario variables seemed to provide a huge load reduction among all analyzed variables. However, the BMPS that modeled the edge-of-field VFS with SWAT obviously had a fixed load reduction of approximately 90% for both TN and TP load because SWAT used an empirical equation (Eq. 3-19) developed by Moore et al. (1988) to estimate the trapping efficacy for nutrients and sediment in surface runoff. Regardless of field condition, with the VFS length fixed, the reduction rate or trapping efficiency was also fixed. This was a concern in the watershed model. Although some research used SWAT to estimate the efficiency of VFSs for bacteria and sediment yield and found significant loading differences among subbasins (Parajuli et al., 2008), the test does not take into account geophysical or management difference among subbasins. Therefore, research into VFS trapping efficiency equations becomes necessary to keep from using efficiency as an unknown factor in SWAT. It would be better to use an equation with known VFS trapping efficiency applied as a parameter in SWAT.

Fertilizer application method (surface broadcast as opposed to sub-surface fertilizer) tends to affect load difference more for TP than for TN. This high TP load phenomena may be due to increases in surface coverage and surface runoff but also involve management practices as well. Fine tuning the timing of field operations within the management scenario could minimize this effect. The crop rotation and tillage system provide a large load reduction variation within all scenarios. Corn has a large nutrient load, but winter wheat tends to conserve the nutrient yield. Conventional tillage scenarios have more potential to reduce their NPS pollution with the no-till method. Each level of crop rotations and tillage system has specific potential to reduce the load, but listing every combination becomes too complex. ANOVA statistics provides a good way to assess current land management scenarios. Then picking a potential alternative scenario from these tables and charts for a maximum environmental benefit becomes easier.

Given the goal of this paper, we modeled agricultural croplands using 225 alternative land management practices and found some significant differences among them. Geospatial and temporal analyses suggest strong site-specific effects in the study watershed. For future study, to make estimates of the environmental benefits of WQT much more reasonable, dividing the study watershed into several sub-regions and/or splitting annual trade into several seasonal subsets might minimize variation from site to site.

Acknowledgements

The authors gratefully acknowledge Dr. Chun-Yen C. Cochrane, research associate professor in Dept. of Human Nutrition, for assistance in statistical analysis; Dr. Amir Pouyan Nejadhashemi, former research assistant professor in Dept. of Biological and Agricultural Engineering, for watershed model suggestions and data acquisition. We also acknowledge Dr. J.M. Shawn Hutchinson, associate professor of Geography, for his comments on geospatial analysis and GIS techniques. Appreciation is also extended to Drs. Jeffrey M. Peterson and John Leatherman, professors of Agricultural Economics, Mr. Craig Smith, watershed specialist and research assistant, and other watershed specialists and professionals for their expertise in the field survey of water quality trading program in Kansas.

We are grateful for the partial financial supports from the U.S. EPA Section 319 grant and Kansas Water Plan funds provided by the Kansas Department of Health and Environment (KDHE) (Project #: 2004-0017), and U.S. EPA, the National Center for Environmental Research (NCER) Science to Achieve Results (STAR) Program Grant #R831774. Although the research described in the article has been funded in part by KDHE project and the U.S. EPA's STAR program grant, it has not been subjected to any KDHE or EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

3.7 References

Abu-Zreig, M., R. P. Rudra, H. R. Whiteley. 2001. Validation of a vegetated filter strip model (VFSMOD). *Hydrological Processes* 15(5): 729-742.

Anderson, R. M., V. I. Koren and S. M. Reed. 2006. Using SSURGO Data to Improve Sacramento Model A Priori Parameter Estimates. *J. Hydrology* 320:103-116.

Arnold, J. G., R. Srinivasan, R. S. Muttiah, and J. R. Williams. 1998. Large area hydrologic modeling and assessment, Part I: model development. *J. Amer. Water Resour. Assoc.* 34(1): 73-89.

Babcock, B. A., P. W. Gassman, M. Jha, and C. L. Kling. 2007. Adoption Subsidies and Environmental Impacts of Alternative Energy Crops. Briefing Paper 07-BP 50. Ames, IA: Center for Agricultural and Rural Development, Iowa State University.

Barnes, P. L. 2006. Personal communication. Manhattan, KS.

Baumgart, P. 2005. Lower Green Bay and Lower Fox Tributary Modeling Report. Available at: basineducation.uwex.edu/lowerfox/WatershedPlan.html. Accessed April 30, 2009.

Bingner, R. L., C. E. Murphree, and C. K. Mutchler. 1989. Comparison of sediment yield models on various watersheds in Mississippi. *Trans. ASAE* 32(2): 529-534.

Blackmer, A. M., R. D. Voss, A. P. Mallarino. 1997. Nitrogen *Fertilizer Recommendations for Corn in Iowa*. PM-1714. Ames, IA: University Extension, Iowa State University.

Blanco-Canqui, H., C. J. Gantzerb, S. H. Anderson, E. E. Alberts, and A. L. Thompson. 2004. Grass barrier and vegetative filter strip effectiveness in reducing runoff, sediment, nitrogen, and phosphorus loss. *Soil Sci. Soc. Amer. J.* 68: 1670-1678.

Bosch, D. D., J. G. Arnold, M. Volk. 2007. SWAT Revisions for Simulating Landscape Components and Buffer Systems. ASABE Paper No. 072175. St. Joseph, Mich.: ASABE.

Boyer, W. R. 2006. Interview by author. E-mail communication. Manhattan, KS.

Breetz, H. L., K. Fisher-Vanden, L. Garzon, H. Jacobs, K. Kroetz, and R. Terry. 2004. Water quality trading and offset initiatives in the U.S.: a comprehensive survey. Hanover, NH: Dartmouth College. Available at: www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf. Accessed April 30, 2009.

Burkart, M. R. and D. E. James. 1999. Agricultural-Nitrogen Contributions to Hypoxia in the Gulf of Mexico. *J. Environ. Qual.* 28(3):850-859.

Claassen, M. M. 2005. Reduced Tillage and Crop Rotation Systems with Wheat, Grain Sorghum, Corn and Soybean. 2005 Agronomy Field Research: Harvey County. Manhattan, KS: Kansas State University, Agricultural Experiment Station and Cooperative Extension Service.

Cooprider, M. A. and M. S. Coyne. 1999. Do Cover Crop Residue and No-Till Increase Poultry Litter Runoff? *Agronomy notes* 31(3). Lexington, KY: Department of Agronomy, University of Kentucky.

Coyne, M. S., R. A. Gilfillen, and R. L. Blevins. 1997. Filter Strip Length and Fecal Bacteria Trapping From Poultry Waste- An Update. *Agronomy notes* 18(3). Lexington, KY: Department of Agronomy, University of Kentucky.

Curley, D. E. 2003. An analysis of trading ratio for water pollution control trading system using a geographic information system and the finite segment method. PhD diss. Philadelphia, PA: University of Pennsylvania, Department of City and Regional Planning.

Dale, V., T. Bianchi, A. Blumberg, W. Boynton, D.J. Conley, W. Crumpton, M. David, D. Gilbert, R.W. Howarth, C. Kling, R. Lowrance, K. Mankin, J.L. Meyer, J. Opalauch, H. Paerl, K. Reckhow, J.

Sanders, A.N. Sharpley, T.W. Simpson, C. Snyder, D. Wright, H. Stallworth, T. Armitage, D. Wangsness. 2007. Hypoxia in the Northern Gulf of Mexico: An Update by the EPA Science Advisory Board. EPA-SAB-08-003. EPA Science Advisory Board: Washington, D.C. 333 pp.

Devlin, D. 2003. *Water Quality Best Management Practices, Effectiveness, and Cost for Reducing Contaminant Losses from Cropland*. MF-2572, Manhattan, KS: Kansas State University, Agricultural Experiment Station and Cooperative Extension Service.

Di Luzio, M., J. G. Arnold, and R. Srinivasan. 2004. Integration of SSURGO maps and soil parameters within a geographic information system and nonpoint source pollution model system. *J. Soil and Water Conserv.* 59(4):123-133.

Di Luzio, M., R. Srinivasan, J. G. Arnold, and S. L. Neitsch. 2002. ArcView Interface for SWAT2000: User's Guide. Report TR-193. College Station, TX: Texas Water Resources Institute.

Environomics. 1999. A summary of U.S. Effluent trading and offset projects. Bethesda, MD: Environomics. Available at: www.epa.gov/OWOW/watershed/trading/traenvrn.pdf. Accessed April 30, 2009.

Fang, F., M. S. Kieser, D. L. Hall, N. C. Ott, and S. C. Hippensteel. 2005. A preliminary analysis of water quality trading opportunities in the Great Miami River watershed, Ohio. In *Proc. 3rd Watershed Management to Meet Water Quality Standards and Emerging TMDL Conference*, 27-37. P. Gassmann, ed. ASABE Paper No.701P0105. St. Joseph, Mich.: ASABE.

FGDC. 2004. *Federal Standards for Delineation of Hydrologic Unit Boundaries Version 2.0*. Washington, D.C.: Federal Geographic Data Committee (FGDC). Available at: www.ncgc.nrcs.usda.gov/products/datasets/watershed/. Accessed April 30, 2009.

Fjell, D. L. 1998. *Grain Sorghum Production Handbook*. C-687 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., D. Peterson, D. A. Whitney, 1997. *Soybean Production Handbook*. C-449. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., R. L. Vanderlip, K. L. Roozeboom, 2007. *Corn Production Handbook*. C-560 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Gassman, P. W., M. R. Reyes, C. H. Green, and J. G. Arnold. 2007. The soil and water assessment tool—Historical development applications, and future research directions. *Trans. ASABE* 50(4), 1211-1240.

Geza, M. and J. E. McCray. 2007. Effects of soil data resolution on SWAT model stream flow and water quality predictions. *J. Environ. Management* 88(3):393-406.

Gharabaghi, B., R. P. Rudra, H. R. Whiteley, and W. T. Dickinson. 2001. Sediment-Removal Efficiency of Vegetative Filter Strips. ASAE Paper No. 01-2071. St. Joseph, Mich.: ASAE.

Ghidey, F., E. J. Sadler, R. N. Lerch, and C. Baffaut. 2007. Scaling up the SWAT model from Goodwater Creek Experimental Watershed to the Long Branch Watershed. ASABE Paper No. 072403. St. Joseph, Mich.: ASABE.

Gowda, P. H. and D. J. Mulla. 2005. Scale Effects of STATSGO vs. SSURGO Soil Databases on Water Quality Predictions. In *Proc. 3rd Watershed Management to Meet Water Quality Standards and Emerging TMDL Conference.* 579-587. P. Gassmann, ed. ASABE Paper No.701P0105. St. Joseph, Mich.: ASABE.

Grove, M., J. Harbor, B. A. Engel, and S. Muthukrishnan. 2001. Impacts of urbanization on surface hydrology, Little Eagle Creek, Indiana, and analysis of L-THIA model sensitivity to data resolution. *Physical Geography* 22(2):135-153.

Hargreaves, G. H. and Z. A. Samani. 1985. Reference crop evapotranspiration from temperature. *Appl. Eng. in Agric.* 1:96-99.

Harner, J. P., J. P. Murphy, D. L. Devlin, W. H. Fick, and G. L. Kilgore. 2000. *Vegetative Filter Strip System for Animal Feeding Operations.* MF-2454. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Heathman, G. C. and M. Larose. 2006. Modeling streamflow using SWAT with different soil and land cover geospatial datasets. In *Proc. 2nd IASTED International Conference on Environmental Modeling and Simulation.* H. Q. Tian ed. St. Thomas, U.S. Virgin Islands.

Hoag, D. L. and J. S. Hughes-Popp. 1997. Theory and Practice of Pollution Credit Trading. *Review of Agric. Economics* 19: 252-262.

Jones, C., and J. Jacobsen. 2003. Fertilizer Placement and Timing, Nutrient Management Module No. 11. 4449-11. Bozeman, MT: Montana State University Extension Service, Montana State University-Bozeman.

KDHE. 2004. *Surface Water Nutrient Reduction Plan*. Topeka, KS: Kansas Department of Health and Environment (KDHE).

KDHE. 2008. 2008 Kansas Integrated Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

Kent, K. M. 1972. Travel Time, Time of Concentration and Lag. Chapter 15 in: *National Engineering Handbook, Part 630 Hydrology*. Washington, D.C.: USDA-NRCS.

Kilgore, G. L. and F. K. Brazle. 1994. *Tall Fescue Production and Utilization*. C-729. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Kramer, J. M. 2003. *Lessons from the Trading Pilots: Applications for Wisconsin Water Quality Trading Policy*. Fox-wolf Watershed Alliance. Madison, WI: Resource Strategies, Inc. Available at: www.fwwa.org. Accessed April 10, 2007.

KSU. 2006. Common Kansas Crop Rotations. Unpublished technical note. Manhattan, KS: Extension Agronomy, Kansas State University (KSU).

Lauer, G. N. and C. P. Han. 1974. Power of Cochran's test in the Behrens-Fisher problem. *Technometrics* 16(4): 545-549.

Leatherman, J., C. Smith, and J. M. Peterson. 2004. An Introduction to Water Quality Trading. In *Proc. Department of Agricultural Economics' Risk & Profit Conference.* Manhattan, KS: Kansas State University.

Leatherman, J., J. M. Peterson, and K. R. Mankin. 2005. Is Water Quality Trading a Policy Option for Kansas? In *Proc. 22nd Annual Water and the Future of Kansas Conference.* Topeka, KS: Kansas State University.

Lee, M., K. R. Mankin, J. M. Peterson, and J. Leatherman. 2005. Water Quality Trading Issues in Kansas. ASAE Paper No. MC05-306. St. Joseph, MI.: ASAE.

Leikam, D. F., R. E. Lamond, D. B. Mengel. 2003. *Soil Test Interpretations and Fertilizer Recommendations*. MF-2586. Manhattan, KS: Kansas State University Cooperative Extension Service and the Agricultural Experiment Station.

Maddux, L. D. 2006. Interview by author. E-mail communication. Manhattan, KS. February 23.

Mankin, K. R., D. M. Ngandu, C. J. Marden, S. L. Hutchinson, and W. A. Geyer. 2007. Grass-shrub riparian buffer removal of sediment, phosphorus, and nitrogen from simulated runoff. *J. Amer. Water Resourc. Assoc.* 43(5): 1108-1116.

Mankin, K. R., P. L. Barnes, J. P. Harner, P. K. Kalita, and J. E. Boyer. 2006. Field evaluation of vegetative filter effectiveness and runoff quality from unstuck feedlots. *J. Soil and Water Conserv*. 61(4): 209-217.

Maski, D., K. R. Mankin, K. A. Janssen, and P. Tuppad. 2007. Sensitivity analysis of SWAT nutrient modeling under different management practices. 2007 ASABE Annual Meeting Paper No. 072060. St. Joseph, Mich.: ASABE.

Maski, D., K.R. Mankin, K.A. Janssen, P. Tuppad, and G.M. Pierzynski. 2008. Modeling runoff and sediment yields from combined in-field crop practices using SWAT. *J. Soil and Water Conserv.* 63(4): 193-203.

Mednick, A. C., J. Sullivan, and D. J. Watermolen. 2008. Comparing the Use of STATSGO and SSURGO Soils Data in Water Quality Modeling-A Literature Review: Resources, Research/Management Findings. SS-760 2008. Madison, WI: Bureau of Science Services, Wisconsin Department of Natural Resources (WDNR). Available at: www.dnr.state.wi.us/org/es/science/publications/PUB_SS_760_2008.pdf. Accessed April 30, 2009.

Moore, J. A., J. D. Smyth, E. S. Baker, and J. R. Miner. 1988. Evaluating coliform concentrations in runoff from various animal waste management systems. Special Report 817. Corvallis, OR: Oregon State University, Agricultural Experiment Stations.

MRLC. 2008. National Land Cover Database 2001 (NLCD 2001). Washington, D.C.: Multi-Resolution Land Characteristics Consortium (MRLC). Available at: www.mrlc.gov. Accessed April 30, 2009.

NASS. 2004. Kansas, State and County Data, Volume 1, Geographic Area Series Part 16, 2002 Census of Agriculture. AC-02-A-16. Washington, D.C.: National Agricultural Statistics Service (NASS), Agricultural Statistics Board, USDA.

NCDC. 2009. Daily surface data. Climate Data Online (CDO), National Climatic Data Center (NCDC). NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and U.S. Department of Commerce. Available at: cdo.ncdc.noaa.gov. Accessed March 31, 2009.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, and J. R. Williams. 2005. *Soil and Water Assessment Tool Theoretical Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS & Blackland Research and Extension Center, Texas A&M University.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and J. R. Williams. 2004. *Soil and Water Assessment Tool Input / Output File Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS.

Nelson, N. and A. Keeler. 2005. Water Quality Trading in Georgia: Addressing Two Potential Impediments to Success. In *Proc. 2005 Georgia Water Resources Conference*. Kathryn J. ed. Athens, Georgia: Institute Ecology, University of Georgia. Available at: www.uga.edu/water/GWRC/Papers/NelsonN-GWRCpaper%20April13.pdf. Accessed April 30, 2009.

Nelson, R. G., J. C. Ascough II, and M. R. Langemeier. 2006. Environmental and economic analysis of switchgrass production for water quality improvement in northeast Kansas. *J. Environ. Management* 79(4): 336-347.

NRCS. 1995. State Soil Geographic Database (STATSGO): Data Use Information. Miscellaneous publication: No. 1492. Washington, D.C.: USDA-NRCS, National Soil Survey Center.

NRCS. 1996. National Soil Survey Handbook. Title 430-VI. USDA-NRCS. Washington, D.C.: U.S. Government Printing Office.

NRCS. 1997. State Soil Geographic (STATSGO) Database. Fort Worth, TX: USDA-NRCS, National Cartography and GIS Center. Available at: www.ncgc.nrcs.usda.gov/products/datasets/statsgo/. Accessed April 30, 2009.

NRCS. 1999. *Soil Taxonomy, a Basic System of Soil Classification for Making and Interpreting Soil Surveys*. 2nd Ed. Agriculture Handbook: No. 436. Washington, D.C.: USDA-NRCS.

NRCS. 2004. Hydrologic Soil-Cover Complexes. Chapter 9 in: *National Engineering Handbook, Part 630 Hydrology*. Washington, D.C.: USDA-NRCS

NRCS. 2007a. Transmission Losses. Chapter 19 in: *National Engineering Handbook, Part 630 Hydrology.* Washington, D.C.: USDA-NRCS

NRCS. 2007b. SSURGO Data Packaging and Use. USDA-NRCS. Available at: soildatamart.nrcs.usda.gov/SSURGOMetadata.aspx. Accessed April 30, 2009.

NRCS. 2007c. Hydrographs. Chapter 16 in: *National Engineering Handbook, Part 630 Hydrology*. Washington, D.C.: USDA-NRCS

NRCS. 2008a. Soil Data Availability Status Map. USDA-NRCS. Available at: soildatamart.nrcs.usda.gov/StatusMap.aspx. Accessed April 30, 2009.

NRCS. 2008b. Soil Survey Geographic (SSURGO) Database. USDA-NRCS. Available at: soils.usda.gov/survey/geography/ssurgo/. Accessed April 30, 2009.

NRCS. 2008c. SSURGO Metadata Version: 2.2.3. USDA-NRCS. Available at: soildatamart.nrcs.usda.gov/SSURGOMetadata.aspx. Accessed April 30, 2009.

NRCS. 2008d. U.S. General Soil Map (STATSGO2) Database. USDA-NRCS. Available at: soils.usda.gov/survey/geography/statsgo/. Accessed April 30, 2009.

NRCS. 2008e. Electronic Field Office Technical Guides. USDA-NRCS. Available at: www.nrcs.usda.gov/technical/efotg. Accessed April 30, 2009.

NRCS-Kansas. 2002. Operation and Maintenance for Filter Strip. Kansas Agronomy Technical Note KS-42. Salina, KS: USDA-NRCS, Kansas Division.

NRCS-Kansas. 2003. Conservation Practice Standard, Filter Strip (acre.) Code: 393. Salina, KS: USDA-NRCS, Kansas Division.

NRCS-Kansas. 2006. Crop field management record (dry land). Unpublished technical note. Lyndon, KS: USDA-NRCS, Kansas Division, Osage County Field Office.

Ohlenbusch, P. D. 1997. *Establishing Native Grasses*. MF-2291. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Ohlenbusch, P. D., E. P. Hodges, and S. Pope. 1983. *Range Grasses of Kansas*. C-567 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Osterman, L. E., P. W. Swarzenski, and R. Z. Poore. 2006, Gulf of Mexico Dead Zone—the Last 150 Years: USGS Fact Sheet 2006-3005. Available at: pubs.usgs.gov/fs/2006/3005/. Accessed April 30, 2009.

Parajuli, P. B., K. R. Mankin, and P. L. Barnes. 2008. Applicability of targeting vegetative filter strips to abate fecal bacteria and sediment yield using SWAT. *Agric. Water Management* 95(10): 1189-1200.

Parajuli, P. B. 2007. SWAT bacteria sub-model evaluation and application. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

Peschel, J. M., P. K. Haan, and R. E. Lacey. 2006. Influences of soil dataset resolution on hydrologic modeling. *J. Amer. Water Resour. Assoc.* 42(5):1371-1389.

Peschel, J.M., P. K. Haan, and R. E. Lacey. 2003. A SSURGO Pre-Processing Extension for the ArcView Soil and Water Assessment Tool. ASAE Paper No.032123. St. Joseph, Mich.: ASAE.

Peterson, J. M., J. A. Fox, J. C. Leatherman, and C. M. Smith. 2007. Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market. In *Proc: 2007 Annual Meeting,* July 29-August 1, 2007, Portland, OR: AAEA.

Regehr, D. L., D. L. Davlin, and P. L. Barnes. 1996. *Using Vegetative Filter Strips in Crop Fields*. MF-2224. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

SAS Institute Inc. 2004. *SAS OnlineDoc® 9.1.3*. Cary, NC: SAS Institute Inc.

Satterthwaite, F. E. 1946. An approximate distribution of estimates of variance components. *Biometrics Bulletin* 2: 110-114.

Schauder, H. and K. Auerswald. 1992. Long-term trapping efficiency of a vegetated filter strip under agricultural use. *Zeitschrift für Pflanzenernährung und Bodenkunde (J. Plant Nutr. Soil Sci.)* 155(5): 489-492.

SCS, 1972. *National Engineering Handbook: Section 4 - Hydrology*. Washington, D.C: USDA, Soil Conservation Service (SCS, now Natural Resources Conservation Service, NRCS), Engineering Division.

Shiono T., H. Nakamura, N. Haraguchi, and T. Miyamoto. 2004. Sediment removal efficiency of vegetative filter strips under a rainstorm condition. In *Proc. International Symposium on Identification and Use of Microbial Resources for Sustainable Agriculture*. Paper No. P-52. Kumamoto, Japan.

Shroyer, J. P., D. Whitney, and D. Peterson. 1997. *Wheat Production Handbook*. C-529. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Sloan, P. G. and I.D. Moore. 1984. Modeling subsurface storm flow on steeply sloping forested watersheds. *Water Resour. Res.* 20(12): 1815-1822.

Sloan, P. G., I. D. Morre, G. B. Coltharp, and J. D. Eigel. 1983. Modeling surface and subsurface storm flow on steeply-sloping forested watersheds. Water Resources Inst. Report 142. Lexington KY: Univ. of Kentucky.

Smith, C. M. 2004. A Water Quality Trading Simulation for Northeast Kansas. MS Thesis. Manhattan, KS: Kansas State University, Department of Agricultural Economics.

Sophocleous, M. A. 1998. Water resources of Kansas - a comprehensive outline. In: Sophocleous, M. A. ed. *Perspectives on Sustainable Development of Water Resources in Kansas*. Lawrence KS: Kansas Geological Survey, Bulletin 239: 1-59.

Sophocleous, M. A. and S. P. Perkins. 2000. Methodology and application of combined watershed and ground-water models in Kansas. *J. Hydrol.* 236(3-4): 185-201.

Sophocleous, M. A., J. K. Koelliker, R. S. Govindaraju, T. Birdie, S. R. Ramireddygari and S. P. Perkins. 1999. Integrated numerical modeling for basin-wide water management: The case of the Rattlesnake Creek basin in south-central Kansas. *J. Hydrol.* 214(1-4): 179-196.

Staggenborg, S. A., J. P. Shroyer, D. Leikam, D. Fjell. 2004. *Managing No-till Wheat Following a Summer Crop in Eastern Kansas*. MF-2641. Manhattan, KS: Kansas State University, Department of Agricultural Economics.

Tuppad, P., 2006. Hydrologic modeling response to NEXRAD and raingage spatial variability and strategic watershed management. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

Tuppad, P., K. R. Mankin, J. M. S. Hutchinson, J. A. Harrington, and J. K. Koelliker. 2003. Targeting watershed improvement efforts using AGNPS-GIS modeling results. In *Proc. AWRA Agricultural Hydrology and Water Quality Conference*. Kansas City, MO: AWRA

USDA. 2008. Geospatial Data Gateway. USDA. Available at: datagateway.nrcs.usda.gov/, Accessed Dec. 31, 2008.

USEPA. 2004. *Water Quality Trading Assessment Handbook*. Washington, D.C.: Office of Water. USEPA.

USGS. 1999. National Land Cover Dataset 1992 (NLCD 1992). USGS. Available at: landcover.usgs.gov/mapping_proc.php. Accessed April 30, 2009.

USGS. 2006. National Elevation Dataset (NED). USGS. Available at: ned.usgs.gov. Accessed April 30, 2009.

Wang, X. and A. M. Melesse. 2006. Effects of STATSGO and SSURGO as inputs on SWAT Model's Snowmelt Simulation. *J. Am. Water Resour. Assoc.* 42:1217-1236.

Wang, Y. Y., 1971. Probability of the type I error of the Welch tests for the Behrens-Fisher problem. *J. Am. Statistical Assoc.* 66: 605-608.

Wanielista, M. P., R. Kersten, and R. Ealgin, 1997. *Hydrology: Water Quantity and Quality Control*. New York, NY: John Wiley & Sons.

Welch, B. L., 1947. The generalization of "student's" problem when several different population variances are involved. *Biometrika* 34: 28-35.

Whitney, D. A., D. L. Devlin, and D. J. Jardine. 1999. *Kansas No-Till Handbook*. S-126. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Whitney, D. A., L. R. Stone, K. A. Janssen, and J. H. Long. 1991. *The Effects of Nitrogen Fertilizer on Soil*. C-625. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Williams, J. R., and H. D. Berndt. 1977. Sediment yield prediction based on watershed hydrology. *Trans. ASAE* 20 (6), 1100-1104.

Williamson, T. and K. R. Odom. 2007. Implications of SSURGO vs. STATSGO data for modeling daily stream flow in Kentucky. In *Proc: ASA-CSSASSSA 2007 International Annual Meetings.* New Orleans, LA.

Wischmeier, W. H. and D. D. Smith. 1965. *Predicting Rainfall Erosion Losses from Cropland East of the Rocky Mountains*. Agriculture Handbook: No. 282. USDA. Washington, D.C.: U.S. Government Printing Office.

Wischmeier, W. H. and D. D. Smith. 1978. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning*. Agriculture Handbook: No. 537. USDA. Washington, D.C.: U.S. Government Printing Office.

Woodward, R. T., and R. A. Kaiser, 2002. Market Structures for U.S. Water Quality Trading. *Rev. Agr. Econ.* 24: 366-383.

Yang, L., C. Homer, K. Hegge, C. Huang, B. Wylie, and B. Reed, 2001. A Landsat 7 Scene selection strategy for a national land cover database, in *Proc. IEEE 2001 International Geoscience and Remote Sensing Symposium.* Sydney, Australia: University of New South Wales.

Chapter 4 Estimating Delivery Effect of Water Quality Trading

Abstract

Water quality trading (WQT) is a market-based approach to improving water quality. Stakeholders who register with the WQT program may trade pollutant load reductions to each other and also earn economic benefits. However, WQT does not address trading risks nor quantify uncertainty of potential nutrient load reduction, particularly for trades involving nonpoint sources (NPSs), which may cause the WQT program to fail. The processes of NPS pollutant load delivery to a downstream location involve both in-field and in-stream phases. Previous studies have analyzed in-field NPS nutrient load reduction. The goals of this study are to estimate the in-stream delivery effect of NPS nutrient load and to incorporate previous results to allow a comprehensive point source-NPS WQT program assessment. Based on previous WQT studies, we developed a systematic method with a SWAT model for 33 potential alternative scenarios to analyze in-field TN and TP load reductions as well as in-stream delivery effect for 36 years in the Lower Kansas watershed, northeastern Kansas. To include lake detention effects in trading risk analysis, we used EUTROMOD loading function, a lake water quality model. The results show a significant delivery effect within the subbasins: the delivery ratio ranged from 0.8882 to 0.9997 excluding lake effects and from 0.388 to 0.791 including lake effect. These phenomena suggest geospatial site-specific effects also apply to the delivery ratio for each subbasin across the watershed. The overall trading ratio for both nutrients ranged from 1 to 2.2 or more in different scenarios. That suggests a floating TR system would be more suitable than fixed TR in study watershed. The cluster analysis based on the nutrient load reduction trading ratio presents a potential method to group similar subbasins into a trading zone. This eliminates the problems involved in fixed TRs while keeping the method simpler than finer-resolution floating TR system.

4.1 Introduction

Although the water quality of U.S. waterways has improved in recent decades, much of this improvement has been due to programs that target point sources (PSs) of pollution, such as wastewater treatment facilities. However, meeting water quality goals is still a long way off, even with current progress in developing and implementing Total Maximum Daily Loads (TMDLs). In Kansas, according to the KDHE 305(b) report of 2008, 63% of stream miles and 81% of lake acreages are impaired for one or more designated uses and much of the rest is threatened (KDHE, 2008).

In Kansas, one major water quality issue is excess nutrients, which affects more than 35% of total impaired lake acreage (KDHE, 2004). Wastewater treatment plants are responsible for 5-30% of the nutrient contribution in many states (KDHE, 2004), with nonpoint sources (NPSs) responsible for the remainder. Unfortunately, NPSs cause most pollution and are unregulated under the Clean Water Act. As a result, few mandatory actions are required of major pollution sources and many requirements for the minor sources. Moreover, Kansas streams must meet EPA's Ecoregional criteria, which range from 0.56 to 2.18 mg/L for total nitrogen (TN) and from 0.020 to 0.067 mg/L for total phosphorus (TP) (USEPA, 2000a). Unfortunately, the best performance expected for wastewater treatment plants using secondary treatment methods is around 3.0 mg/L TN and 0.3 mg/L TP (KDHE, 2004). Moreover, the EPA has also proposed similar nutrient criteria for lakes/reservoirs: 0.36 mg/L of TN and 0.02 mg/L of TP (USEPA, 2000b). That means current treatment technology and equipment in wastewater treatment plants cannot meet the EPA's regulations. In addition, renewing treatment technologies and facilities is typically beyond the financial and technical capabilities of many small towns throughout Kansas.

On the other hand, water quality trading (WQT), promoted for decades, involves at least 70 projects implemented or proposed nationwide in 2004 (Environomics, 1999; Breetz et al., 2004; Morgan and Wolverton, 2005). Despite the many implemented WQT programs, the actual traded volumes and cases are much smaller than expected (Nelson and Keeler, 2005). The trading volume in the WQT market largely depends on incentives from the trading processes and the willingness of potential stakeholders to participate. These incentives must be estimated precisely to minimize costs in the trading process and produce equal or better water quality after a trade. The most likely impediments to low trading volume include, but are not limited to, lack of information among stakeholders, excessive transaction costs, a fixed trading ratio, inability to address environmental uncertainties, and other intangible costs among stakeholders (Smith, 2004; Lee et al., 2005). An empirical, fixed trading ratio might overestimate (or underestimate) trading uncertainty because it disregards environmental uncertainties and treats the whole watershed as a large, homogeneous system, averaging the variants and generalizing the phenomena of pollutant load on the spatiotemporal scale. Lee and Mankin (2007a) estimated the site-specific trading ratio using a watershed model and GIS in northeastern Kansas. Their work used a dedicated environmental benefits calculation method for the WQT program and found several strong site-specific phenomena across study watershed in both geospatial and temporal aspect. However, they only evaluated the in-field processes of WQT. A more precise estimate of the pollutant fate via the water network to downstream outlets must be addressed.

Therefore, the primary goal of this study is to expand upon the previous site-specific NPS in-field trading ratio research of Lee and Mankin (2007a) by simulating and quantifying the spatiotemporal delivery effects of nutrients (nitrogen and phosphorus) transported along stream networks. We will simulate the nutrient fate and transport in both stream and lake systems with watershed/water-quality models under potential management practices. We also used GIS network analysis techniques to estimate the pollutant load variations from NPS to watershed outlet in space and time. Based on modeling simulations and statistical analyses, we expect to develop a method of quantifying trade-specific TRs that incorporates both in-field load uncertainty and in-stream delivery effects, and ultimately minimizes trading costs.

4.2 Materials and Methods

4.2.1 Water Quality Trading

WQT is a market-based approach to improving water quality. It is an innovative, voluntary tool that connects industrial and municipal facilities, or PSs, to agricultural producers, NPSs, to economically achieve improvements in water quality in the watershed. Assuming all sources account for a certain minimal level of pollution prevention and that no water quality degradation is permitted, the trading program would allow a pollution source with a high reduction cost to purchase the same or a higher level of equivalent pollutant reduction from others with lower costs. The source with high costs achieves a targeted level of pollution reduction at less overall cost, while the source with low costs sells environmental equivalents or “credits” as pollution is reduced. This trading process provides mutual benefits for both the seller and buyer. WQT is a flexible and cost effective approach for maintaining, restoring, or enhancing water quality.

The biggest issue with WQT is that the actual traded volume might be smaller than anticipated (Nelson and Keeler, 2005). The basic idea behind WQT is to create a “market” in which all the sources of pollution are jointly charged with the task of meeting a water quality goal. In this market, providing incentives for traders to participate while reducing the pollution load from each participant is the ultimate goal. Nelson and Keeler (2005), however, reported that existing WQT programs have had unexpectedly low trading volumes. Motivation for trading requires a large number of pollution sources willing to trade and significant disparity in the costs of pollution reduction. Too few potential trading partners might cause the WQT market to fail (Letson et al., 1993; Crutchfield et al., 1994). For example, the total cost for an agricultural producer to implement alternative land management practices or install certain structural remedies is less than the total cost of reducing pollutants by the same amount at water treatment facilities by installing complex industrial pollution control technologies and equipment. Hoag and Hughes-Popp (1997) pointed out that improving trading processes and methods of simulating trading results can make trading programs more successful.

4.2.2 Trading Direction within Watershed

Another important issue is the direction of a trade, as it relates to WQT stakeholder availability and environmental suitability. The trading direction depends on where each trading partner, both buyer and seller, is located. In most of cases, WQT provides an opportunity for a buyer to purchase environmental credits from a seller to replace specific load reduction requirement. Based on the relative location of buyer and the targeted water body of the WQT program, the direction of a trade can be categorized as upstream or downstream. Figure 4-1 illustrates the spatial location of buyer (PS) and seller (NPS) in both downstream and upstream scenarios. If sellers reside upstream and trade their credits to downstream buyers, this is a downstream trade, but when sellers are downstream and trade their credits to upstream buyers, it is an upstream trade. A third type of scenario, not illustrated in Figure 4-1, is mixed direction trading. In this scenario, sellers and buyers are both upstream and downstream, so the scenario cannot be categorized clearly as a downstream or upstream trade.

For a downstream trade, an NPS that sells a pollutant load reduction to a downstream PS will reduce the total amount of pollution discharging to the river, which will improve the water quality of that river section. In contrast, an upstream trade in which the NPS sells its credits to an upstream PS; the PS discharges its pollution first and then reduces the total pollutant load by purchasing load reduction from the downstream NPS. Both downstream and upstream trades might reduce the overall pollutant loads discharging from the watershed outlet or to the target water body (such as a lake or reservoir). However, the upstream trade may not solve local water quality issues along a river section between the PS and NPS and might also cause some localized environmental degradation or “hot-spot” issues. The hot-spot is due to total pollutant loads in one or more stream sections between buyers and sellers, which may become too high to meet the water body’s designated use. The factors that might create a hot spot include the nature and quantity of pollutants, low flow, or inability the receiving water body to assimilate pollution (Rowles, 2005). The hot spot might violate the TMDLs or worsen local water quality. Applying TMDL constraints to a specific river section or splitting a watershed into several sub-trading regions can prevent the hot spots. The geophysical difference between lakes and streams mean that lakes often provide suitable locations to divide a watershed into two discontinuous trading regions. Similar to the upstream trade scenario, the mixed trading direction scenario may result in uncertainty in intermediate river sections. Consequently, the downstream trade scenario is generally preferable. In this study, all trading directions were downstream.

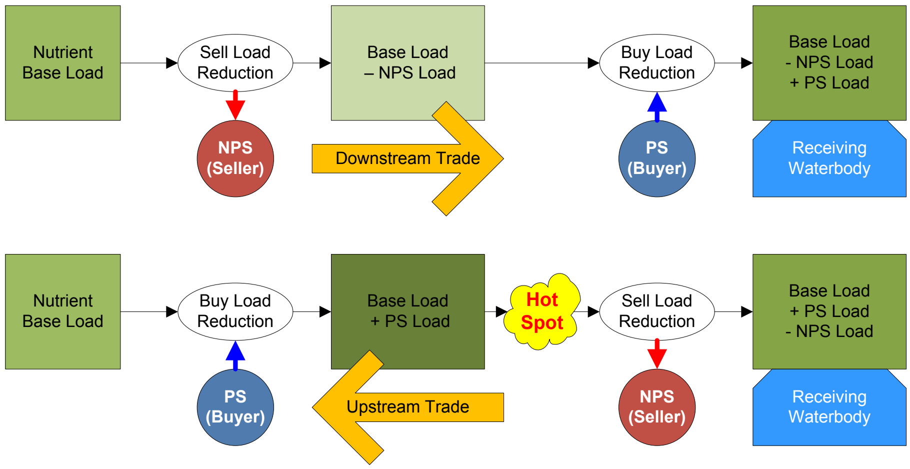


Figure 4-1 Direction of WQT Partners and Potential Hotspot

4.2.3 Effect of Fixed Trading Ratio

The trading ratio (TR) is the ratio of pollution reductions purchased from a supplier to the pollution reductions a buyer needs. The ratio is based on the probability that pollutant loads will be reduced by supplier at a specific confidence level. Comparing the daily based PS to event based NPS, one unit pollutant load reduction from PS may not equal the one from NPS. For example, 1 credit of load reduction having 100% certainty would be equivalent to 2 credits of load reduction having 50% certainty. The TR in this case would by 2:1. To account for the differences in certainty (or risk) among potential source reductions and to help ensure an environmental equivalent between seller and buyer, current research uses either fixed or variant (floating) TRs in their WQT programs.

Fixed TR means only one of several ratios can be used for any trade in a WQT program. In this WQT program, the PS purchasing credits equal the required credits multiplied by the TR, no matter what risk is introduced by alternative land management practices or the distance (and potential for natural degradation) between buyer and seller. A variant or floating TR either uses an individual ratio for each trading partner or a series of ratios for different management practices in each sub-area of a WQT program. The variant TR accounts for variation in soil type, land management, climate, landscape slope, and land management practices in a spatiotemporal scale as well as the pollutant delivery effects along stream network from source to target. In general, a fixed TR is easier to implement in a trading program and simplifies the calculation of total cost, but the environmental benefits of each trade would vary. In contrast, a variant TR, based on the watershed spatiotemporal heterogeneity and the probability of load reduction for each management practice, would increase the complexity of calculation and implementation of each trade and the overall WQT program. However, it would also provide evidence of more precise and consistent environmental benefits for each trade at a certain level of confidence.

Figure 4-2 demonstrates both fixed and variant (floating) TR scenarios. Consider a case in which there is a PS that requires 1x pollutant load reduction (L/R) credits to meet a new regulation, and where two NPSs, NPS1 and NPS2, have unlimited amounts of pollutant load reduction credits to sell to the PS. With a watershed-wide fixed TR of 2:1, the PS must purchase 2x credits from either NPS1 or NPS2. The NPS with a lower credit price would be the best choice for the PS. However, the delivery effect between NPS1 and PS differs dramatically from the delivery effect between NPS2 and PS. If the R_D between NPS1 and PS is 0.8 and the R_D between NPS2 and PS is 0.4, the final amount of load reduction from the purchase of 2x credits transported from NPS1 to PS would be 1.6x (delivered) credits and from NPS2 to PS would be 0.8x (delivered) credits. In this case, a trade with NPS1 would meet the water quality target (> 1x actual delivered reduction) whereas a trade with NPS2 would not result in sufficient pollutant load reduction to meet the target (< 1x actual delivered reduction). This case shows that using a fixed TR might create a trade with insufficient load reduction.

In contrast, if a floating trade ratio system is implemented in a watershed, a set of TRs that retain the 2:1 factor of safety might be 2.5:1 for NPS1 and 5:1 for NPS2. Variant TRs, including not only in-field load reduction uncertainty but in-stream delivery attenuation effects, the delivered load reduction for both NPS1 and NPS2 would be similar. Therefore, the PS would need to purchase 2.5x credits from NPS1 or 5x credits from NPS2 depending on their individual TRs.

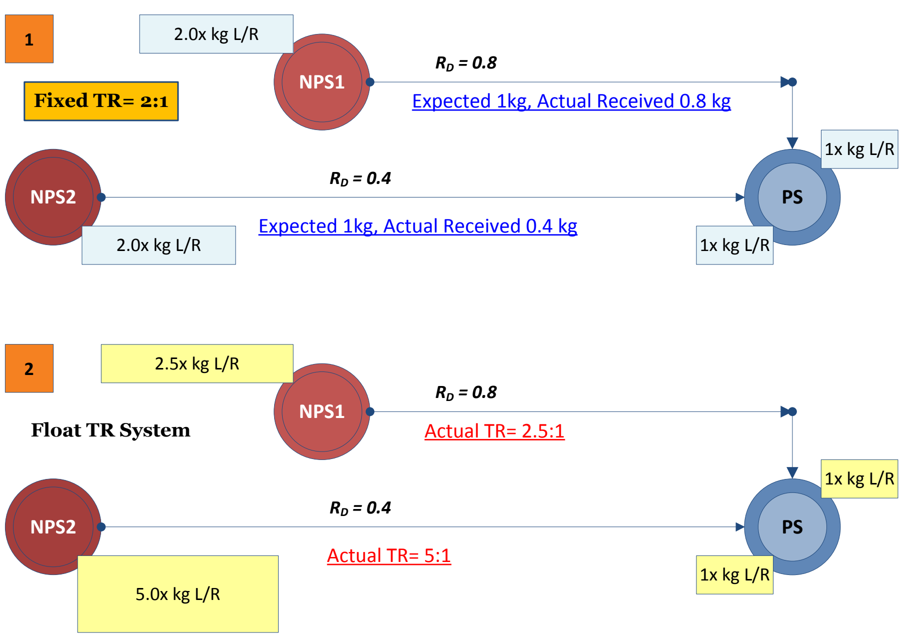


Figure 4-2 Fixed and Variant TR Scenario

4.2.4 Environmental Equivalents of WQT

The distribution of NPS pollutant reduction will be simplified as a normal distribution (a curve), and the required abatement of PS will be assumed to be a constant (a vertical line). The ideal match point between PS and NPS would be located on the mean of NPS reduction distribution curve. To minimize trading risks, we must either increase the purchased amount or decrease the effective load reduction from NPS. Therefore, the intersection of the PS line and NPS curve will shift to the left side of the NPS curve. This shift implies that a lower PS load equals a given NPS load with a higher confidence level (lower risk) in the same trade.

Once the load reduction distribution is found, estimating the TR is easy with a given confidence level, even if we must find the confidence level from given load reduction threshold. For instance, assuming the NPS load reduction mean equals 1000 kg and standard deviation is 200 kg, for a mean minus one standard deviation confidence, the trading results are 800 kg. That means when purchasing 1000 kg load reduction from an NPS, at least 800 kg are effective under one standard deviation or for the 86.4% confidence level. In other words, the NPS can be confident of providing at least 800 kg load reduction to a PS 86.4% of the time. The TR, also known as Environmental Equivalent Ratio (USEPA, 2004), can then be defined as the purchased amount divided by effective amount of pollutant load reduction. For an 86.4% confidence level, the TR would be 1000/800 = 1.25.

4.2.4.1 *Pollutant Load Reduction and Trading Ratio*

In WQT, TRs help in calculating the equivalence of load reductions to compensate for trading uncertainty among different pollutant sources based on their physical characteristics, land management practices, multi-pollutant cross-effects, and the other spatiotemporal influences within trading partners. It could be treated as an exchange rate that establishes equivalence among trading partners who may have different measures and baselines of the pollutant load. TRs also ensure that the equivalence of trades can be achieved at a specific confidence level. Traditionally, fixed, universal TRs (commonly 2:1) used in WQT programs provided a safety net for the empirical estimation of trading results. However, this artificial ratio may force a trade with an unreasonable confidence level, which might require a PS to purchase unneeded credits from an NPS at a higher total cost. Alternatively, a variable, floating TR system, based on the pollutant load reduction uncertainty and watershed spatiotemporal variation, can provide a matrix of TRs for each trade-eligible land-management scenario and geographical location. A fixed TR gives a simple solution for WQT, but a floating TR provides more accurate information for trades.

Although previous WQT studies have defined TRs from both environmental and economic perspectives (Jones et al., 2005; CTIC, 2006), in this study, the TR was separated into an in-field uncertainty ratio (R_U) and an in-stream delivery ratio (R_D). Both ratios were derived from the probability distributions of pollutant load reductions using sound, scientific watershed models and GIS techniques.

Assuming P_{LMP1} is the annual pollutant load from current land management practice (LMP_1) and P_{LMP2} is the annual pollutant load from an alternative land management practice (LMP_2), the annual pollutant load reduction from LMP_1 to LMP_2 is (P_{LMP1} - P_{LMP2}) at the same year. Environmental uncertainty within the watershed means the pollutant load reduction for each year might be different. If $P_{AVG\,(1-2)}$ is the mean value of n years of pollutant load reduction for land management practices changing from LMP_1 to LMP_2, $P_{AVG\,(1-2)}$ would be equal to the weighted average of all annual load reductions (see Eq. 4-1). If the current land management practice is used as a baseline scenario, the pollutant load reduction for each baseline-alternative scenario can be explained as the relative pollutant load reduction index, or BMP reduction efficiency factor ($BMP_{R(b-*)}$), where the "b" represents the baseline scenario and the "*" could be any other potential alternative land management practice applied on a field. Assuming current land management practice as LMP_1 and an alternative practice as LMP_2, Eq. 4-2 describes the relationship of $BMP_{R(1-2)}$, the relative pollutant load reduction index between P_{LMP1} and P_{LMP2}.

$$P_{AVG(1-2} = \frac{1}{n}\sum_{i=1}^{n} w_i\left(P_{LMP_1} - P_{LMP_2}\right)_i \qquad \text{Eq. 4-1}$$

$$BMP_{R(1-2)} = \frac{1}{n}\sum_{i=1}^{n} \frac{w_i\left(P_{LMP_1} - P_{LMP_2}\right)_i}{P_{LMP_1}} \qquad \text{Eq. 4-2}$$

Based on Eq. 4-2, the nominal tradable in-field load reduction of the seller (P_{NR}) can be expressed as $P_{NR} = P_{LMP_1} \times BMP_{R(1-2)}$, which is similar to $P_{AVG\,(1-2)}$ in Eq. 4-1. To account for the potential environmental uncertainty or trading risk of a trade, two ratios, the R_U for in-field pollutant load reduction and the R_D for in-stream load reduction attenuation, explain the uncertainty due to land management practice or in-stream transport. Furthermore, the in-field R_U is the potential deviation of pollutant load reduction due to uncertainty divided by the arithmetic mean of all load reductions. In general, the R_U should range from 0 to 1. For the special cases, when R_U is equal to 0, there is no potential deviation of load reduction. In contrast, if R_U is equal to 1, the potential load reduction deviation is equal to its mean, an unacceptable scenario with extremely high uncertainty. The in-stream

R_D is the outflow pollutant load divided by the inflow load within a watershed section or a river reach. In general, the R_D also ranges from 0 to 1. For some extreme cases, when R_D is equal to 0, there is no outflow pollutant load, possibly indicating all the pollutant load settling in that watershed or river section. If R_D equals 1, the entire inflow pollutant load is completely transported to the outlet without any attenuation or degradation. Thus, the actual pollutant load reduction (P_{AR}) transported from upstream seller to downstream buyer should be revised using Eq. 4-3, in which both R_D and R_U imply the spatial variation and potential temporal variances of a trade. As described previously, a TR is the exchange rate for maintaining the pollutant load reduction equivalence between the seller and buyer, explained as the nominal tradable load reduction (P_{NR}) divided by actual pollutant load reduction (P_{AR}). Therefore, a TR can be simplified as a function of in-field R_U, and in-stream R_D as Eq. 4-4.

$$P_{AR} = P_{LMP_1} \times BMP_{R(1-2)} \times (1 - R_U)R_D \cong P_{AVG(1-2)} \times (1 - R_U)R_D \qquad \text{Eq. 4-3}$$

$$TR = \frac{In\ Field\ Load\ Reduction}{Delivered\ Load\ Reduction} = \frac{P_{NR}}{P_{AR}} = \frac{P_{LMP_1} \times BMP_{R(1-2)}}{P_{LMP_1} \times BMP_{R(1-2)} \times (1 - R_U)R_D}$$
$$\cong \frac{P_{AVG(1-2)}}{P_{AVG(1-2)} \times (1 - R_U)R_D} = \frac{1}{(1 - R_U)R_D} \qquad \text{Eq. 4-4}$$

4.2.5 In-Field Uncertainty Ratio

To quantify the uncertainty of in-field pollutant load reduction, the load reduction between current and alternative land management practice must be defined. If the load reduction between current and alternative practice is not significant, the change in land management will not produce a significant change in pollutant load, which implies that the alternative method would not be a tradable option. Even if the load reduction is statistically significant, it should be positive to benefit the environment. A method should also assess and quantify the probability associated with in-field load reduction uncertainty. Based on statistical theory (e.g., t-test) with a given confidence level, the R_U then can be derived to address the degree of difference among alternatives.

Assuming α is type I error in the statistical analysis, the approximate 100(1-α)% confidence interval (CI) for unpaired observations scenario, with the mean of LMP_1 and LMP_2 ($\bar{X}_1$ and $\bar{X}_2$), their variance (S_1^2 and S_2^2), and the number of observations (n_1 and n_2), the confidence interval (CI) can be derived (see Eq. 4-6). In studying the probability of pollutant overload cases, only the lower bound confidence limit is of interest. Therefore, Eq. 4-6 is written in estimating the lower bound confidence limit at one-side 100(1-α)% confidence level for unpaired scenarios. An effective pollutant load reduction implies a potential positive load reduction from a trade. Hence, the confidence intervals in Eq. 4-6 need to be greater than zero to support a potential trade.

$$CI(\mu_1 - \mu_2) = \bar{X}_1 - \bar{X}_2 \pm t_{(1-\alpha/_2),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \quad \text{Eq. 4-5}$$

$$CL_L(\mu_1 - \mu_2) = \bar{X}_1 - \bar{X}_2 - t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \quad \text{Eq. 4-6}$$

With one-sided 100(1-α)% confidence level equations like Eq. 4-6, the magnitude of load reduction uncertainty can be described as the observations deviated from the mean of potential load reduction. Thus, the potential magnitude of uncertainty, or the observed load reduction deviation at 100(1-α) % confidence level, can be explained as a deviation radius as in Eq. 4-7. Furthermore in statistics, the same distribution around a larger mean value produces a larger standard deviation. Therefore, to compare the magnitude of potential uncertainty of pollutant load reduction, or the deviation radius of a baseline scenario with several alternative scenarios, the absolute value is often transformed into relative form. Thus Eq. 4-7 can be divided by its mean as the relative deviation radius. Therefore, the R_U is defined as the relative deviation radius in Eq. 4-8. Eq. 4-8 formulates the R_U at 100(1-α) % confidence level with the mean of load reduction ($\bar{X}_1 - \bar{X}_2$), variance (S_1^2 and S_2^2), and the number of observations (n_1 and n_2).

$$Deviation\ Radius = t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \quad \text{Eq. 4-7}$$

$$R_U = Relative\ Deviation\ Radius = \frac{t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}{\bar{X}_1 - \bar{X}_2} \quad \text{Eq. 4-8}$$

In a simplified WQT scenario, if the pollutant transport or delivery effect can be neglected, the potential load reduction or tradable environmental credits will only account for the uncertainty of in-field load reduction. Therefore, the R_D in Eq. 4-4 can be assumed as 1, and Eq. 4-4 can be rewritten as Eq. 4-9. In this simplified WQT scenario, TR is solely decided by in-field load reduction R_U; this TR is defined as in-field TR (TR_{IF}).

$$TR_{IF} = \frac{1}{(1 - R_U) \cdot R_D} = \frac{1}{(1 - R_U) \cdot 1} = \frac{1}{(1 - R_U)} \quad \text{Eq. 4-9}$$

4.2.6 In-Stream Delivery Ratio

If a watershed is large enough, the time of concentration for storm water would be substantial. In other words, without any new source of pollutant, the amount of pollutant load at a stream reach inlet might not equal that at its outlet. Thus, in-stream nutrient load attenuation or degradation, pollutant deposition, natural assimilation, and other delivery effects could be substantial. Pollutant load delivery effect is a gross term that describes the changes of pollutant load in stream and/or lake due to transport or detention effects. Modeling or monitoring data analysis is usually used to estimate the load for stream attenuation and transport. The R_D includes the both effects of pollutant load transported in the stream network ($\prod R_{D_S}$) and the load detained in a lake/reservoir ($\prod R_{D_L}$). Within an individual sub-watershed, the R_D is defined as a ratio of the amount of pollutant load at the downstream sub-watershed outlet to the original pollutant load at the inlet (see Eq. 4-10). Delivery ratio also can be defined as the ratio of the pollutant load received at the downstream PS to the original amount at the edge of field of the NPS.

For a large watershed with a complex stream network, the watershed usually is divided into several sub basins, and the stream is divided into several sections for monitoring or modeling. To connect several stream sections or water bodies, the R_D for load transported from source to sink can be expressed as the product of all the individual R_Ds of each stream segment and/or lake/reservoir as in Eq. 4-11. This TR is here defined as an aggregated or cumulative R_D (R_D^*).

$$R_{D_i} = \frac{N_{OUT_i}}{N_{IN_i}} \qquad \text{Eq. 4-10}$$

$$R_D^* = \prod_{i=1}^{n} R_{D_i} = \prod_{j=1}^{p} R_{D_{S_j}} \times \prod_{k=1}^{q} R_{D_{L_k}} \qquad \text{Eq. 4-11}$$

where:

R_D^* = Cumulative delivery ratio
R_{D_i} = individual delivery ratio within the i^{th} waterbody. The i = 1 ~ n
$R_{D_{S_j}}$ = individual delivery ratio within the j^{th} stream segment. The j = 1 ~ p
$R_{D_{L_k}}$ = individual delivery ratio within the k^{th} lake. The k = 1 ~ q

If we only consider pollutant transport attenuation for the load reduction uncertainty of a trade, the potential load reduction or tradable environmental credits can be calculated based on the delivery effect in the stream. That means in Eq. 4-4, the R_U can be assumed to be 0, and Eq. 4-4 can be rewritten as Eq. 4-12. The TR for this scenario is solely decided by R_D in the water body (stream and/or lake), and it is defined as in-stream TR (TR_{IS}).

$$TR_{IS} = \frac{1}{(1 - R_U) \cdot R_D} = \frac{1}{(1 - 0) \cdot R_D} = \frac{1}{R_D} \qquad \text{Eq. 4-12}$$

4.2.7 Stream Network Analysis

The distance between two points that reside in a geospatial network can be defined several ways. An inquiry on the geospatial network will affect how distance is defined and quantified. Classically, networks are modeled as a set in graph G(V, E), where V denotes the set of vertices or nodes, and E denotes the set of edges or arcs within the network (Samet, 1990; Sankaranarayanan et al., 2005). The E represents the connectivity of G. In a simple network, two nodes u and v are directly connected if, and only if, there is an edge: E(u,v) $\in$ G(V,E). In a complex network, u and v might have more than one edge between them (Samet, 1990; Sankaranarayanan et al., 2005). Stream network is an example of a simple network, while a highway network is an example of a complex network. Thus, in the physical property of spatial networks, the shortest distance could be either the spatial distance or network distance. The spatial distance refers to the straight line between the two vertices, u and v, in the reference coordinate system space. The network distance means the smallest amount of movement between two vertices u and v along the network.

On the other hand, the spatial network might be weighted. Given $e_i \in E$, the $W(e_i)$ denotes the i^{th} weighted distance along that i^{th} edge in the physical network (Samet, 1990). For the weighted property of spatial network, the shortest distance is the summation of all weighted edges in either spatial distance or network distance. Sometimes the weighted distance is called cost distance, meaning the network applies weighted and constrained rules, the distance is the amount of cost between two nodes along that network. Assuming X_u, Y_u denote the spatial position of the u node in the reference coordinate system space, and X_v, Y_v is the spatial position for v node, the shortest distance for network analysis is shown in Eq. 4-13 to Eq. 4-15 (Samet, 1990). For numerical calculation, a network with n vertices between two nodes can be explained as a (n+1) by (n+1) matrix for further analyses.

Spatial Distance: $dS(u,v) = \sqrt{(X_u - Y_v)^2 + (X_u - Y_v)^2}$ Eq. 4-13

Network Distance: $dN(u,v) = \sum_{i=1}^{n} dS(e_i)$ Eq. 4-14

Weighted Distance: $dW(u,v) = \sum_{i=1}^{n} W\big(dS(e_i)\big)$ Eq. 4-15

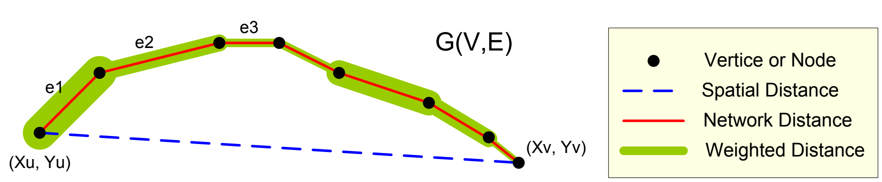


Figure 4-3 Conceptual Model of Shortest Distance in a Spatial Network

A typical simple GIS network model usually represents a set of nodes/links entities with the nodes at the link intersections. Unlike other network structures, the stream water network mainly focuses on stream connectivity to each watershed outlet. Streams flow downhill (a single direction), which characterizes them as following a “two parent links topology” (Maidment, 2002; ESRI, 2009). Therefore, the network design of natural stream or open channel systems in most GIS applications was based on this topology.

ESRI ArcGIS Desktop is a GIS software package that implements the spatial network with Network Analyst and Utility Network Analyst. In its conceptual model, the nodes or vertices are called junctions (ESRI, 2006). Streets, transmission lines, pipe, and stream reaches are examples of edges. Street intersections, fuses, switches, and the confluence of stream reaches are examples of junctions. Edges connect at junctions, and the flow from one edge—automobiles, electrons, water—can be transferred to another edge. In ArcGIS, network analysis is defined as navigation through the connectivity of a network to yield logical connection, resource capacity or limit, such as tracing an upstream reach for a given point or the shortest path between two points (ESRI, 2006). Simply calculating the statistics of edges is also valid for a network, but this cannot be a network analysis because network connectivity is not involved.

In this WQT study, ArcGIS Desktop Utility Network Analyst and its tracing functions can calculate the network hierarchies for the watershed stream and examine the topology of stream network connections in the source data. The generated stream network can then be used to find the path between source and sink, to calculate the delivery length, to find the total upstream/downstream links, and to trace back for potential trading partners.

4.3 Model Selection

4.3.1 SWAT

A watershed model, Soil and Water Assessment Tool (SWAT), was selected to simulate potential nutrient loads in this study. SWAT has been applied in many watersheds worldwide (Gassman et al., 2007) including several Kansas watersheds at Kanopolis Lake (Tuppad et al., 2003; Tuppad, 2006), Clinton Lake (Parajuli, 2007), Cheney Lake (Parajuli et al., 2009), Rattlesnake Creek (Sophocleous et al., 1999), Delaware (Nelson et al., 2006), among others (Sophocleous and Perkins, 2000), and is well suited for investigating long term effects of watershed-process variability in Kansas. SWAT was developed to help water resource managers predict and assess the impact of management on water, sediment, and agricultural chemical yields in large ungauged watersheds or river basins (Neitsch et al., 2005). It is physically-based, with daily steps, a continuous simulation model developed by Dr. Jeff Arnold for USDA Agricultural Research Service (ARS) at Temple, TX, during the 1990s (Neitsch et al., 2005). SWAT can simulate a very extensive set of agricultural BMPs ranging from changes in crop rotation types (more than 80 crops/plants), tillage practices (more than 100), manure/fertilizer management (from more than 50 sources), and conservation practices. SWAT also models in-stream processes affecting nutrient and sediment transport including sorption and desorption to bed sediment and scouring and deposition of sediment. However, SWAT is not designed to simulate detailed, single-event flood routing. It operates on a daily time step to study long-term effects within a watershed.

For modeling, SWAT partitions a watershed into several subbasins based on topography and given hydrology thresholds. Each subbasin is simulated as a homogeneous area in terms of climatic conditions and topography, but additional subdivisions can be delineated within each subbasin to represent unique combinations of land cover, soil, and management practices. Each subdivision of subbasin areas is called a hydrologic response unit (HRU), assumed to be uniformly distributed and to inherit the subbasin geospatial properties. SWAT predicts runoff separately for each HRU at each time step and aggregates the weighted results to represent the total runoff of the subbasin as well as routes to obtain the final surface runoff for the watershed at that time step. Therefore, SWAT can model more realistically the specific soil, topography, landuse, climate, and management practices in a particular area.

SWAT uses water balance as the driving force to model the hydrologic cycle of a watershed. Based on hydrologic cycle, it can be separated into two major divisions: the land phase and the water or routing phase. The land phase of the hydrologic cycle controls the amount of water, sediment, and nutrient and pesticide loadings to the main channel in each subbasin. The second division is the water or routing phase of the hydrologic cycle, defined as the movement of water, sediments, or other effluents through the stream network of the watershed to the designated outlet (Neitsch et al., 2005). Both land phase and water routing phase include several subcomponents or processes. The land phase uses the water balance equation to simulate the hydrologic cycle in the watershed. With the hydrologic cycle, SWAT simulates land phase processes with several components such as precipitation, snow, soil temperature, infiltration, evapotranspiration, lateral flow, surface runoff, soil water, groundwater, nutrients/pesticides/ bacteria estimation, plant growth, and land management practices, as well as sediment erosion and nutrient, pesticide, and bacteria transport via overland flow. Once SWAT determines the pollutant loads at the edge of field in land phases, the water routing phase of SWAT activates to route the water, sediment, nutrients, pesticides, bacteria or heavy metals in both channel/reach and lake/pond. In addition to keep track of mass flow in the water body, SWAT models the transformation of nutrients and pesticides between the water and benthos (Neitsch et al., 2005).

For this study, the daily water budget in each HRU was computed using historical daily precipitation and temperature as well as simulated runoff, evapotranspiration (ET), percolation, and return flow from sub-surface and groundwater flow. Runoff and infiltration volume in each HRU was computed using the Soil Conservation Service (SCS, now the Natural Resource Conservation Service, NRCS) runoff curve number method (USDA Soil Conservation Service, 1972). Peak runoff rate was computed using modified rational method (Neitsch et al., 2005). Potential evapotranspiration (PET) was estimated using Hargreaves method (Hargreaves and Samani, 1985), which requires daily air temperature only.

Flow in a watershed is classified as overland or channelized. SWAT uses Manning's equation to define both types of flow rate and flow velocity with separate roughness coefficients (Manning's n). Water is routed through the channel network using the variable storage routing method or the Muskingum routing method. Both the variable storage and Muskingum routing methods are variations of the kinematic wave model (Neitsch et al., 2005). Reservoir flow routing uses the water balance approach and user provided measured or targeted outflow.

In this study, we used channel runoff routing based on the variable storage routing method (Williams, 1969), assuming the flow was delivered in a trapezoidal intersection with 2:1 side slopes and a 10:1 bottom width-depth ratio. SWAT adjusted the flow for transmission losses, evaporation, diversions, and return flow in the study area (Neitsch et al., 2005).

SWAT uses the Modified Universal Soil Loss Equation (MUSLE) factors to compute sediment yield (Williams and Berndt, 1977) expressed in terms of runoff volume, peak flow, and other original Universal Soil Loss Equation (USLE) factors (Wischmeier and Smith, 1965; 1978). Furthermore, the transport of sediment in channel is controlled by the simultaneous operation of two processes, deposition and degradation. SWAT uses the peak channel velocity in estimating the maximum amount of sediment that can be transported from a reach segment (Neitsch et al., 2005). Bed degradation is adjusted with USLE soil erodibility and cover factors, and deposition is based on particle fall velocity (Neitsch et al., 2005). Reservoir sediment routing is based on a simple continuity equation on volumes and concentrations of inflow, outflow, and reservoir storage (Neitsch et al., 2005).

SWAT tracks the movement and transformation of the complete nutrient cycle for nitrogen and phosphorus for each HRU in the watershed. Nitrogen may be added to the soil using fertilizer, manure, or residue, fixation by symbiotic or non-symbiotic bacteria, and rain. Nitrogen is removed from the soil by plant uptake, leaching, volatilization, de-nitrification, and erosion. Phosphorus may be added to the soil using fertilizer, manure, or residue. It is removed from the soil by plant uptake and erosion. SWAT estimates plant use of nutrients using the supply and demand approach described in the section on plant growth. However, nutrients may be introduced to the main water channel and transported downstream through surface runoff and lateral sub-surface flow or percolation.

The primary forms of nutrients in transport are nitrate and organic N for nitrogen and soluble, organic, and mineral phosphorus. The total mass of nitrate lost from the soil layer is obtained using the concentration of nitrate in the mobile water and the volume of water moving in each pathway. Most organic N attaches to soil particles and is then transported to the main channel with sediment. The amount of organic N transported with sediment to the stream is calculated with a loading function developed by McElroy et al. in 1976 and modified by Williams and Hann in 1978 (Neitsch et al., 2005). The loading function estimates the daily organic N runoff loss based on the concentration of organic N in the top soil layer, the sediment yield from the HRU, and the enrichment ratio. Due to the low mobility of solution phosphorus, surface runoff will only partially interact with the solution P stored in the top 10 mm of soil. The amount of solution P transported in surface runoff is estimated with P concentration in the top soil layer, runoff volume, and a partitioning factor. Organic and mineral P also attached to soil particles to be transported by surface runoff to the main channel. The amount of phosphorus load transported with sediment is simulated using the similar loading function of organic N transport.

SWAT models in-stream water quality with algorithms that incorporate constituent interactions and relationships used in QUAL2E model (Brown and Barnwell, 1987). It also provides an optional feature to simulate in-stream nutrient transformations (Neitsch et al., 2005). To simplify the modeling analyses, SWAT routed nutrient loads downstream without simulating transformations in this study.

4.3.2 EUTROMOD

To include the delivery/detention effect of a lake in WQT, lakes were considered a point in the stream network with specific characteristics; we then used EUTROMOD, a lake water quality model, to estimate the potential nutrient load reduction due to lake effects. EUTROMOD is an empirical regression, watershed-scale nutrient loading, and lake response model, developed by Kenneth Reckhow of Duke University (Reckhow et al., 1992). The model uses spreadsheets incorporated with several empirical equations to predict the pollutant load and lake water quality based on source discharges, landuse, and land management controls.

EUTROMOD is intended to predict lake-wide annual nutrient loadings. Therefore, short-term, local water quality and dynamic responses cannot be predicted (Hession et al., 1998). In EUTROMOD, the annual runoff, erosion, and nutrient loads can be simulated using lumped watershed modeling. Lake response can also be predicted by a set of nonlinear regression equations. The information required includes climate, watershed characteristics, and morphometry of lake (Hession et al., 1998). The model treats each landuse within the watershed as a homogeneous unit (Hession et al., 1998). Up to 12 landuse types can be simulated: 5 for agriculture, 1 for forest, 2 for urban areas, 1 for feedlots, and 3 for user-defined categories (Reckhow et al., 1992). We used the EUTROMOD Loading Function to estimate the nutrient load difference between inflow and outflow of the lake and then estimated the delivery/detention ratio of the lake.

EUTROMOD has been incorporated into several watershed-lake water quality studies: Blue Mountain Lake, New York (Martin and DeAngelo, 1998); Crystal Lake, Iowa (Iowa DNR, 2002); Melvern Lake, Kansas (Mankin et al., 1999); Lake Wauberg, Alachua County, Florida (Wu et al., 2003); and Wister Lake, Oklahoma (Hession et al., 1995). It has also been reviewed in several articles (Mankin, 2000; Hession et al., 2001; Lamon and Stow, 2004).

EUTROMOD uses the following equations and estimated the nutrient concentration for Melvern Lake in Kansas (Reckhow et al., 1992). If we use Eq. 4-16, we can estimate the general detention effect for each lake within the watershed. EUTROMOD did not have built in parameters for k factor for Melvern Lake. To simulate in-lake TP and TN concentrations in Kansas with EUTROMOD, we borrowed the k parameters from the Mid-West version of EUTROMOD. Therefore, the k factor in EUTROMOD Loading Function (Eq. 4-16) was calculated with Eq. 4-17 for TP and Eq. 4-18 for TN.

$$\log_{10}(\hat{C}) = \log_{10}\left[\frac{C_{in}}{1 + k\tau}\right] \quad \text{Eq. 4-16}$$

$$k_P = 10.77 \times \tau^{-0.61} \times z^{0.01} \times P_{in}^{0.82} \quad \text{Eq. 4-17}$$

$$k_N = 0.46 \times \tau^{-0.75} \times z^{0.22} \times N_{in}^{0.95} \quad \text{Eq. 4-18}$$

where:

$\hat{C}$= predicted in-lake nutrient concentration (mg/L)
Cin = average influent nutrient concentrations (mg/L)
k = regional lake statistics factor
τ = hydraulic detention time (yr)
z = lake mean depth (m)

4.3.3 Model Operation

To calculate the pollutant load at a specific point downstream, the modeling of nutrient fate is divided into two phases: (1) pollutant load at the edge of field and (2) pollutant decay in the stream network. The conceptual model processes are shown in Figure 4-4. In SWAT, subbasin is assumed to be a homogeneous unit in a particular climate condition, and HRU is the basic unit for different soil, landuse, and topographic properties. In this study, we used only subbasin level information for stream network simulation. In other words, fields in the same subbasin will inherit the subbasin average pollutant load reduction characteristics, so any field in any subbasin will share the same in-field load reduction potential as all other fields in that subbasin. Although each field has its own outlet at the nearest tapping point in the stream network, found using the shortest flow path, we assumed each subbasin outlet was the beginning point of channel flow to minimize calculation loads. This assumption also fit the definition of NPS pollution.

To provide a simple pollutant load indication for each subbasin, the TN and TP were estimated by adding all the relative water quality factors in the SWAT simulation. The R_D within a subbasin, defined as the ratio of pollutant load in the out flow to the in-flow load, was then calculated. For environmental uncertainties of nutrient load reduction among alternative scenario pairs, the statistics of TN and TP were analyzed at the edge of field and then later calculated through the stream network and/or lake. The annual and monthly in-field nutrient loads, load reduction, reduction index, R_U, and TR for each potential scenario were analyzed at both watershed and subbasin level. Similarly, throughout the stream network in the watershed, the annual and monthly R_D for each alternative scenario was analyzed. These delivery ratios either estimated the delivery effect within a single subbasin or the cumulative delivery effect as the nutrient load was transported to another subbasin outlet or watershed main outlet. The monthly (or seasonal) contributions of nutrient load and load reduction then could be calculated by comparing annual and monthly information. With the in-field environmental R_U and the in-stream RD, the overall TR for WQT could then be calculated using Eq. 4-4.

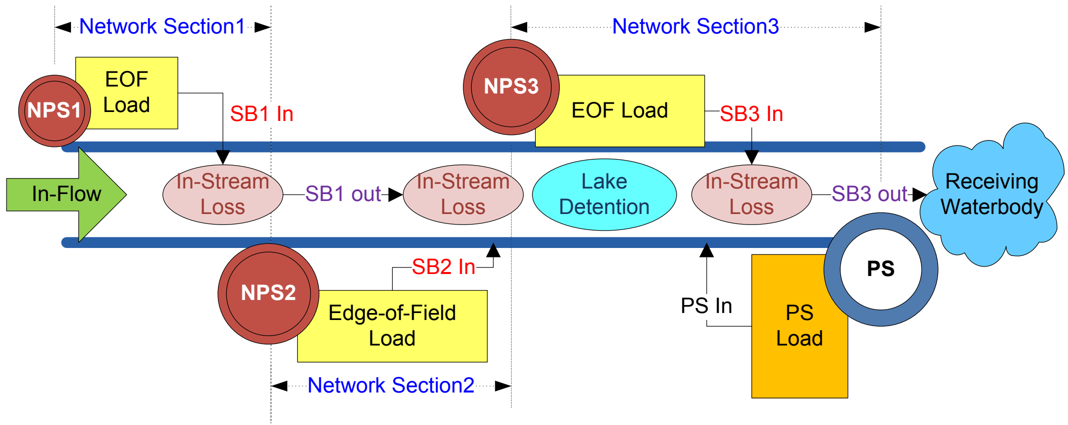


Figure 4-4 Conceptual model for estimating download stream water quality

4.4 Model Simulation

4.4.1 Watershed Description

To test the WQT delivery effect theory and equations in this study and connect results with previous WQT research (Lee and Mankin, 2007b; Lee et al., 2007a; Lee et al., 2007b), a study was established in the Lower Kansas watershed (HUC8: 10270104) (Figure 4-5) in the Kansas and Delaware River Basin (HUC6: 102701) in northeastern Kansas. The area encompasses a large proportion of the Kansas population within its 429,000 ha (1,060,000 ac) drainage basin, which also includes many and diverse PSs and NPSs. Approximately 99% of the watershed is in Atchison, Douglas, Jefferson, Johnson, Leavenworth, Osage, Shawnee, Wabaunsee, Wyandotte, and Wyandotte counties of northeastern Kansas, with approximately 0.5% in Jackson County, Missouri. Grassland and woodland cover approximately 46% of this area, and 18% is in crop land, 17% in forest, and 2% in various water classes. The elevation ranges from 424 m to 220 m, with an average of 301 m. The Lower Kansas watershed is identified by Kansas State agencies as a high priority for NPS nutrient abatement and also is a potential TN pollution WQT pilot study area (KDHE, 2004; Leatherman et al., 2005).

To apply the SWAT model in this study, geospatial referenced data must describe topography, landuse/landcover, soil types and attributes, and climate. Digital stream network information, historical stream discharge of available gauging stations, and upstream ponds and reservoirs storage data were collected and manipulated for stream network analysis. Potential land management practices, plant/crop growing information, field operations, and fertilizer applications were requested from watershed specialists and professionals of the Kansas State University Extension Service (Barnes, 2006; Boyer, 2006; KSU, 2006; Maddux, 2006), with additional information from literature reviews, USDA

NRCS field offices, and the USDA NRCS electronic field office technical guides (eFOTGs) website (NRCS-Kansas, 2006; NRCS, 2008). This information was used to develop criteria for the design of potential alternative land management scenarios and also to adjust SWAT modeling parameters and inputs. Geospatial referenced data were placed in a Universal Transverse Mercator (UTM) coordinate system (NAD 1983 UTM Zone 15N [spheroid = GRS80, NAD 1983]) before they were applied to the model.

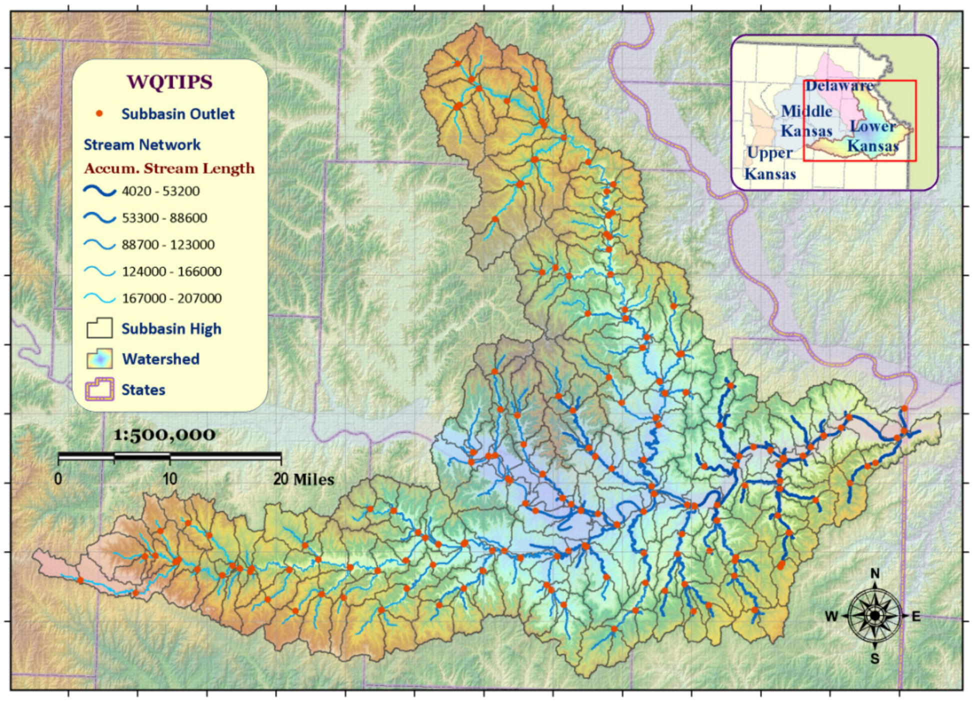


Figure 4-5 Topography and Subbasin Delineation in Lower Kansas Watershed, Kansas

4.4.2 Hydrography Data Preparation

4.4.2.1 *Stream Network*

In the SWAT model, the hydrography data is a comprehensive set of water flow and storage information that requires surface water bodies like lakes, ponds, streams, and rivers to be in geo-referenced format. In preprocessing, the SWAT model will calculate the potential surface flow direction and flow accumulation based on watershed digital elevation model (DEM) information. With the subbasin area threshold input, the river system, subbasin, and subbasin outlet can be constructed. However, this process is solely based on DEM information. Any measuring errors in DEM or a large flat area in the watershed could cause a loop or discontinued stream network. Moreover, most lake or reservoir areas in DEM are assigned an estimated water surface elevation, which does not directly correspond to either the conservation pool or flood pool elevations, and does not include the actual lake terrain under the water. This potential issue will affect model simulation of downstream water quality and pollutant delivery. Alternatively, SWAT could use a customized stream network or burn-in information that has correct network topology and hierarchies.

The National Hydrography Dataset (NHD), hosted by USGS, is based upon the content of USGS Digital Line Graph (DLG) hydrography data integrated with reach related information from the EPA Reach File Version 3 (RF3) (USGS, 2008). NHD is a good source for surface hydrology features that meet the SWAT model preprocessing requirements. However, NHD incorporated several hydrography datasets without a detailed revision and adjustment process in its feature topology and network connectivity, which caused some network hierarchy errors or redundant features in the study area. Therefore, we used the Utility Network Analyst Tool (ESRI, 2006) to fix both stream network hierarchy and topology problems. This revised network helped SWAT delineate more reasonable sub basin and river routes without trivial pieces or isolated loops. With the SWAT delineated stream network, the stream flow length, flow direction, and sequence was developed for following analyses.

4.4.2.2 *Lake and Reservoir*

As in cleaning up the faulty stream line in the NHD stream layer, the NHD water body layer also contained many reservoirs, lakes, ponds, and other un-named water bodies in the study area. It is difficult to simulate all 10761 water bodies in one SWAT project, not to mention that most of them are missing basic hydrologic properties, attributers, and correct position.

To simplify the modeling workload while also simulating stream delivery processes that include lake/reservoir effects, we were forced to neglect smaller water bodies, keeping only those with a major impact on the study watershed. By analyzing the feature attributes in the NHD water body layer, we found that only 7 of 10761 blocks are larger than 50 ha, and most are within the source subbasin, in the upstream area, and would not significantly affect the pollutant load attenuation via the stream network. Of these seven lakes, only Clinton Lake is larger than 100 ha (1 km^2). Clinton Lake was more important with more influence on stream network delivery in the study watershed. In this study, we discussed the lake detention effect for the stream delivery scenario only for Clinton Lake.

4.4.3 Scenario Design

The primary goal of this study is to understand the delivery effects within the watershed stream network. Connecting previous field-level modeling to delivery analysis is important. Therefore, the SWAT modeling scenario designs in this study followed previous research. Inspired by prior research on in-field nutrient load reduction, we developed a small set of alternative land management scenarios.

Referring to SWAT documents (Neitsch et al., 2004; Neitsch et al., 2005), four variable categories and balanced scenario design have been suggested for the alternative scenarios design: crop type (CROP), tillage system (TILL), edge-of-field BMPs (BMPS), and fertilizer application method (FERT). By changing one of these four categories at a time, a balanced alternative management scenario design can be implemented. The balanced scenario design can minimize cross effects from other static variable categories and provide a clearer comparison of the dynamic variable category levels. The details for each design level in every variable are listed in Table 4-1.

Table 4-1 Design Variables and Levels of Modeling Scenario for Stream Delivery Analysis

Variable	Attribute	Level
CROP[1]	Growing crops or rotation	BBLS, SWCH, FESC, CORN-SOYB
TILL[2]	Tillage system on the field	NT, OT, RT, MT, CT
BMPS[3]	Edge-of-field BMPs	Blank, FS; FSGZ
FERT[4]	Fertilizer application method	SB, DB

Note: **1.** BBLS: big bluestem, used to simulate native prairie grass with SWAT default Big Bluestem parameters; SWCH: switchgrass, used to simulate alternative energy source (bio-fuel) with SWAT default Alamo Switchgrass parameters; FESC: tall fescue, used to simulate a general VFS with SWAT default Tall Fescue parameters for Kansas pasture land; CORN-SOYB: two-year corn-soybean rotation. **2.** NT: no-till; OT: rotational tillage, which is a tillage system with halftime no-till (NT) and halftime minimum tillage (MT); RT: reduced tillage; MT: minimum tillage; CT: conventional tillage. **3.** Blank: without any BMP at the edge of field; FS: with VFS at the edge of field; FSGZ: with the grazing actives on VFS at the edge of field. **4.** SB: general surface fertilizer application; DB: general sub-surface fertilizer application.

4.4.4 SWAT Model Simulation

To analyze the potential nutrient load delivery effects within the watershed stream network, we first estimated the in-field load for each subbasin and stream section and then calculated the degradation of nutrient (TN and TP) loads after they left the edge of field and were transported through the stream network to the main outlet of study watershed. With the balance design criteria described in Table 4-1, we have 20 scenarios developed from one common corn-soybean crop rotation, five tillage systems, two edge-of-field BMPs options (excluding FSGZ), and two fertilizer application methods. Additional scenarios included big bluestem (using built-in SWAT modeling parameters) to represent a scenario where prairie grasses were restored, switchgrass (modified from SWAT default Alamo Switchgrass parameters) to represent a cellulosic bio-energy plant, and tall fescue as common cool season grass in Kansas, also commonly used as the base plant for vegetative filter strips (VFSs). Although these three additional grass scenarios (big bluestem, switchgrass, and tall fescue) were modeled for different purposes, all of them were classified as major grasses for later comparison.

Furthermore, to simulate the fall cattle grazing event on VFSs, two extra scenarios were simulated: with and without fall grazing on a tall fescue field. Based on the modeling results of these two scenarios, another 10 scenarios, which approximated the fall grazing event on VFS, were established.

All 35 scenarios were designed and modeled with SWAT. To stabilize model responses, all scenarios used historical climate data (NCDC, 2009) from 1968 to 2006 (39 years) for simulation, but only the modeling outputs from 1971 to 2006 (36 years) were analyzed for potential trading effects. Annual values were simulated for pollutant load and load reduction for both TN and TP at a daily time step. Each scenario had its unique schedule for planting, harvesting, cultivating, and fertilizing, given specific management assumptions. Although the study area had 286 subbasins and 5395 HRUs, only 255 subbasins and 1053 HRUs were classified as cropland area. Each simulation was calculated for all HRUs in every subbasin, but only the cropland was subjected to changing land management practices, because only cropland HRUs could produce load reduction between two alternatives. The subbasin level outputs were aggregated using the area weighted values of each HRU within each subbasin. Hence, the overall watershed level information was calculated as the average of each subbasin level output for the study watershed for later comparisons.

In this study, SWAT was used to obtain the annual nutrient load associated with 35 scenarios. Before the modeling post-analysis could be conducted, we had to ensure that SWAT could reasonably predict the pollutant load in the Lower Kansas watershed. Therefore, we modified SWAT parameters and management operations with the calibrated and validated information from previous studies. Table 4-2 lists the major modified modeling parameters for each scenario in this study. Based on research by Maski et al. (2007, 2008), the soil and management properties for modeling no-till tillage system with SWAT were adjusted. Hence, for simulating no-till, the runoff curve number of moisture condition II (CN2) was adjusted based on the hydrologic soil groups of local soil and usually promoted one group (e.g., from Group C to D); the USLE Crop cover management factor (USLE-C) decreased because no-till increased surface coverage; conversely, no-till consolidates the soil surface, so saturated soil hydraulic conductivity (K_{SAT}) values were multiplied by 2 to compensate (Maski et al., 2007, 2008). Moreover, Parajuli (2007) calibrated and validated flow and sediment with SWAT near Clinton Lake in study area. Based on this study, the SWAT soil evaporation compensation coefficient (ESCO) has been fine-tuned as 0.50 for all scenarios (Parajuli, 2007).

Furthermore, the SWAT default uses a single roughness coefficient (Manning's n) for overland flow on the same type of surface coverage plant and a single Manning's n for the channel flow along the whole stream network. These defaults are not reasonable for modeling a huge watershed. Therefore, surface Manning's n for overland flow was increased because no-till operations create an impermeable surface (Neitsch et al., 2005). The channel flow Manning's n was changed to 0.050 for the tributary and 0.025 for the main channel based on channel conditions in study watershed (Wanielista et al., 1997; Neitsch et al., 2005). For simulating the rotational tillage system, adjusted no-till values and the original SWAT defaults of the other rotated tillage were averaged to get the CN2, USLE-C, and K_{SAT} properties.

Furthermore, different tillage systems have specific cultivating operation dates as well as different types, amounts, application dates, and application methods for fertilizers. These parameters were adjusted based on watershed specialist experience as well as reports from NRCS field office (Whitney et al., 1991; Fjell et al., 1997; Whitney et al., 1999; Leikam et al., 2003; Fjell et al., 2007). The SWAT default VFS trapping efficiency was modified based on USDA NRCS technical notes and several literature reviews (NRCS-Kansas, 2003; Neitsch et al., 2005; Mankin et al., 2006). For simulating fall grazing event on VFS, the SWAT modeling parameters were assigned according to ASABE standard (ASAE Standard, 2005) and field experience (Moore et al., 2001; Honeyman et al., 2006). The detailed methods for simulating with-grazing status can be found in Appendix A.2.3.

Table 4-2 List and Major Adjusted SWAT Parameters for Modeling Scenarios

Scen#	Case#	Crop Rotation	Till[2]	Abbrev.[3]	Plant	Harvest	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
S1		CORN-SOYB (2-yr)	CT	CS5SB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.27	67	77	84	88	0.09	---
S2				CS5SBFS									
S3				CS5DB									
S4				CS5DBFS									
S5	SBase		MT	CS4SB			0.27	67	77	84	88	0.12	---
S6	SCase3			CS4SBFS									
S7	DBase			CS4DB									
S8	DCase3			CS4DBFS									
S9			RT	CS3SB			0.27	67	77	84	88	0.14	---
S10				CS3SBFS									
S11				CS3DB									
S12				CS3DBFS									
S13	SCase2		OT	CS2SB			0.2	72	80	86	89	0.18	1.5x
S14				CS2SBFS									
S15	DCase2			CS2DB									
S16				CS2DBFS									
S17	SCase1		NT	CS1SB			0.12	77	84	88	90	0.24	2x
S18				CS1SBFS									
S19	DCase1			CS1DB									
S20				CS1DBFS									
S21			CT	CS5SBFSGZ			0.27	67	77	84	88	0.09	---
S22				CS5DBFSGZ									
S23	SCase4		MT	CS4SBFSGZ			0.27	67	77	84	88	0.12	---
S24	DCase4			CS4DBFSGZ									
S25			RT	CS3SBFSGZ			0.27	67	77	84	88	0.14	---

Scen#	Case#	Crop Rotation	Till[2]	Abbrev.[3]	Plant	Harvest	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
S26				CS3DBFSGZ									
S27			OT	CS2SBFSGZ			0.2	72	80	86	89	0.18	1.5x
S28				CS2DBFSGZ									
S29			NT	CS1SBFSGZ			0.12	77	84	88	90	0.24	2x
S30				CS1DBFSGZ									
S31	BBLS	Big bluestem	n/a	BBLS	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
S32	SWCH	Switchgrass	n/a	SWCH	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
S33			n/a	FESC									
S34	FESC	Fescue	FS	FSGZ0	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
S35			GZ	FSGZ1									

Note: 1. NT: no-till; OT: rotational tillage (50% No-till). Apply no-till on corn and minimum tillage on soybean; RT: reduced tillage; MT: minimum tillage; CT: conventional tillage. **2.** C: corn; S: soybean; CS: two-year corn-soybean rotation; BBLS: big bluestem; SWCH: switchgrass; FESC: tall fescue; FSGZ0: without grazing event; FSGZ1: with grazing event; SB: surface fertilizer application (surface broadcast); DB: sub-surface fertilizer application (deep band application); FS: with VFS at the edge of field; FSGZ: with the grazing on VFS at the edge of field. **3.** CN2: Curve Number for moisture condition II or antecedent moisture condition II (AMC II); HSG: Hydrologic Soil Group.

4.4.5 EUTROMOD Model Simulation

4.4.5.1 *Lake Delivery/Detention Ratio Equation*

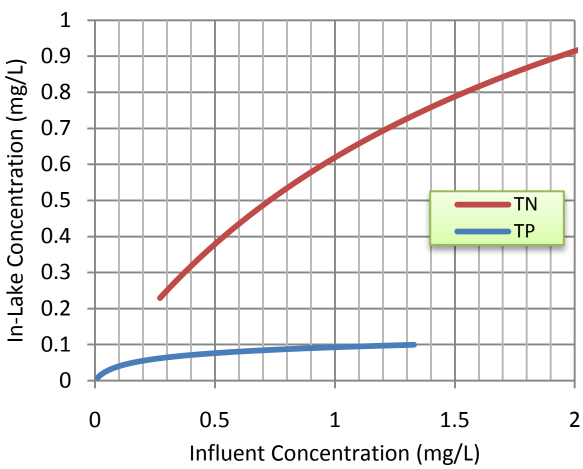
To estimate the TN and TP load delivery/detention ratio in Clinton Lake, Kansas, we used Reckhow's EUTROMOD Loading Functions (Eq. 4-16). We first estimated the potential in-lake nutrient concentration and then divided in-lake concentration by influent concentration to estimate the delivery/detention ratio. As described previously, to simulate in-lake TP and TN concentrations in Kansas with EUTROMOD, we used the parameters from the Mid-West version of EUTROMOD. Therefore, the EUTROMOD Loading Function (Eq. 4-16) can be calculated using Eq. 4-17 for TP and Eq. 4-18 for TN. Moreover, some constraints are applied in EUTROMOD to reflect the data set used to fit the models. In some instances (e.g., nutrient retention < 0), additional constraints were imposed to create homogeneity in the data set or to eliminate suspected errors (Reckhow, 1992; Reckhow et al., 1992). Following these constraints and EUTROMOD Loading Function in Eq. 4-17, the relationship between influent concentration and the in-lake nutrient concentration can be illustrated (see Figure 4-6 (a)).

Assume L_{in-N} is the TN load and L_{in-P} is the TP load for the annual Clinton Lake influent nutrient loads. Assuming the annual influent volume of Clinton Lake is V_{in} and outflow volume is V_{out}, the nutrient load of inflow (L_{in}) and outflow (L_{out}) can be explained as the inflow or in-lake nutrient concentration multiplied by its flow volume. For calculating lake delivery/detention ratio, Eq. 4-19 described the needed information. If we assume the inflow and outflow volume is the same, R_D can be rewritten as an equation using only the nutrient concentration parameters. Using the EUTROMOD Loading Function in Eq. 4-16, Eq. 4-17, and Eq. 4-18 to replace the parameters in Eq. 4-19, the new lake delivery/detention ratio can be described as Eq. 4-20 for TN and Eq. 4-21 for TP load. Therefore, generally, the Kansas lake delivery/detention ratio for TN and TP load can be roughly estimated by Eq. 4-20 and Eq. 4-21 based on the EUTROMOD model. The relationship between lake influent concentrations versus general lake delivery/detention ratio is demonstrated in Figure 4-6 (b).

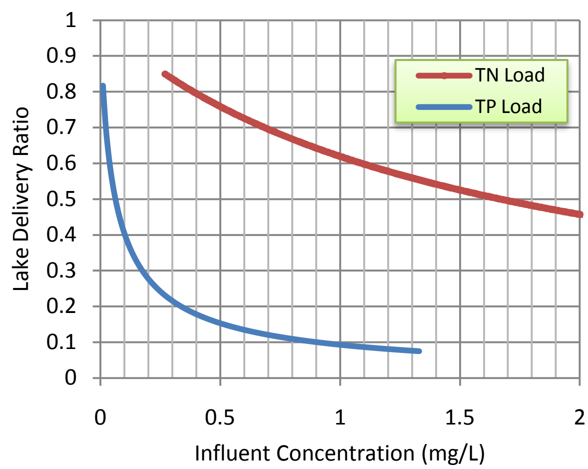
$$R_{D_L} = \frac{L_{out}}{L_{in}} = \frac{V_{out} \times \hat{C}}{V_{in} \times C_{in}} = \frac{\hat{C}}{C_{in}} \qquad \text{Eq. 4-19}$$

$$R_{D_L} = \frac{\hat{C}}{C_{in}} = \frac{\frac{C_{in}}{1+k\tau}}{C_{in}} = \frac{1}{1+k\tau} = \frac{1}{1+\tau\left(0.46 \times \tau^{-0.75} \times z^{0.22} \times N_{in}^{0.95}\right)} \qquad \text{Eq. 4-20}$$

$$R_{D_L} = \frac{\hat{C}}{C_{in}} = \frac{\frac{C_{in}}{1+k\tau}}{C_{in}} = \frac{1}{1+k\tau} = \frac{1}{1+\tau\left(10.77 \times \tau^{-0.61} \times z^{0.01} \times P_{in}^{0.82}\right)} \qquad \text{Eq. 4-21}$$



(a) Influent versus In-lake Nutrient Concentration



(b) Influent Concentration versus Lake Detention Ratio

Figure 4-6 Relationship between Influent, Nutrient Concentration and Lake Detention Ratio

4.4.5.2 *Estimate Delivery/Detention Ratio for Clinton Lake*

Clinton Lake is approximately 6.4 km (4 miles) southwest of Lawrence, Kansas. The dam is at river km 35.5 (river mile 22.2) of the Wakarusa River, a tributary of the Kansas River (USACE, 2007). Clinton Lake was impounded in 1977 and reached full pool in 1980 (KWO, 2008). The main threats to Clinton Lake's watershed are sedimentation, nutrients, and bacterial contamination. The lake is listed on the state's 303(d) list for water quality impairment due to eutrophication and fecal contamination. Therefore, TMDL's have been developed for the watershed to reduce nutrients, total suspended solids (TSS), and fecal bacteria, and to increase dissolved oxygen (USACE, 2007). Specific TMDL targets are TP < 0.1 mg/L, developed by the Upper Wakarusa Watershed Restoration and Protection Strategy (WRAPS) to protect Clinton Lake and ultimately remove it from the 303(d) list of impaired waters (USACE, 2007). EPA also has proposed nutrient criteria of 0.36 mg/L for TN and 0.02 mg/L for TP (USEPA, 2000a).

From historical data analyses, the high TN and TP median concentrations as well as chlorophyll values indicated Clinton Lake is nutrient-eutrophic (USACE, 2007). Statistically, the surface water sample measured at several lake sites from 1996 through 2006 at Clinton Lake have a median TN concentration of 0.62 to 0.96 mg/L and TP concentration of 0.06 to 0.13mg/L (USACE, 2007). However, all sites exceed the proposed EPA nutrient criteria and also exceed WRAPS and TMDL's targets (USACE, 2007).

To include lake effects in R_D and TR calculations as well as provide a scenario for evaluating the WQT program, we chose a TP influent concentration of 0.1 mg/L to represent the current median value/TMDL requirement and 0.02 mg/L to represent the current EPA proposed value (USEPA, 2000b; USACE, 2007). Similarly, we chose a TN influent concentration of 0.8 mg/L for the current median value and 0.36 mg/L for EPA proposed value (USEPA. 2000b; USACE, 2007). Using these criteria and Figure 4-6(b), the potential lake R_D of TP would be 0.403 for TMDL requirement and 0.716 for EPA proposed; lake R_D of TN would be 0.669 for current median value and 0.811 for EPA recommendation.

4.4.6 First-Order (Exponential) Kinetics Equation

4.4.6.1 *The Equation*

When the nutrient loads move along stream network, the decay processes can be simply described as a one-dimension first order or exponential kinetics equation. We can use this method to determine the potential R_D from SWAT modeling results. A general first-order kinetics equation can be expressed as Eq. 4-22. In Eq. 4-22, C_{OUT} is the pollutant load concentration at the outlet while C_{IN} is the inflow pollutant load concentration; k_T is the decay coefficients at water temperature T (°C), and t (day) is the overall water traveling time from the remotest point of subbasin to downstream watershed outlet or specific points. The decay coefficient k_T might be affected by the water temperature (Eq. 4-23), and the traveling time t might be affected by the watershed topography and its characteristics. The water temperature can be estimated using the average daily air temperature (see Eq. 4-24), which is used by SWAT (Neitsch et al., 2005).

$$C_{out} = C_{in} \cdot e^{-k_T t} \qquad \text{Eq. 4-22}$$

$$k_T = k_{20} \cdot \theta^{T-20} \qquad \text{Eq. 4-23}$$

$$T_w = 5.0 + 0.75 \times \bar{T}_{av} \qquad \text{Eq. 4-24}$$

4.4.6.2 *Time of Concentration and Travel Time*

SWAT assumes the main channels or reaches have a trapezoidal shape with a 2:1 channel side slope (z_{ch}) (Neitsch et al., 2005). Based on this assumption and Manning's equation for a uniform flow in a channel, the variable storage routing method developed by Williams (1969) and used in SWAT (Neitsch et al., 2005) can estimate the travel time (TT) of water flowing through a specific channel section with Eq. 4-25. Eq. 4-25 describes the TT equation based on the storage volume (Q) and discharge rate (q) of that stream section. Following Eq. 4-21, the TT of water flow from one subbasin outlet through the stream network to another one or even the main watershed outlet can be estimated.

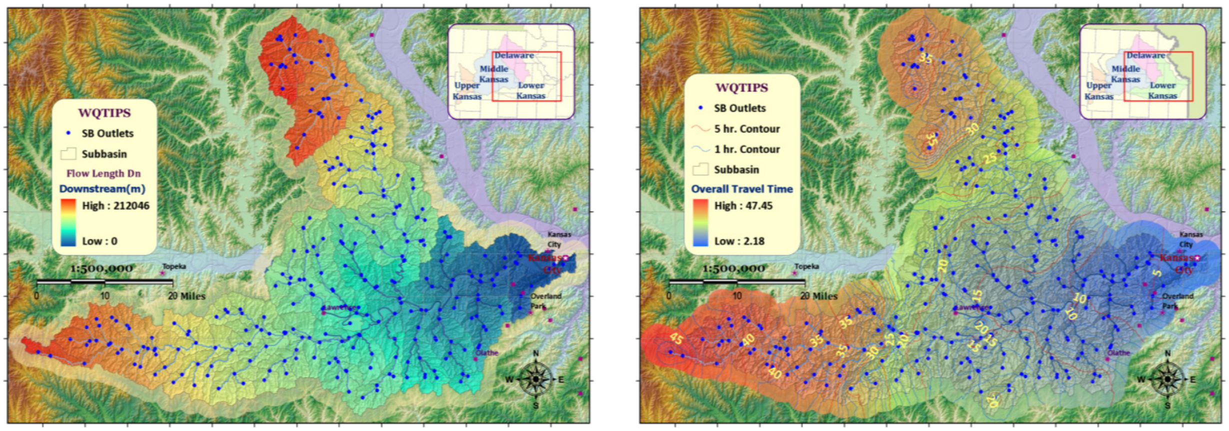
$$TT = \frac{Q}{q} = \frac{nL}{R^{\frac{2}{3}} \times S^{\frac{1}{2}}} = \frac{nL\left(W + \left(2\sqrt{5} - 4\right)D\right)^{\frac{2}{3}}}{\left((W - 2D)D\right)^{\frac{2}{3}} \times S^{\frac{1}{2}}} \qquad \text{Eq. 4-25}$$

SWAT simulates the time of concentration for storm water runoff within a subbasin based on Manning's equation. SWAT uses the assumptions that an average flow rate of the rain drop from the remotest point to outlet of subbasin is 6.35 mm/hr (2.5 in./hr) and a trapezoidal channel with 2:1 channel side slope and 10:1 flood plain bottom width-depth ratio for the calculations (Neitsch et al., 2005). Therefore, SWAT uses Eq. 4-26 to describe the time of concentration for overland flow and Eq. 4-27 for the channel flow (Neitsch et al., 2005). Based on these two equations, the time of concentration for each individual subbasin can be calculated.

$$t_{ov} = \frac{L^{0.6} \times n^{0.6}}{18 \times S^{0.3}} \qquad \text{Eq. 4-26}$$

$$t_{ch} = \frac{0.62 \times L \times n^{0.75}}{A^{0.125} \times S^{0.375}} \qquad \text{Eq. 4-27}$$

Figure 4-7 (a) displays the stream length from each subbasin to watershed outlet. Incorporating Eq. 4-25, Eq. 4-26, and Eq. 4-27, the overall TT for the water flow from the most remote point in each subbasin to the watershed main outlet is illustrated in Figure 4-7 (b). The limitations of GIS software and watershed characteristics mean that only the points along the stream network in Figure 4-7 (b) are meaningful. In Figure 4-7, the block with more reddish color represents a longer TT. Therefore, the longest overall TT in study watershed is approximately 47.45 hours, almost 2 days. The details of TT calculation are discussed in Appendix G.3.



(a) Stream Length **(b) Overall Traveling Time**

Figure 4-7 Stream Length and Overall Traveling Time from Each Subbasin to Watershed Outlet

4.4.7 Cluster Analysis

Cluster analysis is a statistical assignment for classifying a set of observations into several subsets (called clusters) so that observations in the same cluster are similar in some senses. With this method, we can simply group subbasins with similar nutrient load responses into a group and assign a single TR to them. It should minimize the difference among subbasins of the same cluster but maximum the differences between groups (SAS Institute Inc., 2004), thus splitting whole watershed into several sub-regional trading zones. Within the same zone, the TR is a constant.

Several applications can provide the cluster analysis functions for research. ArcGIS Desktop Spatial Statistics Extension has several built in cluster analysis tools, such as Anselin Local Moran's I or Getis-Ord Gi* functions (ESRI, 2009). Spatial Autocorrelation (Morans I) measures the spatial autocorrelation based on feature locations and attribute values. High/Low Clustering (Getis-Ord General G) measures the degree of clustering for either high or low values (ESRI, 2009). However, ArcGIS Desktop lacks control of cluster thresholds and clustering information, thus SAS Cluster analysis function is preferable.

SAS CLUSTER procedure hierarchically clusters the observations in the dataset using either the coordinates or distances method (SAS Institute Inc., 2004). The coordinates method uses the agglomerative hierarchical clustering procedure. Each observation begins as a cluster by itself. The two closest clusters are then merged to form a new cluster that replaces the two old clusters. Merging the closest clusters is repeated until only one cluster is left (SAS Institute Inc., 2004). The distance clustering method used the Ward's Minimum-Variance Method (error sum of squares) (Ward, 1963) in the SAS procedure. In Ward's minimum-variance method, the distance between two clusters is the ANOVA sum of squares between the two clusters added up over all the variables (see Eq. 4-28; SAS Institute Inc., 2004). At its cluster analyzing iteration, the within-cluster sum of squares is minimized over all partitions obtainable by merging two clusters from the previous step (SAS Institute Inc., 2004). Ward's method of cluster analysis allows the results to be more easily interpreted using the proportions of variance (squared semi-partial correlations), which are the sums of squares divided by the total sum of squares. Ward's method tends to join clusters with a small number of observations and is strongly biased toward producing clusters with roughly the same number of observations (SAS Institute Inc., 2004). For the cluster analysis in this study, the Ward's distance method was used to estimate the potential trading zones.

$$D_{KL} = B_{KL} = \frac{\|\bar{X}_K - \bar{X}_L\|^2}{\frac{1}{N_K} + \frac{1}{N_L}} \qquad \text{Eq. 4-28}$$

Where:

C_K: K[th] cluster, subset of {1, 2, ... , n }
N_K: number of observations in C_K
$\bar{X}_K$: mean vector for cluster C_K
X_i: i[th] observation (row vector if coordinate data)
W_K: $\sum_{i \in C_K} \|X_i - \bar{X}_K\|^2$
D_{KL}: any distance or dissimilarity measure between clusters C_K and C_L
B_{KL}: $W_M - W_K - W_L$, if $C_M = C_K \cup C_L$

4.5 Results and Discussion

4.5.1 Delivery Ratio for Individual Subbasin

To determine in-stream nutrient load delivery effects, SWAT first estimated the amount of potential TN and TP load yields from 1971 to 2006 for all 286 subbasins and 5395 HRUs. SWAT also calculated and recorded in an RCH table the nutrient loads in each stream section for individual subbasins. With SWAT RCH tables, the nutrient load reduction for each individual stream section can be calculated. In Eq. 4-10, the subbasin inflow nutrient load equals the outflow nutrient load at the previous subbasin outlet for the intermediate subbasin. In contrast, the inflow load for a source subbasin is the load in the overland flow itself. Following Eq. 4-10, the R_D for individual subbasin is then calculated.

To coordinate with the testing scenarios from the field survey of "choice experiments of producers (NPS)" in the study watershed (Peterson et al., 2007; Smith et al., 2007), which compared the farmers' willingness to participate in WQT programs using different land management practices, 13 specific alternative land management scenarios were arranged and simulated. These 13 scenarios include two sets of economic model cases and 3 major grasses, all listed in Table 4-2. Figure 4-8 portrays the watershed level R_D for selected scenarios. In Figure 4-8 (a), the R_Ds of TN load in all scenarios ranged from 0.991 to 0.994. Cases #3 (SCase3 and DCase3: 2-yr corn-soybean, minimum till, with VFS) and #4 (SCase4 and DCase4: 2-yr corn-soybean, minimum till, with VFS and fall grazing) as well as BBLS (native grass, big bluestem) and SWCH (native grass, switchgrass) tend to have a lower R_D; however, the difference between maximum and minimum is less than 0.002. Similarly, the TP load R_Ds in Figure 4-8 (b) ranged from 0.9980 to 0.9985. The TP R_D for every scenario is almost identical except for BBLS and SWCH. Again, the R_D differences among scenarios are tiny. Figure 4-9 illustrates the average R_D for each scenario's group. In Figure 4-9, the TP load R_D (PDR) is higher than the TN load R_D (NDR). However, the R_D of each group in each category is almost identical. The potential reason for these phenomena might be the time of concentration and travel time of water is relative small within individual subbasins.

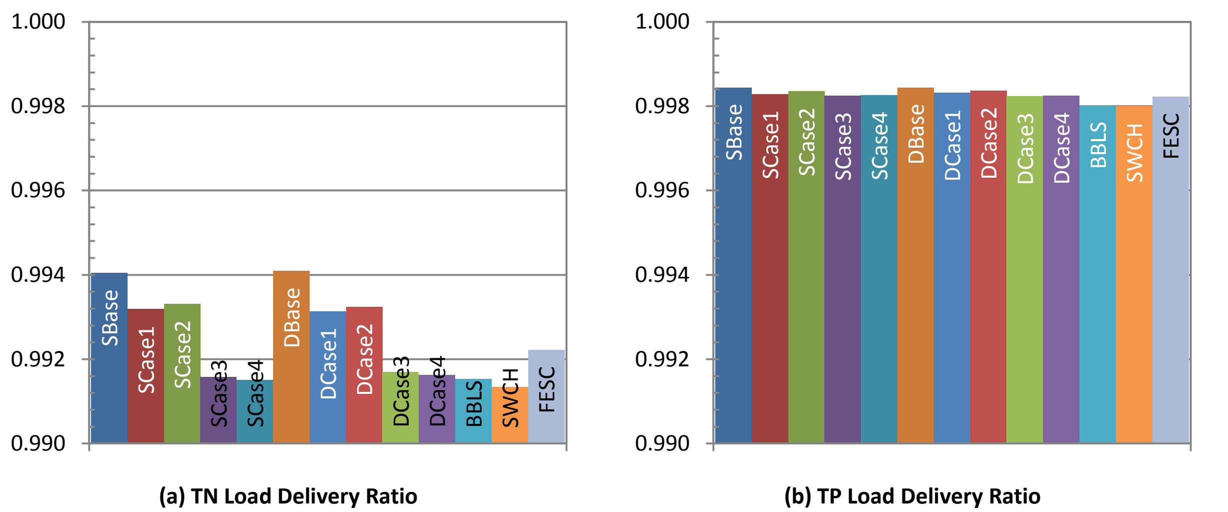


Figure 4-8 Watershed Level Delivery Ratios for Selected Scenarios

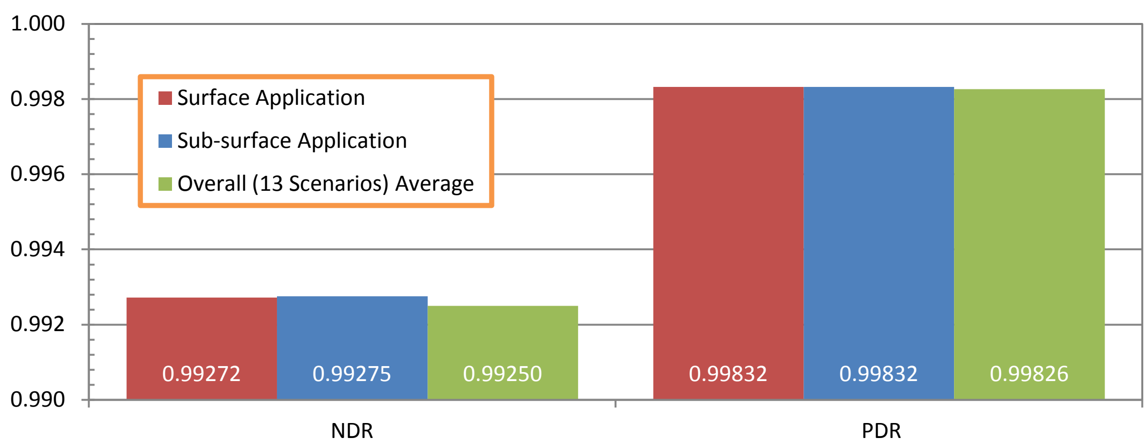
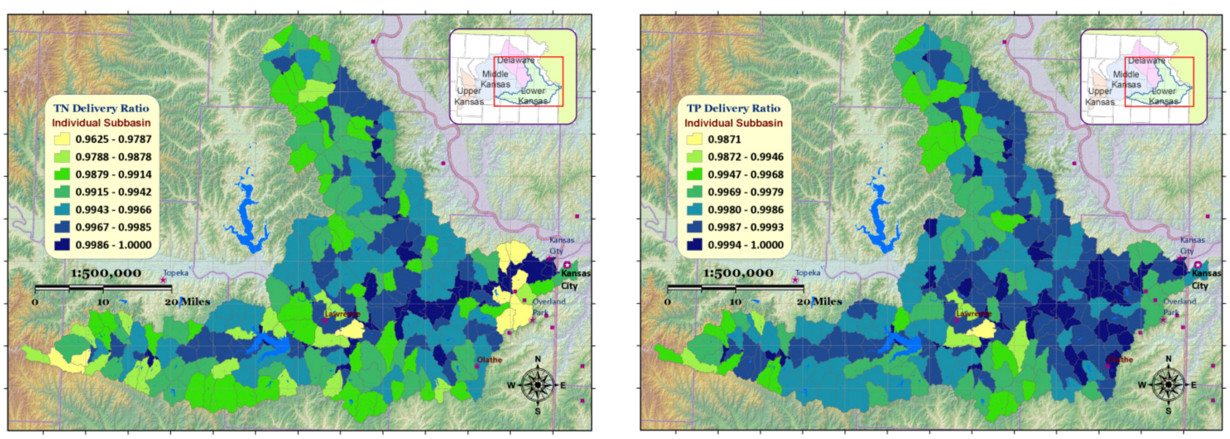


Figure 4-9 Average of Individual Subbasin Delivery Ratios for Specific Scenario Groups

We used ANOVA to determine the differences of nutrient load R_Ds among modeling scenarios and also applied the pairwise comparison and Least Significant Distance (LSD) to test the R_D differences between any two scenarios. The p-value of main effect in each scenario level is 0.0556 for the TN load R_D and 0.7935 for the TP load R_D. Both p-values are less than 0.05, which confirms the test null hypothesis: the difference of R_D among the modeling scenarios is not statistically significant. Furthermore, in Tukey's Studentized Range (HSD) and Fisher's Least Significant Distance (LSD) test for the R_D of TN and TP loads, both grouped all scenarios into single group. In other words, R_D of every modeling scenario did not differ significantly. To simplify the calculation in estimating nutrient load TR, different in-field alternative management scenarios can share a single R_D for the same river section. In contrast, every river section still has its specific R_D, which might be significantly different from others. The p-value of main effect at the subbasin level is less than 0.0001 for both TN and TP load R_D, so the R_D for each subbasin differs significantly. The HSD and LSD tests for the R_D of TN and TP loads also show significant differences among subbasins. Therefore, the mean of R_D in all the potential alternative scenarios was calculated and applied for each river section.

The potential TN load R_D is illustrated in Figure 4-10 (a) and the TP load R_D in Figure 4-10 (b) for each subbasin in the study watershed. The TN load R_D in Figure 4-10 (a) ranges from 0.9625 to 1.0 for each subbasin, and the TP load R_D in Figure 4-10 (b) ranges from 0.9871 to 1.0. The patterns for both R_D of TN and TP loads are similar but not identical, showing the TN and TP load delivery effects are different, which supports the ANOVA analysis results. For WQT, a set of R_D could be applied for alternative scenarios but might not suitable for estimating delivery effects of different nutrient loads.



(a) TN Load R_D **(b) TP Load R_D**

Figure 4-10 Potential Nutrient Load R_D of Individual Subbasin

4.5.2 Cumulative Delivery Ratio

4.5.2.1 *Estimated with SWAT Simulation*

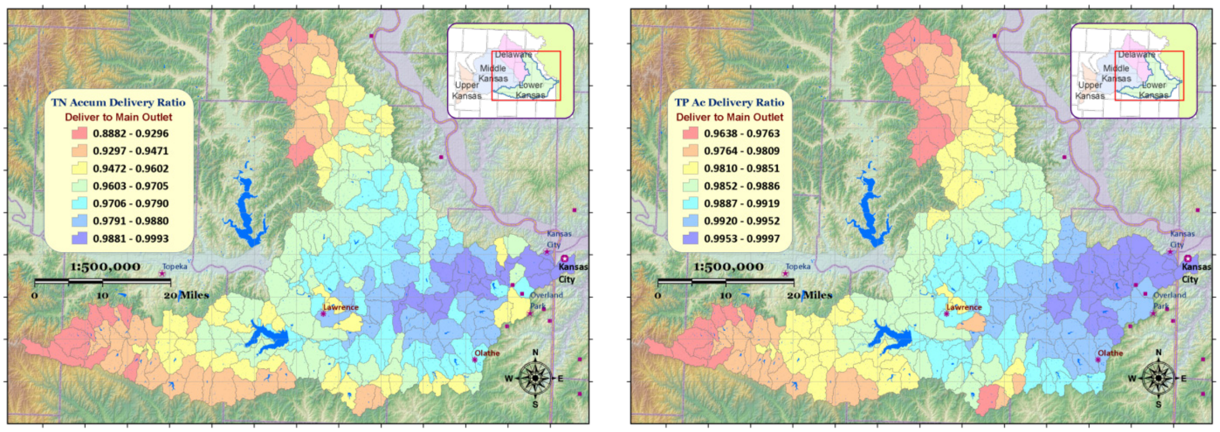
If only the stream delivery effects are considered, not the lake or reservoir effect along the waterway in the watershed, the cumulative R_D (R_D^*) in Eq. 4-11 can be reduced to Eq. 4-29, where the R_D^* is the product of all individual subbasin R_Ds for the river section along the stream network from source to sink, thus providing an estimate of the downstream delivery for any pair of subbasins. Table 4-3 lists a partial matrix of the R_D^* of TN load. In Table 4-3, subbasin #186 (SB186) is the outlet subbasin of Clinton Lake, the major lake on the west side of watershed; subbasin #73 (SB73) is the watershed main outlet subbasin on the east side of watershed. From SB186 to SB73, we have 24 intermediate subbasins along the stream network; the R_D^* for all potential routes were also tabulated. In Table 4-3, the first row lists the potential source subbasins in the sequence from upstream to downstream. Similarly, the first column of Table 4-3 lists the potential sink subbasins in the same sequence. The last column and bottom row indicate position in the flow sequence. To find a R_D^* from one subbasin to another in Table 4-3, the cell at the column and row intersection represents the R_D^* for load transported from column subbasin to row subbasin.

$$R_D^* = \prod_{i=1}^{n} R_{D_i} = \prod_{j=1}^{p} R_{D_{S_j}} \qquad \text{Eq. 4-29}$$

Table 4-3 Partial Cumulative TN Load R_D Matrix from SB186 to SB73

SB	SB186	SB188	SB202	SB197	SB191	SB181	SB165	SB137	SB148	SB121	SB99	SB114	SB95	SB86	SB79	SB92	SB88	SB73	Seq.
SB186	0.9979																		0
SB188	0.9971	0.9992																	1
SB202	0.9961	0.9982	0.9990																2
SB197	0.9929	0.9950	0.9958	0.9968															3
SB191	0.9919	0.9940	0.9948	0.9958	0.9990														4
SB181	0.9909	0.9930	0.9938	0.9948	0.9980	0.9990													5
SB165	0.9886	0.9907	0.9915	0.9925	0.9957	0.9967	0.9978												7
SB137	0.9856	0.9877	0.9885	0.9895	0.9926	0.9936	0.9948	0.9991											9
SB148	0.9843	0.9863	0.9871	0.9881	0.9913	0.9923	0.9934	0.9977	0.9998										11
SB121	0.9817	0.9838	0.9846	0.9856	0.9887	0.9897	0.9908	0.9951	0.9972	0.9986									13
SB99	0.9805	0.9826	0.9834	0.9844	0.9875	0.9885	0.9896	0.9939	0.9960	0.9974	0.9991								15
SB114	0.9801	0.9822	0.9829	0.9839	0.9871	0.9881	0.9892	0.9935	0.9955	0.9970	0.9986	1.0000							17
SB95	0.9793	0.9814	0.9822	0.9832	0.9863	0.9873	0.9884	0.9927	0.9947	0.9962	0.9978	0.9992	0.9997						19
SB86	0.9784	0.9805	0.9812	0.9822	0.9854	0.9864	0.9875	0.9918	0.9938	0.9952	0.9969	0.9982	0.9988	0.9995					21
SB79	0.9781	0.9801	0.9809	0.9819	0.9850	0.9860	0.9871	0.9914	0.9935	0.9949	0.9966	0.9979	0.9984	0.9992	0.9997				22
SB92	0.9766	0.9787	0.9794	0.9804	0.9836	0.9845	0.9857	0.9900	0.9920	0.9934	0.9951	0.9964	0.9969	0.9977	0.9982	0.9985			23
SB88	0.9763	0.9784	0.9792	0.9802	0.9833	0.9843	0.9854	0.9897	0.9917	0.9932	0.9948	0.9961	0.9967	0.9974	0.9979	0.9982	0.9997		24
SB73	0.9757	0.9777	0.9785	0.9795	0.9826	0.9836	0.9847	0.9890	0.9910	0.9925	0.9941	0.9954	0.9960	0.9967	0.9972	0.9976	0.9991	0.9993	25
Seq.	0	1	2	3	4	5	7	9	11	13	15	17	19	21	22	23	24	25	

Figure 4-10 illustrates the potential individual subbasin R_D of nutrient load. Based on stream network hierarchies in the study watershed and on Eq. 4-29, the R_D^*s for both nutrient transports from an arbitrary subbasin to watershed main outlet were calculated and are shown in Figure 4-11. The individual subbasin TN load R_D in Figure 4-10 (a) ranges from 0.9625 to 1.0 and the TP load R_D in Figure 4-10 (b) ranges from 0.9871 to 1.0. The cumulative R_D of the TN load in Figure 4-11 (a) ranged from 0.8882 to 0.9993, while the cumulative R_D of the TP load in Figure 4-11 (b) ranged from 0.9638 to 0.9997. Moreover, the distribution of R_D in Figure 4-10 shows some minor clusters in the watershed. In contrast, the R_D^* in Figure 4-11 has an obvious cluster phenomenon within the watershed. Therefore, in WQT, not only the distance or traveling time from seller to buyer will affect the delivery effects (R_D^*) but the characteristics of each subbasin is also important.



(a) TN Load Cumulative R_D **(b) TP Load Cumulative R_D**

Figure 4-11 Potential Nutrient Load Cumulative R_D for Each Subbasin to Watershed Outlet

4.5.2.2 *Estimated with First-Order Kinetics Equation*

Curley (2003) used a first-order kinetics equation to describe the nutrient load decay in transportation. The de-nitrification and volatilization processes in the water cause the decay of nitrogen. Laboratory experiments suggest that most nitrates disappear from the river reaches because of bacterial de-nitrification and nitrate reduction in stream sediments. Because most nitrogen in the stream is in the form of nitrate (NO_3^-), the kinetics of nitrate decay may represent the kinetics of the decay of TN in the stream. Therefore, if the transformation of nitrogen is not a concern in this study, the de-nitrification rate may capture the most of the nitrogen decay (Curley, 2003). However, selecting a reasonable decay coefficient for TN is tedious. However, Metcalf & Eddy, Inc. (1991) has suggested a typical k_T coefficient, ranging from 0.04/day to 0.08/day, of the de-nitrification process for designing engineering structures. Moreover, the USEPA identified the de-nitrification rate of 0.1/day in Chapter 5, p.262 of its "Rates, constants, and kinetics formulations in surface water quality modeling" standard (USEPA, 1985), and

Smith et al. (1997) quantified the in-stream decay coefficients for the decay of TN with the SPARROW model with a range of 0.035/day to 0.29/day depending on stream flow rate.

Therefore, we chose a de-nitrification rate of 0.08/day to estimate the decay coefficient at 20 °C of TN in the stream of study area while the θ equals 1.045. Following Eq. 4-22, the relationship between travel time and R_D (C_{OUT}/C_{IN}) for different temperatures is illustrated in Figure 4-12.

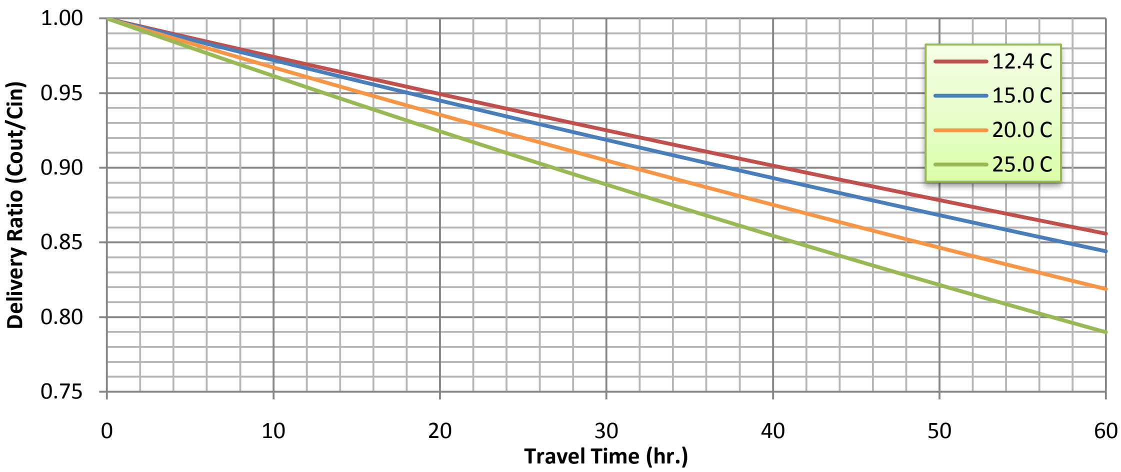


Figure 4-12 First Order Kinetics Delivery Ratio versus Travel Time

Using the calculated storm water TT to the main outlet of the watershed in Figure 4-7 (b) and the potential R_D of individual subbasins from the first-order kinetics equation versus travel time graph in Figure 4-12, the R_D^* for each subbasin to the watershed outlet can be estimated (see Figure 4-13). The R_D^* ranged from 0.88 to 0.99 at the annual mean temperature of the watershed (12.4°C).

The R_D^* estimated with this first order kinetics method is similar to the one developed using the SWAT analysis method as shown in Figure 4-11. The differences in R_D^* between SWAT and first order kinetics methods are shown in Figure 4-14, where the percentage on the map represents the results of solving this equation: $\left(R_{D_{SWAT}} - R_{D_{1st\ Order}}\right)/\left(R_{D_{1st\ Order}}\right)$. The differences ranged from -3% to 5%, suggesting that both methods provide similar results. What is most interesting in Figure 4-14 is the difference between the methods in the upstream of Clinton Lake, where R_D^* with SWAT gives a higher value than the first order kinetics, while the SWAT method shows a slightly lower trend around the main outlet area of the watershed. These phenomena might be due to calculations of TT. Clinton Lake has a flat surface slope in its subbasin parameters, so the upstream area of Clinton Lake had a longer TT to the watershed outlet. Thus, the first order kinetics method provided R_D^* estimation similar to the SWAT model analysis in parts of watershed other than upstream of major lakes or reservoirs. This suggests a simple and easy way to roughly estimate the delivery effects of TN load transports in the watershed.

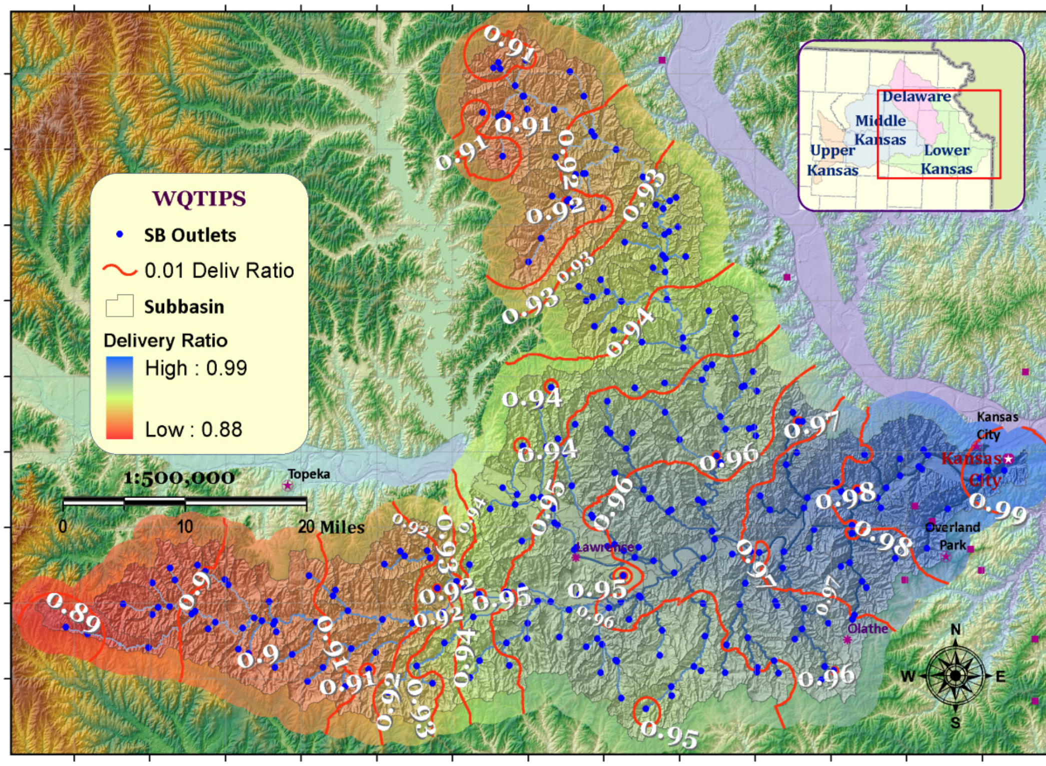


Figure 4-13 Cumulative TN Load Delivery Ratio with First Order Kinetics Method

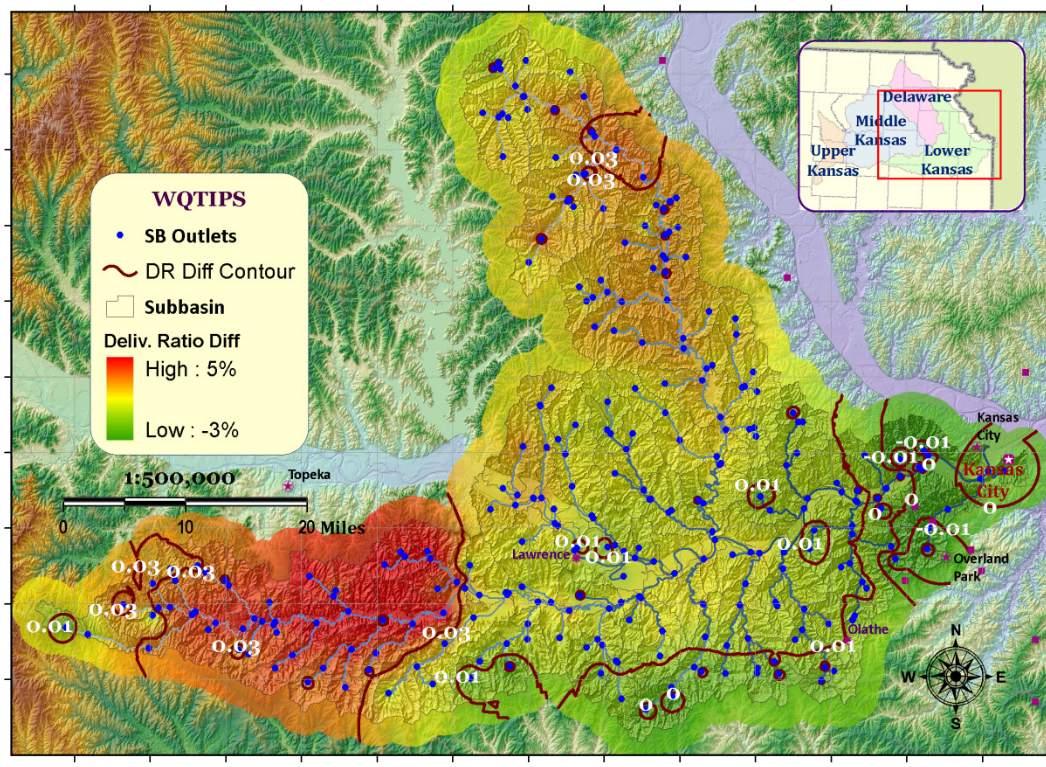


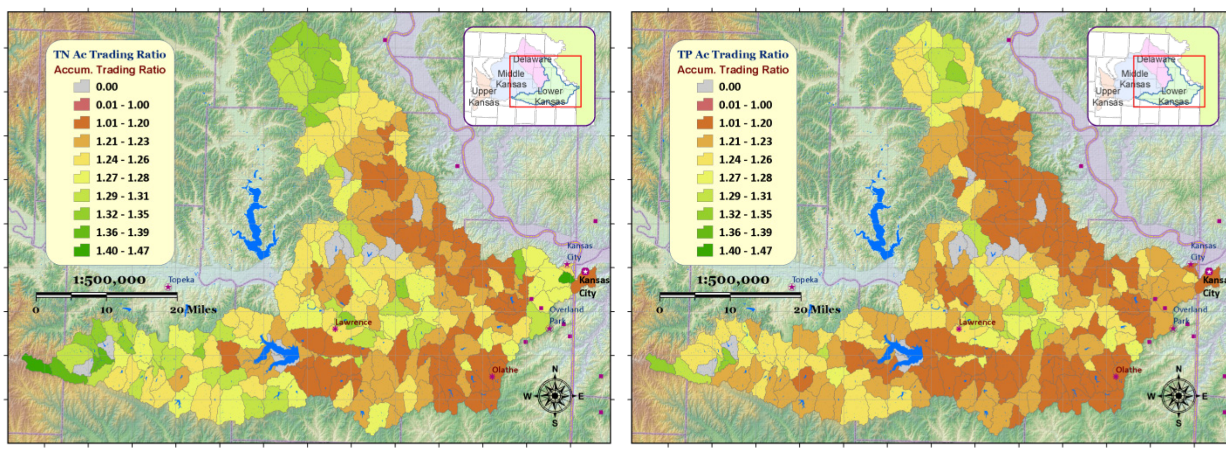
Figure 4-14 TN Load Delivery Ratio Difference between SWAT and First Order Kinetics Methods

4.5.3 Overall Trading Ratio

To estimate the overall TR for the watershed, the in-field R_U for each alternative scenario pair and the R_D for each individual subbasin were integrated into the series matrices for both nutrient load reductions. Eq. 4-4 describes the TR in this study as a function of R_U and R_D. If we include the lake/reservoir effect along the stream network, Eq. 4-4 and Eq. 4-11 can be rewritten as Eq. 4-30. Eq. 4-30 is the overall TR for estimating the lowest amount of potential nutrient load reduction a downstream PS should buy from an upstream NPS.

$$TR = \frac{1}{(1 - R_U)R_D} = \frac{1}{(1 - R_U) \times \prod_{j=1}^{p} R_{D_{S_j}} \times \prod_{k=1}^{q} R_{D_{L_k}}} \qquad \text{Eq. 4-30}$$

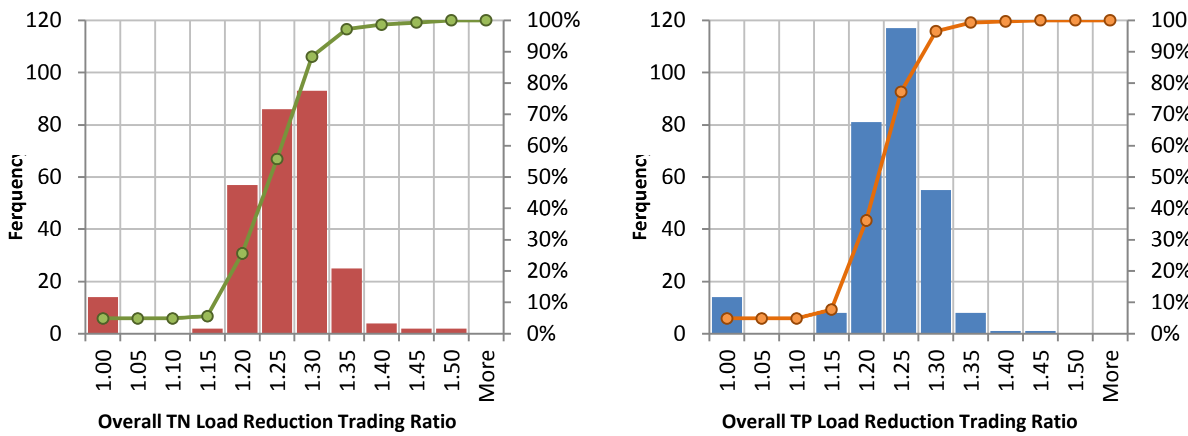
Figure 4-15 (a) and (b) shows examples of the overall TR for the alternative scenario pair S7-S32 (S7: 2-yr corn-soybean, minimum till, sub-surface fertilizer, no VFS; S32: native grass, switchgrass) to watershed main outlet. The TR patterns for each nutrient show strong clustering for both nutrients within the watershed. Moreover, the higher TR values not only occurred in subbasins most remote to the watershed outlet, but also in several subbasins in the middle of watershed. This proves both in-stream delivery and in-field pollutant yield are important factors in calculating TR. Figure 4-16 illustrates the overall TR distributions of this example in the study watershed. Except grey subbasins in Figure 4-16, which are not tradable for S7-S32 alternative scenario pair, overall TRs for TN load reduction range from 1.12 to 1.47 and for TP load reduction from 1.13 to 1.44. Moreover, the means for each nutrient are 1.250 for TN and 1.227 for TP. Given these results, the usual 2:1 fixed TR will obviously overestimate the risk of trading for nutrient load reductions of NPS in study watershed.



(a) TN Load Overall TR **(b) TP Load Overall TR**

Note: S7: 2-yr corn-soybean, minimum till, sub-surface fertilizer, no VFS; S32: native grass, switchgrass.

Figure 4-15 Overall S7-S32 TR for Each Subbasin to Main Outlet



(a) TN Overall TR **(b) TP Overall TR**

Figure 4-16 Overall Nutrient Load Reduction TR Distribution

The overall TR given in Eq. 4-30 is for a potential single NPS-PS trade scenario, with only one PS purchasing load reductions from one NPS. For multiple trade scenarios, the TR calculation becomes much more complex. We estimated the delivery effects in previous sections according to the nutrient load attenuation simulated with SWAT along the stream network. However, this attenuation for each river section is limited, given the natural assimilation of nutrient loads in surface water. Therefore, we used only downstream trading in study watershed to avoid the potential hot spots of pollution.

Moreover, the calculation of actual nutrient load delivered to PS must include all the NPS along the flow path and all the delivery/detention effects of all the involved water bodies. Assuming j sections of river in the flow path to the downstream PS and total i NPS involved in a downstream multiple NPS-PS trade, for each NPS, there should be a BMP_i efficiency ratio for the selected alternative scenario pair, and A_i represents the field area where that alternative scenario is applied. For each stream section, R_{Dj} represents the R_D within the j[th] section, and an R_{Dj}^{*} describes the cumulative R_D of j[th] section to the downstream PS location. Therefore, the overall delivered pollutant load (E_{PS}) transported from all i NPS to the downstream PS location can be calculated using Eq. 4-31.

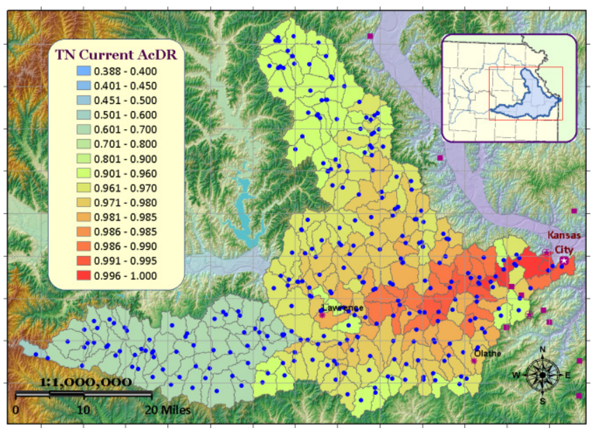
$$E_{PS} = \sum_{i=1}^{n}\left[\left(\prod_{j=1}^{p} R_{D_{S_j}} \times \prod_{k=1}^{q} R_{D_{L_k}}\right)_i \times \left(1 - R_{U_i}\right) \times BMP_i \times A_i\right] \qquad \text{Eq. 4-31}$$

4.5.4 Lake Effect

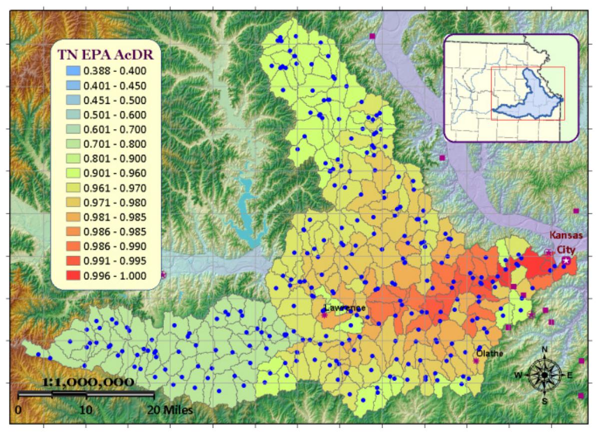
As previously noted, the EUTROMOD load equation was used to estimate the lake effects in the stream network. Based on Clinton Lake's physical parameters, the four lake detention/delivery ratios were calculated and applied to simulate lake effects in this study: 0.403 for TMDL TP requirement and

0.716 for EPA TP recommendations; 0.669 for TN current median value and 0.811 for EPA TN recommendation. Because the Clinton Lake outlet is in subbasin #186 (SB186), only the nutrient loads transported from upstream of SB186 to downstream of that subbasin will be affected. In other words, only the R_D^* for estimating the nutrient load transported through Clinton Lake needs adjustment. Using the selected lake detention/delivery ratios and Eq. 4-11, the potential R_D^* for each subbasin to watershed main outlet are recalculated.

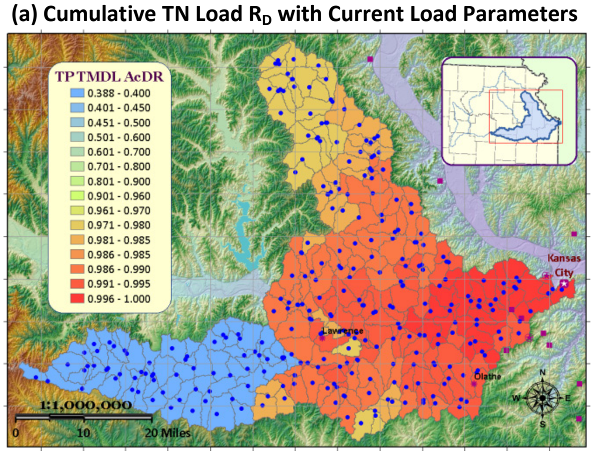
Figure 4-17 (a) illustrates the lake-effect R_D^*, as adjusted with the lake R_D at 0.669 for the current median of TN load. The value of each subbasin in Figure 4-17 (a) represents the potential R_D^* for TN load transported from that subbasin to the main outlet of the watershed. Similarly, Figure 4-17 (b) illustrates the lake-effect R_D^* as adjusted with the lake R_D at 0.811 for the EPA recommended TN load. Figure 4-17 (c) and (d) show the lake-effect R_D^* as adjusted with the lake R_D at 0.403 for TMDL TP load requirement and 0.716 for the EPA TP load recommendation. The TN load R_D^* ranged from 0.594 to 0.652 in Figure 4-17(a) and from 0.720 to 0.791 in Figure 4-17 (b). The TP load R_D^*, ranged from 0.388 to 0.398 in Figure 4-17 (c) and from 0.690 to 0.708 in Figure 4-17 (d).



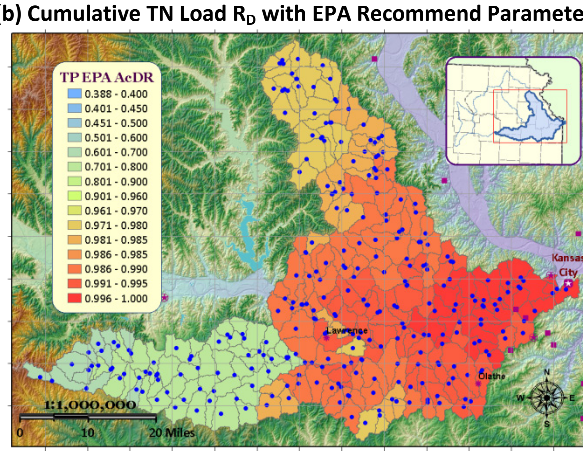
(a) Cumulative TN Load R_D with Current Load Parameters



(b) Cumulative TN Load R_D with EPA Recommend Parameters



(c) Cumulative TP Load R_D with TMDL Parameters

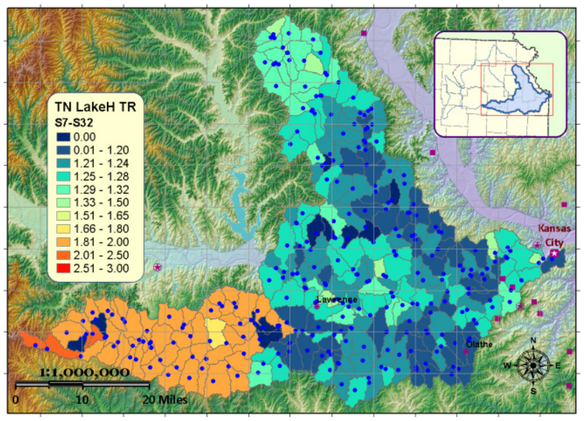


(d) Cumulative TP Load R_D with EPA Recommend Parameters

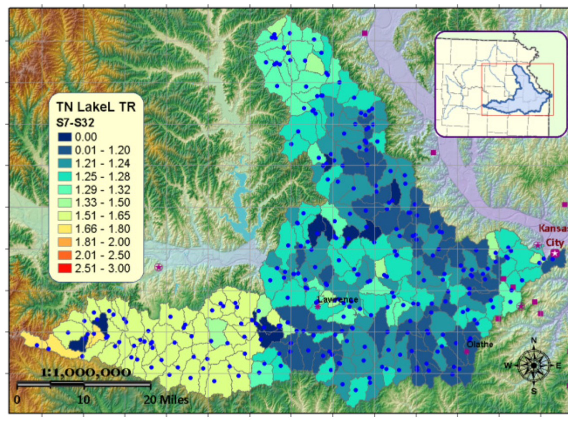
Figure 4-17 Cumulative R_D with Different Lake Detention Parameters in Study Watershed

Using Eq. 4-30, the lake effect overall TRs for every alternative scenario were then developed. Based on the four different lake-effect cumulative R_Ds illustrated in Figure 4-17, the S7-S32 overall TRs for nutrient load reductions transported to watershed's main outlet, as shown in Figure 4-15, can be re-arranged with the lake affected results as shown in Figure 4-18. Figure 4-18 (a) and (b) show the overall TN load reduction TR patterns show a similar trend as Figure 4-15 (a): downstream of Clinton Lake shows a similar pattern but lower magnitude in TR than upstream. Figure 4-18 (c) and (d) also show a similar trend to Figure 4-15 (b) in overall TP load reduction TR. A histogram of the lake-effect parameters (see Figure 4-19) shows the distribution of the cumulative R_Ds from Figure 4-17 (a). Figure 4-19 (b) depicts the distribution of overall TRs from Figure 4-18 (a). Both histograms show two separate data groups for subbasins upstream or downstream of Lake Clinton. The lake affected cumulative R_Ds tend to have a lower value than original ones. However, the lake affected overall TRs tend to have higher value than non-affected ones. Therefore, we must address the lake effects in the WQT program, unless the lake effects are small enough to be ignored.

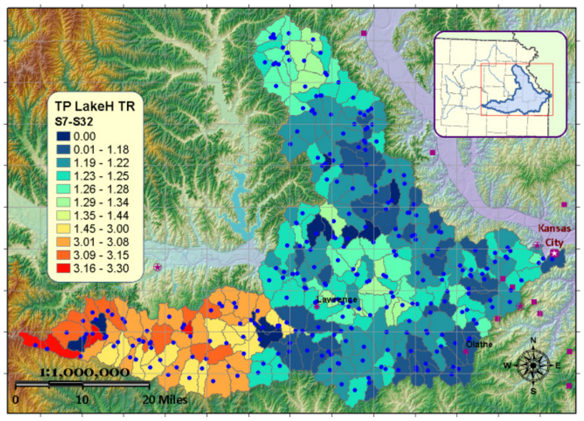
These processes demonstrate a scientific way of accounting for lake effects with a lake water quality model, EUTROMOD; thus we can estimate the specific R_Ds and TRs. However, EUTROMOD is a statistics based empirical model; it may not be suitable for all lakes/reservoirs in Kansas. The alternative is to separate watersheds into two different trading markets at lake outlets to avoid calculating lake effects. Thus, the stakeholders in different markets would not trade directly with each other.



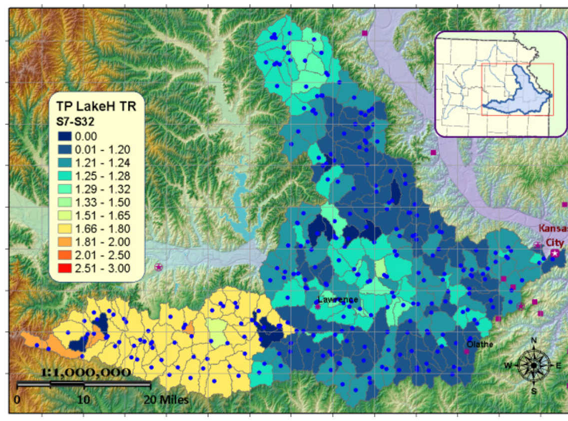
(a) TN Overall TR with Current Load



(b) TN Overall TR with EPA Recommend

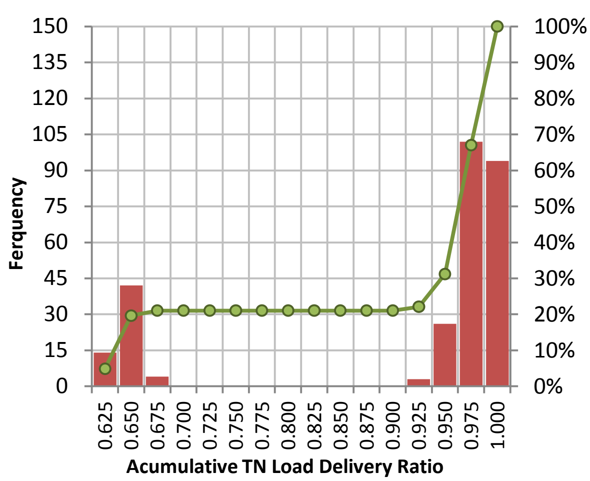


(c) TP Overall TR with TMDL

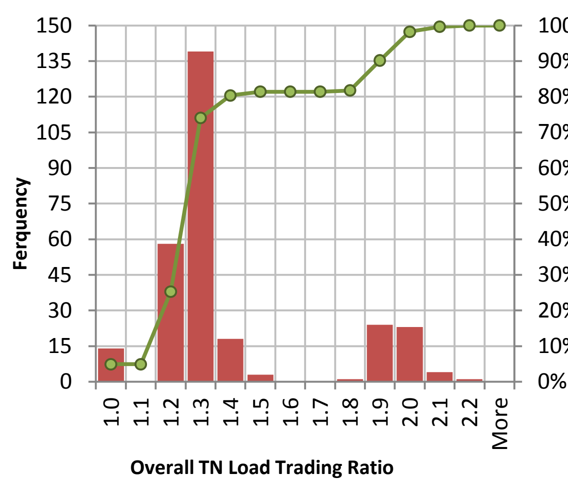


(d) TP Overall TR with EPA Recommend

Figure 4-18 Overall S7-S32 Lake Effect TR for Each Subbasin to Watershed Outlet



(a) TN Load Cumulative R_D



(b) TN Load Overall TR

Figure 4-19 Cumulative Lake-Effect TN Load R_D and Overall TN Load TR Distribution

4.5.5 Trading Zone Analysis

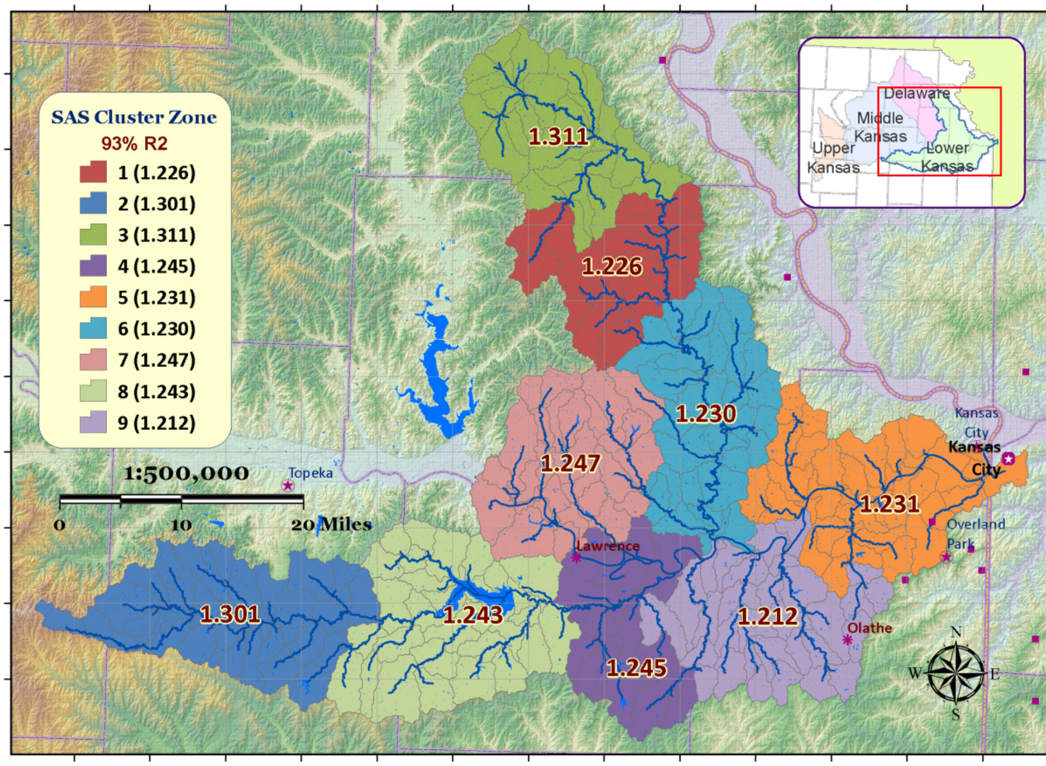
A fixed TR may force a trade under an unreasonable confidence level, requiring a PS to purchase extra credits from an NPS than at a higher total cost. Alternatively, a variable, floating TR system based on model simulations of pollutant load reduction uncertainty could provide an index matrix for TRs in every area of a watershed. Although the fixed TR may overestimate the potential uncertainty of a trade, it does give stakeholder a simple and quick way of calculating the cost of a trade. In contrast, a floating TR system uses a set of systematic methods to develop accurate information, but their variant numbers and tedious processes might be a new impediment for WQT. Therefore, a method that can simplify the minor differences among indexes but still keep the TR accurate would be best. Using the cluster analysis method, a trading zone, aggregated among several subbasins with similar TRs into a larger region, could be developed.

Cluster analysis classifies a set of observations into several subsets (called clusters) so that observations in the same cluster are similar. Using this method, we could simply group subbasins with similar nutrient load responses into a group and assign a single TR to them. Therefore, we could split the whole watershed into several sub-regional trading zones and simplify the long list of TRs in every subbasin.

Using cluster analysis, we can create trading zones and estimate the TRs for each potential alternative scenario pair in the study watershed. Table 4-4 shows a cluster analysis for both TN and TP load reductions of S7-S32 alternative scenario pair. Table 4-4 also shows the last 15 generations of the cluster history from the SAS analysis. In Table 4-4, the peak of cubic clustering criterion (CCC) shows potential clusters are 3 and 9, pseudo F statistic (PSF) indicates possible stopping points of clusters are at 9 and 4, and pseudo t^2 (PST2) statistic shows the possible clustering levels at 12, 9, 8, 7, 4, and 3 clusters. Based on the criteria described in SAS Online-Doc (SAS Institute Inc., 2004), the 9 and 23 clusters were then chosen, indicating the data are grouped into 9 or 23 clusters, with the proportion of variance accounted for by the clusters (R^2) at about 93% for 9 clusters or 97% for 23 clusters. Furthermore, each cluster can be assigned as a trading zone and its TR estimated with the zonal average. Given these processes, Figure 4-20 illustrates the 9 trading zones scenario, and Figure 4-21 displays the 23 trading zones scenario. For the TN load reduction of S7-S32 alternative scenario pair, the TR of each cluster was calculated based on the 9 and 23 clusters and labeled in both figures.

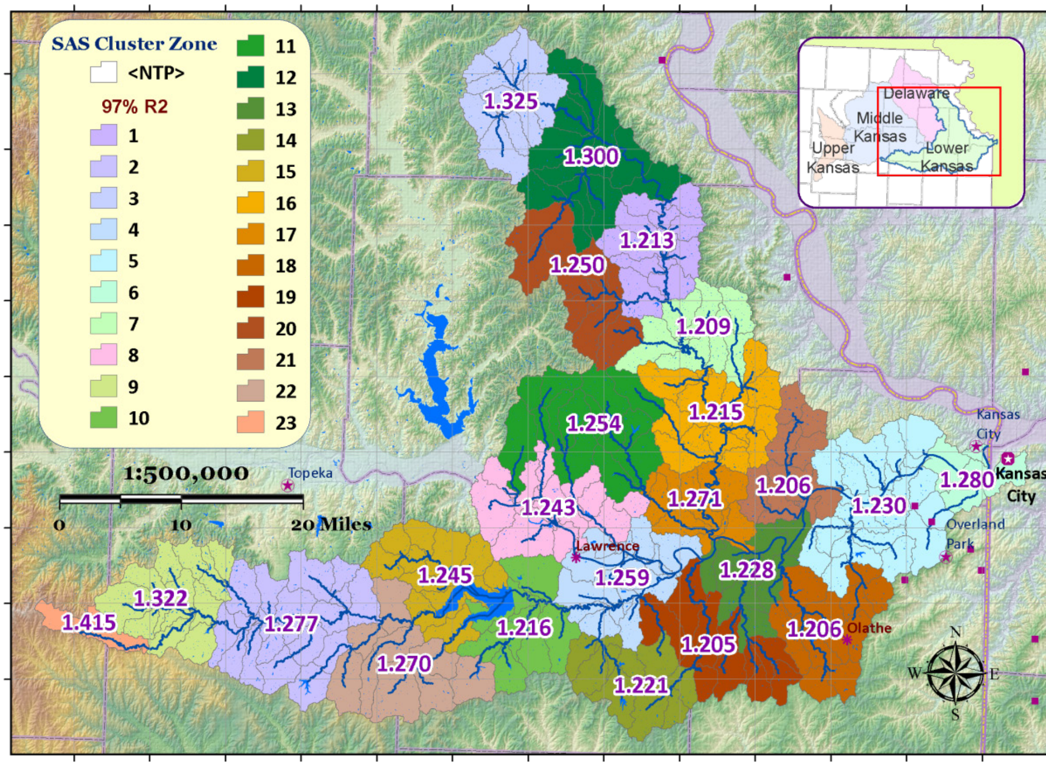
Table 4-4 Cluster Generation History Based on TN and TP Load Reduction for S7-S32

NCL	Clusters	Joined	FREQ	SPRSQ	RSQ	ERSQ	CCC	PSF	PST2
15	CL40	CL26	28	0.0033	0.954	0.941	4.52	404	34.5
14	CL24	CL33	30	0.0034	0.951	0.937	4.66	406	27.1
13	CL42	CL22	31	0.0043	0.947	0.931	4.64	404	30.8
12	CL31	CL18	39	0.0051	0.942	0.925	4.61	401	32.1
11	CL25	CL27	32	0.0054	0.936	0.918	4.78	403	43.5
10	CL19	CL21	39	0.006	0.93	0.909	5.09	408	31.7
9	CL15	CL36	38	0.0074	0.923	0.898	5.41	414	40.3
8	CL17	CL9	62	0.0141	0.909	0.884	4.68	395	47.2
7	CL13	CL20	53	0.0156	0.893	0.866	4.46	388	68.2
6	CL12	CL16	70	0.024	0.869	0.843	3.78	372	87.3
5	CL8	CL10	101	0.0378	0.831	0.81	2.58	346	83.1
4	CL14	CL6	100	0.04	0.791	0.761	3.22	356	79.3
3	CL5	CL11	133	0.1398	0.652	0.678	-2.1	265	199
2	CL7	CL4	153	0.2698	0.382	0.456	-3.9	175	349
1	CL2	CL3	286	0.3817	0	0	0	.	175



Note: S7: 2-yr corn-soybean, minimum till, sub-surface fertilizer, no VFS; S32: native grass, switchgrass.

Figure 4-20 93% R^2 Trading Zones (9 Clusters) and Average TN Load Reduction TRs for S7-S32



Note: S7: 2-yr corn-soybean, minimum till, sub-surface fertilizer, no VFS; S32: native grass, switchgrass.

Figure 4-21 97% R^2 Trading Zones (23 Clusters) and Their TN Load Reduction TRs for S7-S32

As described in general statistics, the original cluster analysis analyzes observations in either magnitude or location in a plane (SAS Institute Inc., 2004). However, the nutrient loads in surface water were transported along the stream network, which may not be well described by the original cluster analysis definition. Therefore, all subbasins in a trading zone need to be adjacent and also comply with the stream hierarchy. In other words, subbasins, which are in the same trading zone, are required to be adjacent and connected by the stream network; there is no leap subbasin within a trading zone. For example, some of the subbasins in the same cluster in Figure 4-20 and Figure 4-21 did not have direct connections to each other via the stream network. In other words, these specific subbasins in the same cluster might be adjacent to each other, but the stream network may not connect every subbasin within the same cluster. Therefore, subbasins in the same cluster that do not connect to each other via the stream network must be separated into two or more sub-clusters or sub-trading zones. Based on the stream network hierarchy, Figure 4-22 illustrates the 24 new clusters developed based on the original 9 clusters in Figure 4-20. In Figure 4-22, every subbasin in the same cluster directly connects via the stream network to each other.

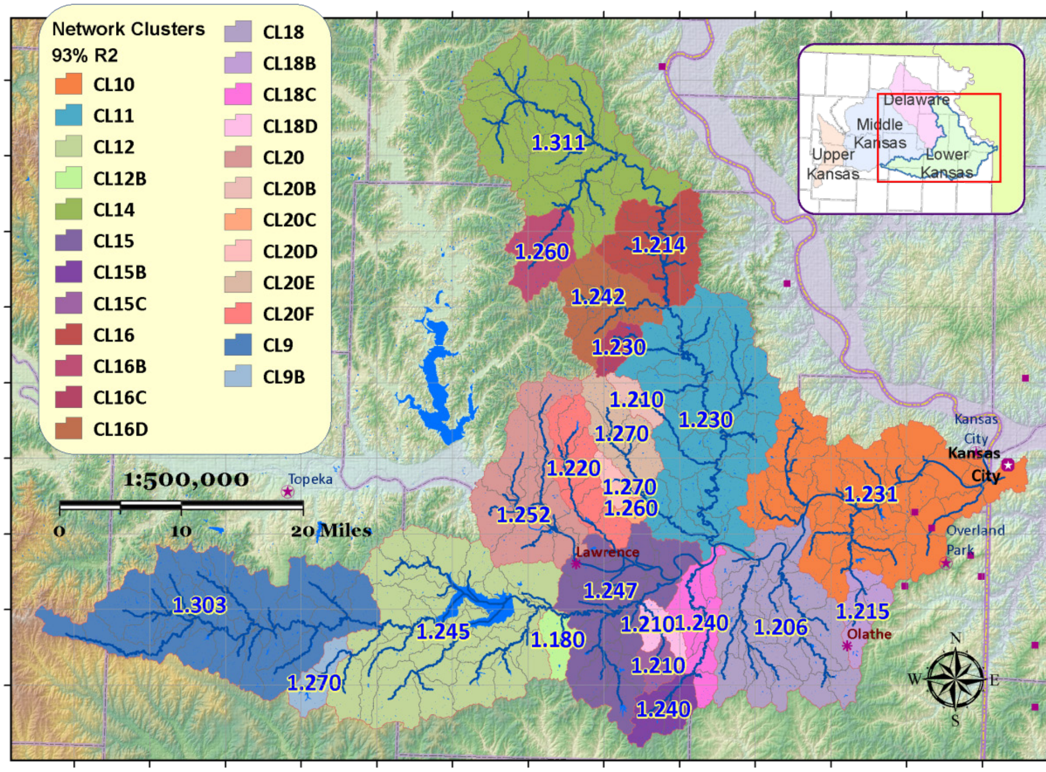


Figure 4-22 Modified 93% R^2 Trading Zones (9 Clusters) and Average TN Load Reduction TRs

4.6 Conclusion

In-stream delivery effect is an important factor that affects environmental benefits of a trade in WQT. In previous research, the nutrient load reduction among alternative in-field management scenarios differs significantly. Both geospatial and temporal site-specific effects are also significant across the study watershed. As described previously, the nutrient load delivered downstream can be separated into two processes: in-field and in-stream. For in-stream processes, nutrient load can be analyzed including or excluding the detention effect of the water body in each subbasin. Incorporating the analyses of in-field and in-stream processes, the overall effects or trading risks can then be assessed.

In this study, we used several approaches to quantify the in-stream uncertainties of WQT in the Lower Kansas watershed. The potential TN and TP loads were estimated at the subbasin level using the SWAT model and calibrated parameters from 1971 to 2006. The delivered effects of both nutrient loads, chosen based on natural attenuation of pollutants and deposition phenomena in the stream network between PS and NPS, were also simulated using the SWAT model. To include the lake/reservoir effect in the trading risk analysis, we used the EUTROMOD loading function to estimate the potential nutrient concentration difference between influent and in-lake flow. This method estimates easily and quickly the potential detention effect on the water body. However, EUTROMOD is based on the state level statistical analysis, which may cause results to differ for regions with dramatically different hydrologic characteristics.

The overall TR, when compared with the in-field TR developed in the SWAT model, differs by less than 10%. The delivery effect within the stream network accounts for this difference, but it is still not what we expected from the first-order kinetics function. This minor effect may be caused by the short time of concentration and traveling time in the watershed. The estimated maximum traveling time from the remotest point of watershed to the watershed main outlet is approximately 86 hours or 3.5 days. However, this number is generated from a rough estimate of channel characteristics. For other pollutant source locations in the model simulation, the traveling time would be still less. Therefore, the delivery effects estimated based on SWAT model results may not be perfect, but they are still a good general estimate. For storm runoff traveling time, which is less than one day, the delivery effect may be small enough to be ignored. However, further study should clarify the delivery effect in stream network.

As we discussed, with a fixed TR, a trade may have to operate under an unreasonable confidence level that requires a PS to purchase more credits from NPS than actually needed at a higher total cost. Alternatively, a variable, floating TR system based on model simulations of pollutant load reduction uncertainty could provide an index matrix for TRs in every part of the watershed. As the modeling results in the ANOVA test showed, delivery ratios across the watershed differ significantly. ANOVA also identified a strong geospatial site-specific effect exists in different parts of the watershed. In practice, it would be hard to choose the better method for implementing TR calculations for WQT. However, a floating system should be much more suitable for a WQT program in a large, complex watershed, especially one with highly heterogeneous properties.

Both fixed TRs and floating TR systems have problems, making cluster analysis an attractive alternative in WQT programs. Cluster analysis eliminates trivial differences among the subbasins in the same group but maintains differences between groups. This allows a watershed to be split into several sub-regional trading zones; within the same zone, the TR remains constant. This eliminates the problems involved in fixed TRs while keeping the method simpler than floating TR system. This system that is both easy to use and accurate would make the WQT program far more viable.

This study provides a scientific and well organized way to quantify the potential nutrient load variation in both in-field and stream networks to provide stakeholders the ability to assess the potential effect and benefits of WQT. Visualizing these potential trading effects and providing a data portal for users are subject to future research.

Acknowledgements

The authors gratefully acknowledge Dr. J.M. Shawn Hutchinson, associate professor of Geography, for his comments on geospatial analysis and GIS techniques. Appreciation is also extended to Drs. Jeffrey M. Peterson and John Leatherman, professors of Agricultural Economics, Mr. Craig Smith, watershed specialist and research assistant, and other watershed specialists and professionals for their expertise in the field survey of water quality trading program in Kansas.

We are grateful for the partial financial supports from the U.S. EPA Section 319 grant and Kansas Water Plan funds provided by the Kansas Department of Health and Environment (KDHE) (Project #: 2004-0017), and U.S. EPA, the National Center for Environmental Research (NCER) Science to Achieve Results (STAR) Program Grant #R831774. Although the research described in the article has been funded in part by KDHE project and the U.S. EPA's STAR program grant, it has not been subjected to any KDHE or EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

4.7 References

ASAE Standard. 2005. D384.2: Manure production and characteristics. St. Joseph, MI: Am. Soc. Agric. Eng. (ASAE).

Barnes, P. L. 2006. Personal communication. Manhattan, KS.

Boyer, W. R. 2006. Interview by author. E-mail communication. Manhattan, KS.

Breetz, H. L., K. Fisher-Vanden, L. Garzon, H. Jacobs, K. Kroetz, and R. Terry. 2004. Water quality trading and offset initiatives in the U.S.: a comprehensive survey. Hanover, NH: Dartmouth College. Available at: www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf. Accessed April 30, 2009.

Brown, L. C. and T. O. Barnwell, Jr. 1987. The enhanced water quality models QUAL2E and QUAL2E-UNCAS documentation and user manual. EPA document EPA/600/3-87/007. Athens, GA: USEPA.

Crutchfield, S. R. and D. Letson. 1994. Feasibility of point-nonpoint source trading for managing agricultural pollutant loadings to coastal waters. *Water Resour. Res.* 30(10): 2825-2836.

CTIC. 2006. *Getting Paid For Stewardship: An Agricultural Community Water Quality Trading Guide*. West Lafayette, IN: Conservation Technology Information Center (CTIC). Available at: www.conservationinformation.org. Accessed December 12, 2006.

Curley, D. E. 2003. An analysis of trading ratio for water pollution control trading system using a geographic information system and the finite segment method. PhD diss. Philadelphia, PA: University of Pennsylvania, Department of City and Regional Planning.

Environomics. 1999. A summary of U.S. Effluent trading and offset projects. Bethesda, MD: Environomics. Available at: www.epa.gov/OWOW/watershed/trading/traenvrn.pdf. Accessed April 30, 2009.

ESRI. 2006. Network Analyst. In ArcGIS 9.2 Desktop Help. Redlands, CA: Environmental Systems Research Institute (ESRI), Inc. Available at: webhelp.esri.com/arcgisdesktop/9.2/. Accessed April 30, 2009.

ESRI. 2009. Hydro Data Model. Redlands, CA: Environmental Systems Research Institute (ESRI), Inc. Available at: support.esri.com/index.cfm?fa=downloads.datamodels.filteredgateway&dmid=15. Accessed April 30, 2009.

Fjell, D. L., D. Peterson, D. A. Whitney, 1997. *Soybean Production Handbook*. C-449. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., R. L. Vanderlip, K. L. Roozeboom, 2007. *Corn Production Handbook*. C-560 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Gassman, P.W., M.R. Reyes, C.H. Green, J.G. Arnold. 2007. The soil and water assessment tool—Historical development applications, and future research directions. *Trans. ASABE* 50(4), 1211-1240.

Hargreaves, G. H. and Z. A. Samani. 1985. Reference crop evapotranspiration from temperature. *Appl. Eng. Agric.* 1:96-99.

Hession, W. C., M. McBride, J. E. Parsons, and K. H. Reckhow. 1998. Evaluation of the water quality model EUTROMOD. In *Proc: Water Resources Engineering '98*, Abt, Young-Pezeshk, and Watson (eds.) 1828-1833. Reston, VA: ASCE.

Hession, W. C., M. McBride, J. E. Parsons, and K. H. Reckhow. 2001. Evaluation of the Water Quality Model EUTROMOD, in *Agricultural Non-point Source Water Quality Models: Their Use and Application, Parsons, Thomas, Huffman* ed. Southern Coop. Ser. Bul. no. 398 (updated 2004). Available at: www3.bae.ncsu.edu/Regional-Bulletins/Modeling-Bulletin/modeling-bulletin.pdf. Accessed April 30, 2009.

Hession, W. C.; Storm, D. E.; Burks, S. L.; Smolen, M. D.; Lakshminarayanan, R.; Haan, C. T., 1995. Using EUTROMOD with a GIS for establishing total maximum daily loads to Wister Lake, Oklahoma. in *Animal waste and the land-water interface*. Boca Raton (USA): Lewis Publishers.

Hoag, D. L., and J. S. Hughes-Popp. 1997. Theory and practice of pollution credit trading. *Rev. Agric. Economics* 19: 252-262.

Honeyman, M., J. Russell, D. Morrical, D. Maxwell, D. Busby and J. Sellers. 2006. Beef cattle on grass supplemented with self-fed by-products. In annual progress reports-2005. Armstrong Research and Demonstration Farm. ISRF05-12. Ames, IA: Iowa State University. Available at: www.ag.iastate.edu/farms/reports.html. Accessed April 30, 2009.

Iowa DNR. 2002. Total Maximum Daily Load for Organic Enrichment Crystal Lake, Hancock County, Iowa. Iowa Department of Natural Resources, Water Resources Section. Available at: www.iowadnr.gov/water/watershed/tmdl/files/final/crystal.pdf. Accessed April 30, 2009.

Jones, C., L. Bacon, M. S. Kieser, and D. Sheridan. 2005. *Water-Quality Trading a Guide for the Wastewater Community*. Water Environment Federation. New York, NY: McGraw-Hill.

KDHE. 2004. *Surface Water Nutrient Reduction Plan*. Topeka, KS: Kansas Department of Health and Environment (KDHE).

KDHE. 2008. 2008 Kansas Integrated Water Quality Assessment (305(b) Report). Topeka, KS: Bureau of Environmental Field Services, Kansas Department of Health and Environment (KDHE).

KSU. 2006. Common Kansas Crop Rotations. Unpublished technical note. Manhattan, KS: Extension Agronomy, Kansas State University (KSU).

KWO, 2008. Clinton Lake, Reservoir Fact Sheet. Kansas Water Office. Available at: www.kwo.org/ReservoirInformation/ReservoirFactSheets/Clinton_Lake.pdf. Accessed April 30, 2009.

Lamon, E. C. III and C. A. Stow. 2004. Bayesian methods for regional-scale eutrophication models. *Water Res.* 38(11): 2764-2774.

Leatherman, J., J. M. Peterson, and K. R. Mankin. 2005. Is Water Quality Trading a Policy Option for Kansas? In *Proc. 22nd Annual Water and the Future of Kansas Conference.* Topeka, KS: Kansas State University.

Lee, M. and K. R. Mankin. 2007a. A Site-Specific Water Quality Trading Ratio: Using GIS and Watershed Modeling to Account for Spatial and Temporal Variability. In *Proc: Watershed Management to Meet Water Quality Standards and TMDLs (Total Maximum Daily Load)*) ASAE Pub #701P0207. A. McFarland and A. Saleh ed. St. Joseph, MI: ASABE.

Lee, M., and K. R. Mankin. 2007b. Site-specific Water Quality Trading Ratio Analysis. 2007 ASABE Annual Meeting Paper No. 72179. St. Joseph, MI: ASABE.

Lee, M., K. R. Mankin, J. M. Peterson, and J. Leatherman. 2005. Water Quality Trading Issues in Kansas. ASABE Paper No. MC05-306. St. Joseph, MI.: ASABE.

Lee, M., K. R. Mankin, J. M. Peterson. 2007a. Evaluation of Potential Water Quality Trading Sites with Network Analysis. 2007 ASABE Annual Meeting Paper No. 071091. St. Joseph, MI: ASABE.

Lee, M., K. R. Mankin, J.M. S. Hutchinson. 2007b. WQTIPS: Water Quality Trading Information Platform System. 2007 ASABE Annual Meeting Paper No. 072021. St. Joseph, MI: ASABE.

Leikam, D. F., R. E. Lamond, D. B. Mengel. 2003. *Soil Test Interpretations and Fertilizer Recommendations*. MF-2586. Manhattan, KS: Kansas State University Cooperative Extension Service and the Agricultural Experiment Station.

Letson, D., S. R. Crutchfield, and A. Malik. 1993. *Point/Nonpoint Source Trading For Controlling Nutrient Loadings to Coastal Waters: A Feasibility Study*. Ag. Econ. Report No. 674. Washington, D.C.: USDA ERS, Research and Technical Division. Available at: www.ers.usda.gov/AboutERS/Sales/index.asp?PDT=2&PID=670. Accessed April 30, 2009.

Maddux, L. D. 2006. Interview by author. E-mail communication. Manhattan, KS. February 23.

Maidment, D. R. 2002. *Arc Hydro: GIS for water resources*. Redlands, CA: ESRI Press.

Mankin, K. R. 2000. An integrated approach for modeling and managing golf course water quality and ecosystem diversity. *Ecological Modeling* 133(3): 259-267.

Mankin, K. R., D. M. Ngandu, C. J. Marden, S. L. Hutchinson, and W. A. Geyer. 2007. Grass-shrub riparian buffer removal of sediment, phosphorus, and nitrogen from simulated runoff. *J. Amer. Water Resour. Assoc.* 43(5): 1108-1116.

Mankin, K. R., Koelliker, J. K. and Kalita, P. K., 1999. Watershed and lake water quality assessment: an integrated modeling approach. *J. Amer. Water Resour. Assoc*. 35 5, pp. 1069-1080.

Mankin, K. R., P. L. Barnes, J. P. Harner, P. K. Kalita, and J. E. Boyer. 2006. Field evaluation of vegetative filter effectiveness and runoff quality from unstuck feedlots. *J. Soil and Water Conserv*. 61(4): 209-217.

Martin, M. R., and M. DeAngelo. 1998. The Carrying Capacity of Blue Mountain Lake, Final Report. Paul Smiths, NY: Adirondack Aquatic Institute at Paul Smith's College. Available at: www.cedareden.com/BLMTN-model.PDF. Accessed April 30, 2009.

Maski, D., K. R. Mankin, K. A. Janssen, and P. Tuppad. 2007. Sensitivity analysis of SWAT nutrient modeling under different management practices. 2007 ASABE Annual Meeting Paper No. 072060. St. Joseph, MI: ASABE.

Maski, D., K.R. Mankin, K.A. Janssen, P. Tuppad, and G.M. Pierzynski. 2008. Modeling runoff and sediment yields from combined in-field crop practices using SWAT. *J. Soil and Water Conserv.* 63(4): 193-203.

Metcalf & Eddy, Inc. 1991. *Wastewater Engineering: Treatment, Disposal and Reuse*. 3rd ed. revised by G. Tchobanoglous and F.L. Burton., New York: McGraw-Hill.

Moore, K. J., M. H. Wiedenhoeft, E. C. Brummer, J. R. Russell, R. Hintz, J. Secor, and D. Maxwell. 2001. Sequential grazing systems for beef cattle production. In annual progress reports-2000. Armstrong Research and Demonstration Farm. ISRF00-35. Ames, IA: Iowa State University. Available at: www.agaware.iastate.edu/farms/2000reports/mcnay/. Accessed April 30, 2009.

Morgan, C. and A. Wolverton. 2005. *Water Quality Trading In the United States*. EPA Working Paper #05-07. Washington, D.C.: USEPA, National Center for Environmental Economics (NCEE).

NCDC. 2009. Daily surface data. Climate Data Online (CDO), National Climatic Data Center (NCDC). NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and U.S. Department of Commerce. Available at: cdo.ncdc.noaa.gov. Accessed March 31, 2009.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, and J. R. Williams. 2005. *Soil and Water Assessment Tool Theoretical Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS & Blackland Research and Extension Center, Texas A&M University.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and J. R. Williams. 2004. *Soil and Water Assessment Tool Input / Output File Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS.

Nelson, N. and A. Keeler. 2005. Water Quality Trading in Georgia: Addressing Two Potential Impediments to Success. In *Proc. 2005 Georgia Water Resources Conference*. Kathryn J. Ed. Athens, Georgia: Institute Ecology, University of Georgia. Available at: www.uga.edu/water/GWRC/Papers/NelsonN-GWRCpaper%20April13.pdf. Accessed April 30, 2009.

Nelson, R. G., J. C. Ascough II, and M. R. Langemeier. 2006. Environmental and economic analysis of switchgrass production for water quality improvement in northeast Kansas. *J. Environ. Management* 79(4): 336-347.

NRCS. 2008. Electronic Field Office Technical Guides. USDA-NRCS. Available at: www.nrcs.usda.gov/technical/efotg. Accessed April 30, 2009.

NRCS-Kansas. 2003. Conservation Practice Standard, Filter Strip (acre.) Code: 393. Salina, KS: USDA-NRCS, Kansas Division.

NRCS-Kansas. 2006. Crop field management record (dry land). Unpublished technical note. Lyndon, KS: USDA-NRCS, Kansas Division, Osage County Field Office.

Parajuli, P. B. 2007. SWAT bacteria sub-model evaluation and application. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

Parajuli, P.B., N.O. Nelson, L.D. Frees, and K.R. Mankin. 2009. Comparison of AnnAGNPS and SWAT model simulation results in USDA-CEAP agricultural watersheds in south-central Kansas. *Hydrological Processes* 23(5): 748-763.

Peterson, J. M., J. A. Fox, J. C. Leatherman, and C. M. Smith. 2007. Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market. In *Proc: 2007 Annual Meeting,* July 29-August 1, 2007, Portland, OR: AAEA.

Reckhow, K. H. 1992. Unpublished document. EUTROMOD Spreadsheet Program, A regional modeling scheme for nutrient runoff and lake trophic state modeling. Duke University.

Reckhow, K. H., S. Coffey, M. H. Henning, K. Smith, and R. Banting. 1992. Technical Guidance and Spreadsheet Models for Nutrient Loading and Lake Eutrophication. Draft technical report, Duke University.

Rowles, K. 2005. A Feasibility analysis of applying water quality trading in Georgia watersheds. Water Policy Working Paper 2005-020. Atlanta, GA: Georgia State University, Andrew Young School of Public Policy.

Samet, H. 1990. *The Design and Analysis of Spatial Data Structures*. Addison-Wesley.

Sankaranarayanan, J., H. Alborzi, and H. Samet. 2005. Efficient query processing on spatial networks. *In Proc: the 13th annual ACM international workshop on Geographic Information Systems,* New York, NY, USA, pp. 200-209. GIS '05. ACM.

SAS Institute Inc. 2004. *SAS OnlineDoc® 9.1.3*. Cary, NC: SAS Institute Inc.

Smith, C. M. 2004. A Water Quality Trading Simulation for Northeast Kansas. MS Thesis. Manhattan, KS: Kansas State University, Department of Agricultural Economics.

Smith, C. M., J. M. Peterson, and J. C. Leatherman. 2007. Attitudes of Great Plains Producers about Best Management Practices, Conservation Programs, and Water Quality. *J. Soil and Water Conserv.* 62: 97A-103A.

Smith, R. A., G. E. Schwarz, and R. B. Alexander. 1997. Regional interpretation of water-quality monitoring data. *Water Resour. Res.* 33(12): 2781-2798.

Sophocleous, M. A. and S. P. Perkins. 2000. Methodology and application of combined watershed and ground-water models in Kansas. *J. Hydrology* 236(3-4): 185-201.

Sophocleous, M. A., J. K. Koelliker, R. S. Govindaraju, T. Birdie, S. R. Ramireddygari and S. P. Perkins. 1999. Integrated numerical modeling for basin-wide water management: The case of the Rattlesnake Creek basin in south-central Kansas. *J. Hydrology* 214(1-4): 179-196.

Tuppad, P., 2006. Hydrologic modeling response to NEXRAD and raingage spatial variability and strategic watershed management. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

Tuppad, P., K. R. Mankin, J. M. S. Hutchinson, J. A. Harrington, and J. K. Koelliker. 2003. Targeting watershed improvement efforts using AGNPS-GIS modeling results. In *Proc. AWRA Agricultural Hydrology and Water Quality Conference*. Kansas City, MO: AWRA

USACE. 2007. Annual Water Quality Report 2006 - Kansas City District. U.S. Army Corps of Engineering (USACE), Kansas City District. Available at: www.nwk.usace.army.mil/lakes/WaterQualityReport/06_Annual_Report.pdf. Accessed April 30, 2009.

USEPA. 1985. Rates, constants, and kinetics formulations in surface water quality modeling, 2nd ed. EPA/600/3-85/040. Athens, GA: USEPA, Environmental Research Laboratory.

USEPA. 2000a. *Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria - Rivers and Streams in Nutrient Ecoregion IX*. Washington, D.C.: USEPA, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Available at: www.epa.gov/waterscience/criteria/nutrient/ecoregions. Accessed March 31, 2009

USEPA. 2000b. *Ambient Water Quality Criteria Recommendations-Lakes and Reservoirs in Nutrient Ecoregion IX*. EPA-822-B-00-011. Washington, D.C.: USEPA, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Available at: www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes. Accessed April 30, 2009.

USEPA. 2001. *Chesapeake Bay Program Nutrient Trading Fundamental Principles and Guidelines*. EPA 903-B-01-001. Washington, D.C.: Chesapeake Bay Program Nutrient Trading Negotiation Team, USEPA.

USEPA. 2001. The National Cost to Implement Total Maximum Daily Loads (TMDLs): Draft Report. Washington, D.C.: USEPA.

USEPA. 2004. *Water Quality Trading Assessment Handbook*. Washington, D.C.: Office of Water, USEPA.

USGS. 2008. National Hydrography Dataset. USGS. Available at: nhd.usgs.gov, Accessed April 30, 2009.

Wanielista, M. P., R. Kersten, and R. Ealgin, 1997. *Hydrology: Water Quantity and Quality Control*. New York, NY: John Wiley & Sons.

Ward, J. H. 1963. Hierarchical Grouping to Optimize an Objective Function. *J. Amer. Statistical Assoc.* 58: 236-244.

Whitney, D. A., D. L. Devlin, and D. J. Jardine. 1999. *Kansas No-Till Handbook*. S-126. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Whitney, D. A., L. R. Stone, K. A. Janssen, and J. H. Long. 1991. *The Effects of Nitrogen Fertilizer on Soil*. C-625. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Williams, J. R. 1969. Flood routing with variable travel time or variable storage coefficients. *Trans. ASAE* 12(1):100-103.

Williams, J. R., and H. D. Berndt. 1977. Sediment yield prediction based on watershed hydrology. *Trans. ASAE* 20 (6), 1100-1104.

Wischmeier, W. H. and D. D. Smith. 1965. *Predicting Rainfall Erosion Losses from Cropland East of the Rocky Mountains*. Agriculture Handbook: No. 282. USDA. Washington, D.C.: U.S. Government Printing Office.

Wischmeier, W. H. and D. D. Smith. 1978. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning*. Agriculture Handbook: No. 537. USDA. Washington, D.C.: U.S. Government Printing Office.

Wu, T. S., A. Baniukiewicz, and D .K. Gilbert. 2003. Nutrient Total Maximum Daily Load for Lake Wauberg Outlet, Alachua County, Florida. Tallahassee, FL: Florida Department of Environmental Protection, Watershed Assessment Section. Available at: www.dep.state.fl.us/water/tmdl/docs/tmdls/final/gp1/lake_wauberg_nut_tmdl.pdf. Accessed April 30, 2009.

Chapter 5 Development of Water Quality Trading Assessment Tool: WQTIPS

Abstract

Water Quality Trading (WQT) is one way to reduce nonpoint source pollution and also achieve both economic and environmental benefits within a watershed. Recent research has shown that trading information level and transaction costs cause problems in implementing WQT. The goals of this study were to develop a geospatial data model schema to standardize the procedure and structure of WQT in data collecting and in maintaining and synchronizing WQT. Based on the WQT geospatial data model (WQTGDM), the blue print of geospatial data structure for WQT, the Water Quality Trading Information Platform System (WQTIPS) was then developed to query WQT for information and assessment. Three-tier GIS-based web interface architecture was used for WQTIPS. In a case study, the application tier was designed to enquire and assess the potential pollutant load reductions and their trading ratios among the trades. According to previous WQT researches, 36 years of data from the Lower Kansas watershed, northeastern Kansas, were modeled with SWAT watershed modeling tools and analyzed both parameters for 13 selected alternative scenarios. The data tier, a geospatial database which is the system data repository, was implemented with ESRI ArcSDE and Microsoft SQL Server using the WQTGDM schema. The presentation tier, a WQT assessment tool with GIS-based web user interface, was then developed by incorporating the previous two tiers with the GIS internet map service, ESRI ArcIMS. The case study demonstrated WQTIPS can provide systematic, spatially variable, quantifiable load reductions and TRs for stakeholders to assess the environmental benefit changes from the land management shifts using a simple interface. This system demonstrates that it is possible to automate water-quality trades, use watershed models to minimize trading risk and maximize water-quality benefits, and prioritize among possible trades both spatially and by BMP.

5.1 Introduction

Reducing environmental pollution is a simple goal but not easily reached. In 1972, the Clean Water Act (CWA) was set up as a guideline for the government and public to reduce pollution. Although CWA has mandated regulations to reduce point sources (PSs) of pollution, such as wastewater treatment plants (WWTPs), it does little to address nonpoint source (NPS) pollution. According to the Kansas Nutrient Reduction Plan in 2004, the nutrients exported from Kansas include approximately 46,266 Mg (51,000 tons) per year of total nitrogen (TN) and 6,985 Mg (7,700 tons) per year of total phosphorus (TP) (KDHE, 2004). The portion PSs contribute of each nutrient pollutant is 18% for TN and 25% for TP (KDHE, 2004). Thus, NPS pollution contributes almost the triple the amount of PS pollution. Even though NPSs contribute most nutrient pollution, those sources are not regulated under CWA. Thus, only voluntary programs focus on ways to reduce NPS pollution. However, voluntary programs show little promise of achieving water quality targets within the desired schedules. Thus alternatives and innovative policy solutions are needed.

One innovative program to manage NPS pollution is water quality trading (WQT). WQT is a market-based approach to improving water quality, originating from the trading programs for air emissions like sulfur dioxide (SO_2). WQT is a voluntary program that connects industrial and municipal facilities, or PSs, with agricultural producers, NPSs, to economically achieve water quality improvements in a watershed. It is a flexible and cost-effective approach for maintaining, restoring, or enhancing water quality. Although the original air emission trading program has had only a few successes in trading effluents, if WQT can attract stakeholders to participate its trading-market program, it may create both economic and environmental benefits for PS, NPS, and government. Many states have adopted trading programs to improve water quality. At least 40 WQT projects are running nationwide, and another 26 watersheds proposed their own WQT projects in 2004 (Environomics, 1999; Breetz et al., 2004). However, implementing a WQT program is not easy. Recent studies show that at least 20% of WQT programs failed to make any significant trades not only because of their inability to address environmental uncertainty, the result of natural nutrient cycles and the surrounding environment, but also because of over/under-estimation of trading benefits. The common, roughly fixed trading ratios, such as 2:1 or 5:1, applied in a WQT program may create un-reasonable trading prices/costs in trading credits.

The challenge ahead is to combine a watershed model and an economic model into a WQT structure to improve benefit estimates and minimize potential uncertainties. The model is a set of formulas and equations that can simplify the mechanisms of the real world and that the user can then use to estimate the results of different scenarios by changing model parameters. More detailed parameters, of course, provide more precise estimates. However, detailed parameters mean huge inputs that must be prepared correctly, efficiently, and easily. Traditionally, preparing modeling parameters requires using paper and pencil to manually draw grids on a topographic map. Once the weighted averages of attributes at each square were calculated and model parameters were saved as ASCII text files in a matrix format, the model could be implemented. For a small watershed or limited data resolution cases, this process could work well even if it was tedious. However, larger watersheds require huge inputs, so using paper and pencil becomes a nightmare. Geographic information systems

(GIS) can capture, manipulate, analyze, and visualize diverse sets of geo-referenced data on a computer. Watersheds have inherent, continuous spatial properties from terrain as part of their geography. Integrating the watershed model and GIS was thus quite natural.

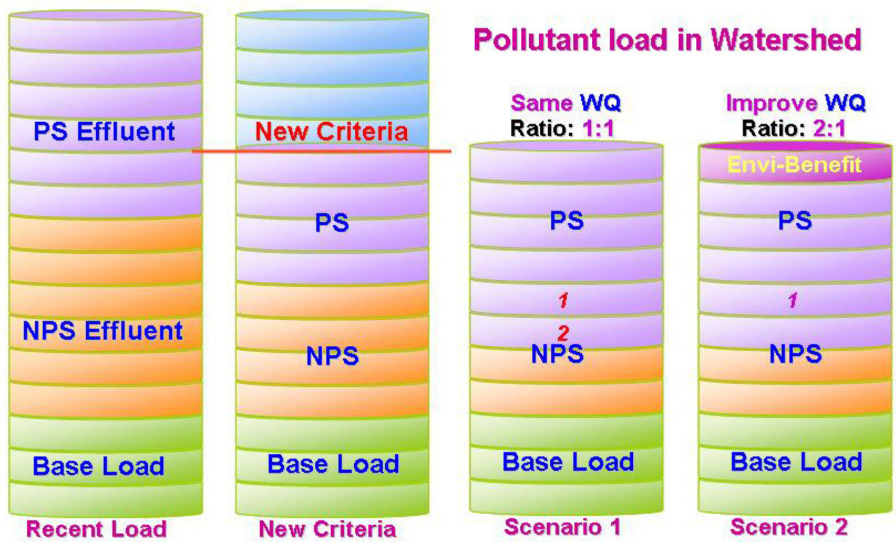
The type of information itself is another challenge for watershed program. Scientists and trained technicians easily adapt to model simulation processes and reading the results. However, most field workers unfamiliar with computer technology might find some difficulty in interpreting the resulting charts and tables. An easy to use assessment tool is thus important. Traditionally, a simple equation or empirical numbers help field workers assess the potential benefits of a scenario. However, with improved technologies, a website with the information visualized might be better for displaying modeling results and estimates to stakeholders.

This study focuses on two primary goals. The first is to develop a geospatial data model to contain the geo-referenced information of WQT. This geospatial data model might include all the activities related to WQT, such as watershed modeling works, field survey results, GIS system base maps, or other related information from other organizations or government agencies. With WQT geospatial data model, the results of site-specific trading ratios (Lee and Mankin, 2007b; Lee et al., 2007a) can be easily organized. The second goal is to develop a GIS, web-based WQT assessment tool: Water Quality Trading Information Platform System (WQTIPS). With this assessment tool, stakeholders can see the potential trading benefits and possible locations of alternative scenarios. Therefore, WQTIPS can provide sufficient information for decision makers and stakeholders to understand the potential effects of WQT in the watershed.

5.2 Materials and Methods

5.2.1 Water Quality Trading

WQT is a market-based approach to improving water quality. It is an innovative, voluntary tool that connects industrial and municipal facilities, or point sources (PS), with agricultural producers, NPSs, to economically achieve water quality improvements in the watershed. Generally, WQT involves a party facing relatively high pollutant-reduction costs compensating another party to achieve less costly pollutant reduction with the same or higher benefits to water quality (USEPA, 2004). This trading program motivates stakeholders with incentives for both buyer and seller. One major motivator is the need to meet mandated water quality goals. Traditional pollution controls become very costly after a specific point (Leatherman et al., 2005). For example, a secondary WWTP can reduce organic matters in the treated effluent by approximately 90%, and tertiary WWTP by approximately 99%, but tertiary treatment to reduce pollutants by that additional 9% is proportionately far more costly (Chapra, 1997). With more advanced technology, almost all WWTPs in U.S. have upgraded their treatment facilities to the secondary treatment level (KDHE, 2004). If secondary treatment cannot reduce pollution sufficiently to meet water quality goals, WWTPs face implementing tertiary treatments although any additional treatment may not reduce pollution significantly or make sense economically. The decision to implement tertiary treatment tends to be economic, not environmental.



Above example explains an ideal WQT scenario: PS buys two units of load reduction from NPS to replace its own one unit. Thus, the environment potentially has one unit reduction from this trade.

Figure 5-1 A simplified example of WQT Scenario

WQT, as illustrated in Figure 5-1, trades nutrient reduction credits from an NPS upstream to a downstream PS in a watershed. In an arbitrary watershed, the pollutant loads could include both PS and NPS effluents as well as the stream base load, which is the natural background load. If new water quality criteria are recommended for a watershed, both PS and NPS are pressured to reduce their effluents to meet the new regulations. Unfortunately, as we have shown, facility upgrades in WWTPs cost the PS more for the same amount load reduction than the NPS. Moreover, although CWA may mandate PS reductions in pollution, they ask little of NPS. Thus, WQT allows PS to buy the less costly reductions from NPS to replace their own mandated reductions. In a 1:1 TR scenario, a PS can buy reductions from an NPS and keep the water quality within the watershed level. However, consider the potential trading risks and uncertainties; with 2:1 TR, a PS must buy two units of reduction from an NPS to replace one of its own units. Because the load reduction costs for a PS are far higher than for an NPS, a 2:1 TR might still have significant economic benefits. Furthermore, a higher TR might increase the willingness of an NPS to implement alternative management practices to gain more load reduction credits. In other words, the trading ratio (TR) may be a risk compensation factor, possibly providing an opportunity to actually improve water quality in the watershed.

However, implementing WQT is a challenge. Creating a significant number of trades in the WQT market largely depends on the incentives and stakeholders' willingness to participate. Incentives need to be estimated precisely to ensure a minimum cost to control pollution while reaching environmental quality goals. Recent studies show that many WQT programs failed to make any significant trades (Nelson and Keeler, 2005) possibly because the trades themselves lack significant cost savings. WQT must address the uncertainties of trade in spatial or temporal scales. Another possible reason for the failure of WQT programs is over- or under-estimating the TR. Higher TRs might increase the willingness of an NPS to participate in a trade. However, those same ratios might also reduce the willingness of a PS to purchase. Therefore, fixed TRs within a watershed may cause unreasonable trading costs for stakeholders.

The site-specific TR, based on watershed modeling statistics, would make estimating environmental equivalence easier and more accurate, thus decreasing the risk in WQT. Lee and Mankin (2007a; 2007b) estimated site-specific TRs using a SWAT model and GIS functions in the Lower Kansas watershed, northeastern Kansas. Their studies showed significant load reduction differences among several alternative scenario pairs as well as in the spatial and temporal scales across the study watershed. However, they discussed only the TR issues in WQT. Further studies on reducing transaction cost of WQT could address the other issues.

5.2.2 Watershed Model

Understanding and evaluating the natural processes in a watershed and the impairments and problems within a watershed continue to challenge scientists and engineers. Mathematical models simulating these complex processes are useful tools for analyzing the problems and finding solutions through land-use changes and BMPs (Borah and Bera, 2003).

In the past, people used simple water quality models (or equations) to simulate water quality changes in streams. Streeter and Phelps (1925) used an equation to model dissolved oxygen levels in stream (Chapra, 1997). More recently, attention has turned to multidisciplinary theories in model development (Chapra, 1997). A modern watershed model combining soil erosion, biological and chemical degradation simulations can estimate pollutant behaviors within a watershed.

5.2.2.1 *Watershed Modeling Tool with GIS*

Traditionally, implementing environmental modeling tools requires a series of complex algorithms to simplify the real world. In recent decades, modeling tools have become more and more complex. They not only consider one type of pollutant at a time but also focus on the interactions and relationships among different pollutants. The rapid growth of computer and multimedia technology has made it possible to deliver high quality audio, graphics, video, and animation in an interactive environment.

Most environmental modeling tools have developed a visual aid interface to help researchers input and prepare spatial data and process, analyze, or even visualize the output results. In these visual interfaces, most use GIS technologies coupled with specific professional GIS software, like ArcView GIS or ArcGIS, and geospatial data to help people to use the modeling tool and also help researchers understand the output data and realize its spatial distribution meaning. These modeling tools include two types of applications. The first type uses the extension method to combine GIS and the original modeling program (most are written in FORTRAN), like SWAT/AVSWAT (Di Luzio et al., 2004), WEPP/GeoWEPP (Renschler, 2003), or EPA's BASINS (Di Luzio et al., 2002). The other type of modeling tool uses a passing-parameters method to coordinate with GIS techniques, like ArcHydro (Maidment, 2002). These applications can help researchers better understand the trends of pollution or the degree of contamination, but they use two dimensions, not three, to explain data.

5.2.2.2 *Soil and Water Assessment Tool (SWAT)*

Efforts to alleviate the effects of agriculture on water have focused primarily on abating soil erosion and properly managing chemical fertilizers. The wider designs of agricultural BMPs demonstrably provide alternative management for cropland that reduces in-field pollutant load and in-stream contaminant levels. In addition to watershed modeling tools used in previous studies, SWAT was used to estimate the pollutant load reductions between current land management and alternative BMPs (Lee and Mankin, 2007a; Lee and Mankin, 2007b; Lee et al., 2007a).

SWAT is the acronym for Soil and Water Assessment Tool, a distributed parameter, daily time step model developed primarily to assess NPS pollution from watersheds and large complex river basins. SWAT simulates hydrologic and related processes to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land-uses, and management conditions over long periods.

With SWAT, a large heterogeneous river basin can be divided into several subbasins. Each subbasin is simulated using homogeneous climatic conditions and topography, but additional subdivisions within each subbasin represent unique land cover, soil, and management combinations. Each of these individual areas is called a hydrologic response unit (HRU) and is assumed to be uniformly distributed and to inherit the geospatial properties of that subbasin. Therefore, SWAT can model specific soil, topography, landuse, climate, and management in a particular area. Major processes simulated within the SWAT model include surface and groundwater hydrology, weather, soil water percolation, crop growth, evapotranspiration, agricultural management, urban and rural management, sedimentation, nutrient cycling and fate, pesticide fate, and water and constituent routing. SWAT also uses the QUAL2e sub-model to simulate nutrient transport in the stream. In addition, PS loads and outputs from other models can be input. Major crop and management components used in the field have been added to SWAT; consequently, it better represents the actual cropping, tillage, and nutrient management practices typically used in northeastern Kansas.

SWAT uses separate ASCII text files as model inputs for watershed configuration (basins, subbasins, HRUs, channels, ponds/wetlands/lakes, or PSs); weather (precipitation, temperature, solar radiation, wind speed, relative humidity, potential evapotranspiration, weather generator, or weather forecast); land management (management operation, soil chemical); monitoring (water use, watershed water quality, stream water quality, lake water quality, reservoir, groundwater); and soil properties for each HRU (Neitsch et al., 2005). SWAT also uses a number of files in ASCII text format for model processing: model database (crop database, tillage database, pesticide database, fertilizer database, and urban landcover database), channel dimensions, auto-calibration, watershed configuration, simulation configuration, model inputs summary files. For every SWAT simulation, a couple of files are generated. These modeling outputs files are also in ASCII text format: summary of input, summary of output, HRU output, subbasin output, main channel or reach output, HRU impoundment output, reservoir output, pesticide output, hydrology, and stream water quality.

ASCII text format has a number of advantages: it can be easily read by any text editor, imported to most spreadsheet software or statistics applications, and therefore is easier for users to read modeling results. However, the disadvantages of ASCII text format are its file size without compression. When modeling a large, complex watershed with various management scenarios, the huge amount of modeling outputs will drain system resources and fill the data storage capacity of a computer, not to mention decreasing the performance of analysis because it is poorly adapted for data searching and/or sorting.

5.2.3 Geospatial Data Model and Database

Location is the element that distinguishes geospatial attributes from all other properties of an object. With location, objects are spatial and can be mapped, measured, or analyzed using the geospatial methods of GIS. The heart of any GIS is its geospatial data model (Fischer, 2006). A geospatial data model is an abstract representation of some real world situation used to organize information in a data collection. It can be used in a GIS to produce maps, perform interactive queries, and execute analyses (Zeiler, 1999). Geospatial data models typically have three major components: a set of data objects or entity types, a set of general integrity rules that constrain the occurrences of entities, and the operators applied to entities (Fischer, 2006; Miller and Shaw, 2001). A data model involves three different levels of abstraction: conceptual, logical, and physical. Atzeni et al. (1999) described the conceptual model with the entity, relationship, and attributes for easy understanding. The logical model translates the conceptual model into a system-specific data scheme, while the physical model provides a physical implementation with a given logical model (Fischer, 2006).

A spatial database, or geodatabase, is the collection of descriptions based on the spatial relationships between different georeferenced elements stored in the database. Most spatial databases use a commercial Relational Database Management System (RDBMS), such as Microsoft SQL Server, Oracle database, IBM DB2, or Informix. When users manage or access data stored in the spatial database, they use the spatial database management system and protocol. Even though the RDBMS can physically manage the relationship of georeferenced records stored in the database, interpreting the spatial meanings remains difficult. Oracle Spatial and ESRI ArcSDE are applications used with the georeferenced properties that permit the database to communicate with GIS applications. This standardizes the development processes. If different information systems in the same area to collect and manage georeferenced data in different ways, the ability to integrate the data limits the effectiveness of using information from different systems for the same element. For example, several federal agencies collected and developed their own hydrography data in the same areas for their own objects. Purpose, techniques and data differed in each case, so these hydrography maps could not be integrated. Therefore, the National Hydrology Dataset (NHD) was established with ArcHydro model to integrate information from different maps (USGS, 2008b). Thus, a unified data structure or data schema is very important in making information accessible and useful at different levels.

Following the data model definitions, a geospatial data model is a schema systematically describing geospatial representations and their relationships in the real world. It includes the main elements of RDBMS and is extended with a set of geospatial objects. The model provides practical templates or a set of "Best Practices" for the geodatabase design in various application domains. It provides a starting point for implementing a GIS information framework and simplifies data management and maintenance on default characteristics of database tables. It also allows people engaged in GIS/information system implementation in different disciplines to integrate information with limited budgets and less effort, bringing consistency and synergy to similar functions. In addition, it can serve as the data exchange protocol for similar geographic information in different research projects.

Using the data model provides an infrastructure of data management for specific disciplines. It provides a template for database implementation, and users can fill in their own data following general instructions and rules. Arctur and Zeiler (2004) define the key design parts of a data model schema: dataset, domains, relationships, spatial rules, and map layers. These are also the main structures for the geodatabase design in the ESRI ArcSDE framework (Arctur and Zeiler, 2004). Maidment (2002) developed the ArcHydro data model to describe the hydraulic and hydrology-related properties. The NHD then was based on the ArcHydro data model schema to provide an integrated framework for national surface water (USGS, 2008b). This definition of data model design focuses more on the spatial database itself and addresses data maintenance and representation issues. However, the geoprocessing steps, or process model, which processes or analyzes series of geospatial data with specific GIS functions, may be also important. For example, people who use a hydrology data model to manage surface water features may also need to use the watershed delineation function, seeking flow direction or flow accumulation for their study area. Therefore, we suggest the conceptual geospatial data model design should include these geoprocessing steps, or process model, as templates to complete data management.

Figure 5-2 is a conceptual diagram showing the elements and relationships of a geospatial data model. A geospatial data model can be separated into two major categories of objects: physical files/datasets and data model elements. The physical data within a geospatial data model can be classified by storage location, source, and georeferenced type. Most of physical data can be converted and stored in the system database environment, a RDBMS. However, to improve efficiency in accessing database data, some large and infrequently used data like aerial photo images or referenced reports should be stored outside the database as single file in specific folder under the operation system (OS). In Figure 5-2, the rectangular blocks represent the physical file or dataset, and oval blocks represent the data model elements. The physical dataset stored in the database can be classified as georeferenced and non-georeferenced. A georeferenced dataset in vector format could be grouped into several feature datasets, and data in raster format also could be grouped into raster catalogs. The non-georeferenced data, the traditional database elements, can be stored as look-up tables and general data tables, either an ID number-landuse type lookup table or modeling results with time series attributes.

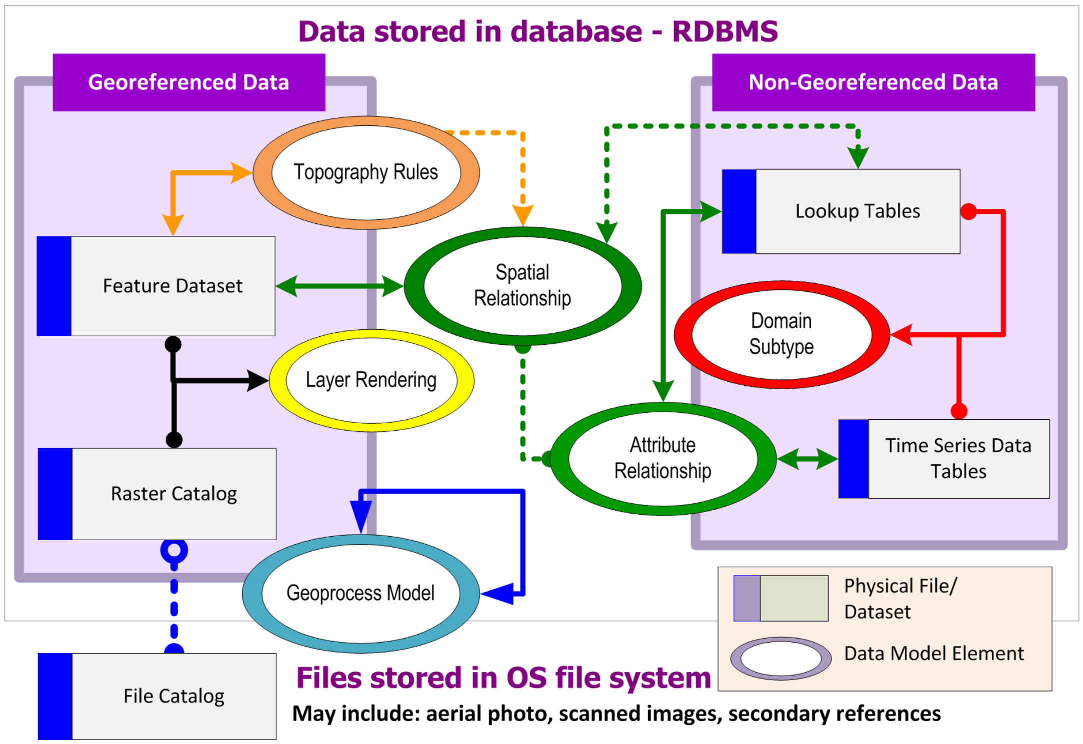


Figure 5-2 Conceptual Diagram for Element and Relation in Geospatial Data Model

This study has five geospatial data model elements: relationships, either spatial or attribute; topographic rules; data domain or subtypes; layer renderings; and geoprocess models. In Figure 5-2, green ovals represent the relationship element, describing two physical data tables in either spatial or attribute relationships. This is similar to the table relationship in traditional RDBMS but addresses the geospatial properties of the data. Topographic rules, the orange ovals in Figure 5-2, describe not only the geospatial relationship between two features but also manage the behavior between or integration of these features in space. For example, in applying topographic rules in data models, the watershed outlets or PS discharging outlets will always remain with the stream network. The domains or subtypes, the red ovals, are a list of rules for validating attribute values of specific table columns. They maintain the data integrity among software applications while importing/exporting datasets. GIS includes the dynamic, interactive user interface for spatial data visualization. Some common symbols, colors, or annotations have become standards for general use and public understanding. Therefore, the layer rendering, shown by the yellow ovals in Figure 5-2, addressed the visualizing specifications, or how features should be symbolized and rendered in presenting data. The last data model element is the geoprocess model. The geoprocess model describes the standard geoprocessing steps and functions for producing new feature or raster datasets, and their ancillary information in data models. For example, the processes for converting USDA NRCS SSURGO soil dataset to SWAT modeling inputs are complicated and tedious. Standardized processes allow us to produce reliable information. The geoprocess model is shown as a cyan oval.

Arctur and Zeiler (2004) listed all five geospatial data model elements except geoprocessing as the key parts of geodatabases. We consider the geoprocess model important because the georeferenced properties of a geoprocessed dataset need to be consistent with and inherited from its sources. Traditional spatial database design focuses on database element arrangement and data structure normalization. The only difference between traditional spatial database design and the geospatial data model is the georeferenced observation. In other words, a geospatial data model is a template to enable GIS. However, from the stand point of data processing, if the geospatial data model only stored datasets but did not guide users in processing data, any inappropriate functions or steps will mar the integrity of the geospatial information, which could be catastrophic. Furthermore, similar modeling data could be acquired from several sources. For example, watershed DEM can be acquired from USGS National Elevation Dataset (NED), the newer LiDAR data, GPS, or even regional field surveys (USGS, 2006). Each source can provide equal or higher quality surface elevation information if potential geoprocess models are applied to transform data between vector and raster format as well as between different resolutions or projections. Therefore, including the data geoprocessing model in the geospatial data model design could help users clarify the data processing steps.

Figure 5-3 shows the partial design elements of a geospatial data model for delineating the subbasin within a watershed. Blocks with different colors represent the different design element properties from Figure 5-2. In Figure 5-3, the geoprocess model “Subbasin Delineation” used the model flow direction and watershed DEM data to delineate the subbasin area of the watershed. The delineated subbasins were then grouped into the “Hydrology” feature dataset. To visualize the subbasin area, a layer rendering rules “Subbasin” was designed. The relationships between features and data tables as well as constraints were also applied. A topographic rule, which required every subbasin be in the watershed and also share the boundary of watershed, was developed.

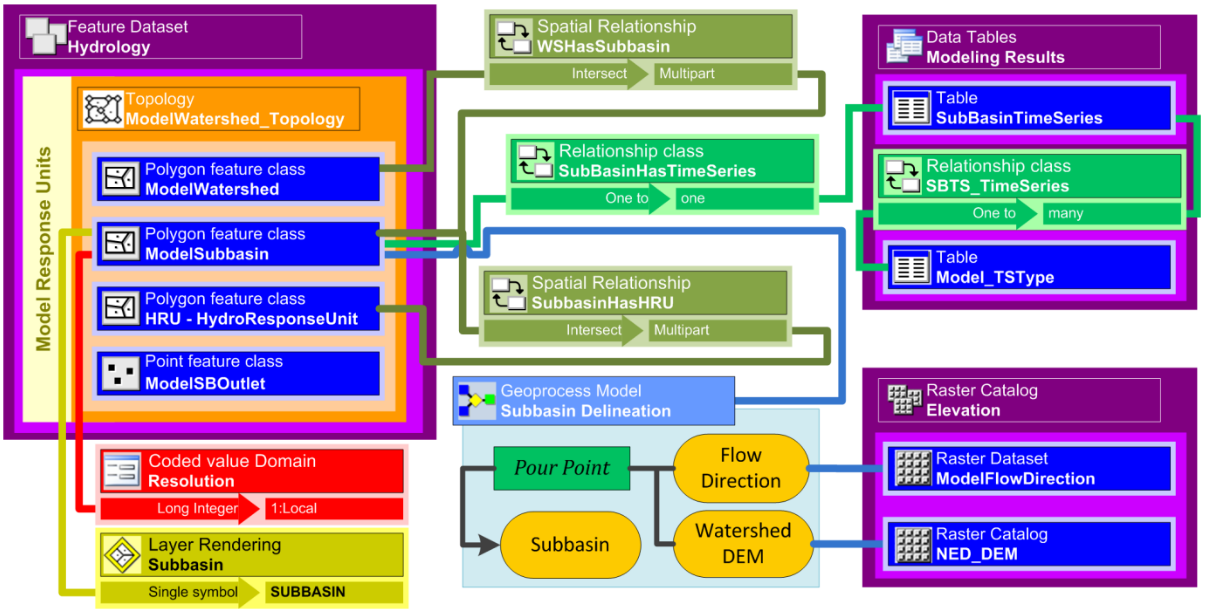


Figure 5-3 Partial Geospatial Data Model Design for Subbasin Delineation

5.2.4 Decision Support System

A decision support system (DSS) provides users with integrated tools to help them better manage decisions. Generally, these tools include databases, simulation models, and some expertise (Shaffer, 1995). GIS can help people to gather information in two or even three dimensions, instead of using the traditional text and table descriptions. However, the quality of decision making does not depend solely on the amount of data; it also depends on the clarity and transparency of key information. The difficulty is how to display suitable information on the DSS and also have the DSS work reasonably well, not producing "garbage in, garbage out" processes. One discipline's techniques can be introduced into a DSS to help simulate another discipline's process. For example, Wang et al. (2002) introduced a routing theory, originally used in traffic analysis, which, coupled with a water quality model, estimated possible pollutant/effluent transport paths. In Figure 5-4, each dot represents a source of pollution, with different colors for different pollution characteristics. The lines conjoin possible pollution sources and sinks in the transportation process, with the color of the line representing the degree of the pollution (Wang et al., 2002; Wang et al., 2005).

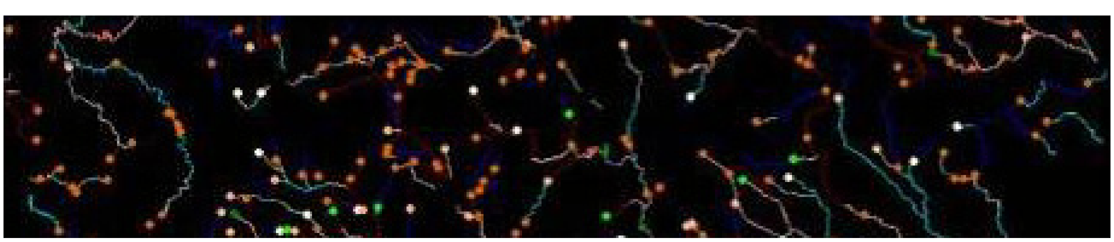


Figure 5-4 GIS-ROUT Systems (Wang et al., 2002)

5.2.5 Web-based System and Internet GIS Map Service

Web-based application systems could provide the advantages of both low cost and easy access. Web browsers are a basic part of every computer system, so a system constructed using a web-based structure means almost no cost for application acquisition on the client side. The new multimedia technologies and data transmit protocols make it possible to deliver vivid graphics and multidimensional visual effects. Internet map services provide vivid graphics and visual effects with georeferenced information. Several commercial applications, like Autodesk MapGuide or ESRI ArcIMS (Autodesk, 2009; ESRI, 2009b), can provide these functionalities. Some private companies and government departments also combine internet map service and their own logistics to provide professional services. USDA-NRCS Soil Data Mart and Geospatial Data Gateway website provide soil data, both tabular and spatial (NRCS, 2008a; USDA, 2008).; USGS National Map website provides online, interactive map service with no special software or download required. For location-based service, private Google Map and Microsoft Virtual Earth combine network route and internet map services to construct a web-based GIS application using the new AJAX structure.

The web-based GIS system does not merely display a static map with fancy multimedia effects; it can be set up for decision support. Such a system, enhanced by DSSs and GIS tools, can be combined with other readily available tools to store and analyze watershed information, which could make a WQT system work well. Other tools include HYMAPS-OWL (2004), which can provide online watershed delineation, hydrologic data preparation, and online digitizing for later watershed model use. GREAT-ER (2003) original is another tool created to study the impact of chemicals emitted by PSs into rivers but adaptable to WQT. The web version of GREAT-ER has been available for public access since 2003, providing easy access. Moreover, in WQT research itself, NutrientNet (WRI, 2007) provides a web-based, on-line trading tool that allows stakeholders to assess trades, as well as providing a platform for bidding trading credits. However, NutrientNet uses only internet map services for locating fields or facilities (WRI, 2007). All of these tools can help us create a platform for assessing watershed information and exchanging information necessary for WQT stakeholders to make decisions.

5.3 Implement WQTIPS

In using all these data sources and tools, our goal for WQT becomes possible. Our purpose in creating a WQT information platform system (WQTIPS) was to provide an information platform for exchanging data and assessing that data for potential WQT stakeholders. Within WQTIPS, stakeholders would learn the potential pollutant load for each management scenario, the potential trading benefits of a trade, and potential trading partner information. A less obvious purpose of WQTIPS is to make the process of acquiring and processing these data easier, which would minimize the transaction cost of WQT. Therefore, collecting relevant WQT information, simulating potential scenarios, managing WQT data, and providing a visualized WQT assessment tool with a user friendly interface should be our goals in implementing WQTIPS.

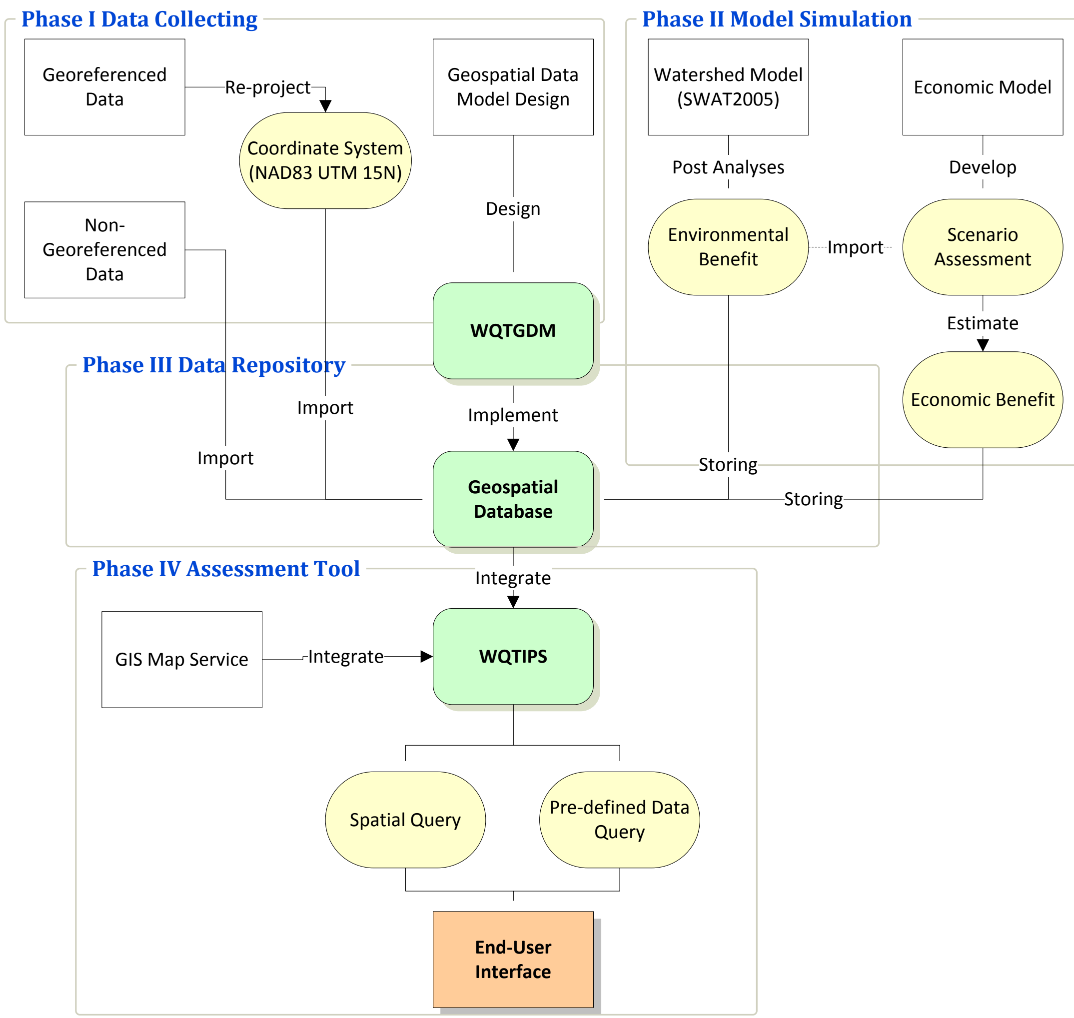


Figure 5-5 Flowchart for WQTIPS Implementation Processes

Given these purposes, implementing WQTIPS falls into four phases: (1) Data Collection, (2) Model Simulation, (3) Data Repository, and (4) Assessment Tool. Figure 5-5 listed the four phases and the major tasks for each phase. Collecting data for WQTIPS fulfills the data requirements of the WQT program. WQT data requirements were developed as a geospatial data model that describes the general requirements of the dataset and the data structure of a WQT program. Model simulation uses the selected watershed model and economic model to estimate the potential benefits of a trade. The data repository stores collected information, modeling estimates, and statistics. In practice, the data repository is the implementation of the geospatial data model design in phase one. The assessment tool provides an interface for WQT stakeholders and end-users to access WQT information. Of these four phases, model simulation has been discussed in previous sections and chapters, so in following sections, we describe the design details and processes for the other phases.

5.3.1 Conceptual Design of WQT Geospatial Data Model (WQTGDM)

Based on the design criteria of the geospatial data model, a conceptual design of WQT geospatial data model (WQTGDM) was developed (see Figure 5-6). This conceptual design was based on the data requirements of modeling inputs, post analyses, and data visualizations. The standard relational database design guidelines usually propose a fully normalizing design, only selectively de-normalized where doing so addresses performance issues. However, the watershed model is one of the major elements in WQT assessment and WQTGDM. Some data tables which related to watershed modeling in WQTGDM are not suitable for data normalizing to third normal form (3NF) (Kimball, 2002). These tables will be kept as the original formats in watershed modeling tool.

To distinguish data sources and an easy to maintain database, WQTGDM used ten major categories, each based on its role and purpose in WQTGDM. Basic information about watershed physical properties such as “Topography,” “Soil,” “Landuse,” and “Hydrology” was added; model settings and their parameters were stored in either “Watershed Model” or “Economic Model” categories. For modeling simulations, historical climate data like precipitation or temperature were listed in “Monitoring,” and potential trading information was classified in “Pollution Source.” Modeling results were then stored in “Estimation.” For WQTIPS, “Basic Map” was added to enhance data visualization and presentation. This conceptual design of WQTGDM provides the broad direction of geodatabase design in WQT. For the geodatabase summary in Figure 5-6, only the recommended data elements and relationships were defined and listed, more optional information could be added. Moreover, all listed datasets can be replaced by any equivalent or newer sources of the same thematic information in the required data structures.

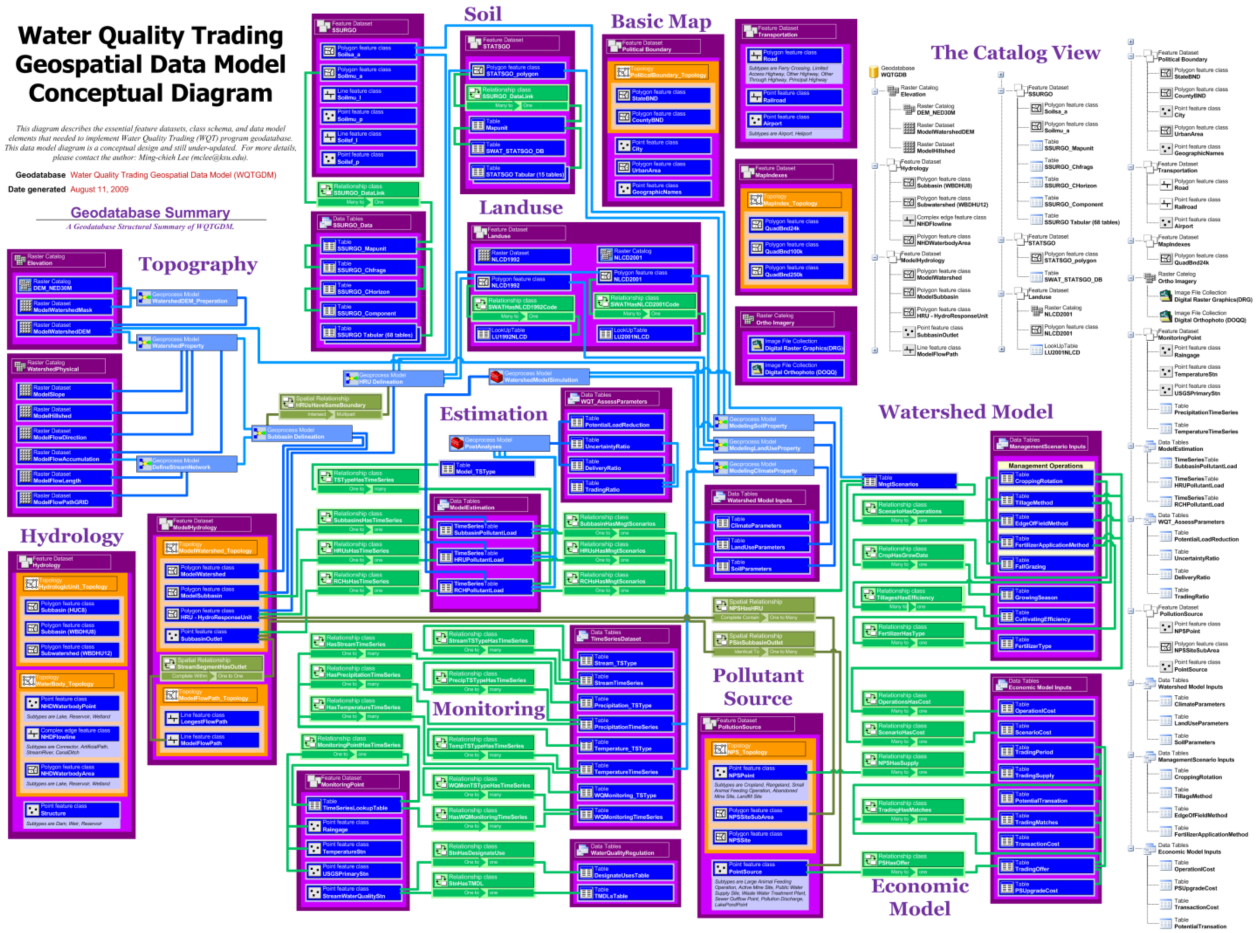


Figure 5-6 Geodatabase Summary of the Conceptual Diagram of WQTGDM

The "Hydrology" category included most datasets in hydrology research using GIS techniques. Designed using ESRI's Hydro Data Model template, the category also uses the designs in ArcHydro and NHD geodatabase structure (Maidment, 2002; USGS, 2008b; ESRI, 2009a), as well as incorporating the stream network design from NHD: the hydrography of stream network or hydrologic units of watershed boundary for advanced network analyses with ArcGIS Network Analyst extension (ESRI, 2006). The category has been fine tuned with watershed modeling inputs like modeling subbasin or HRU boundary, subbasin outlets (pore points), the modeling flow path or the longest flow path in each subbasin. This category provides basic information for watershed delineation and stream network in watershed modeling processes and provides an external link to NHD for the other optional information and further analyses.

The "Topography" included the two major raster catalogs and several geoprocess models that were prepared for watershed modeling and as the base of system geospatial data. The "Elevation" catalog included watershed digital elevation layers from the 30 meters by 30 meters DEM from National

Elevation Dataset (USGS, 2006). Another raster catalog, the "Watershed Physical," containing the geoprocess model with such information as contour line, flow direction, flow accumulations, slope, or hill-shade grids in either raster or vector formats, were also integrated into this category. The geoprocess models in this category were conjoined with the other watershed physical properties like soil or landuse to develop the watershed physical topography information in a raster catalog, "Watershed Physical," or to delineate subbasin or HRU into the "Hydrology" category. The datasets in "Topography" have higher priority in data processing in the whole data model. Once the georeferenced properties of these datasets have been defined, the other categories will follow the defined georeferenced characteristics: projection, coordinate system, or raster resolution.

Landuse, or landcover, datasets are the basic inputs of watershed modeling tools like SWAT. In Kansas, several sources provide decent landuse information for public use. For example, the Data Access & Support Center (DASC) hosted by the Kansas Geographic Information Systems (GIS) Policy Board provides 10 classes of Land Cover, a Land Cover Patterns map, and the Kansas GAP Analysis Land Cover dataset for public download (Kansas GIS Policy Board, 2007). USGS also provides the 1992 and 2001 National Land Cover Databases (NLCD 1992 and NLCD 2001), and their successor, NLCD 2006 revision for all of Kansas (USGS, 1999; MRLC, 2008). The major issue with these landuse datasets is how to match their classifications to each landuse as defined in watershed modeling tools. A suitable lookup table should maintain the relationship between landuse source and watershed model. In this category, the landuse data structure for NLCD 1992 and NLCD 2001 as well as the associated lookup tables are listed for demonstration. This data could be replaced by any potential landuse data source and a watershed model other than SWAT.

Soil is another basic input of watershed modeling tools. It is an important watershed property that describes the field conditions and potential water usage. SSURGO and STATSGO, developed by USDA NRCS, are two commonly used soil datasets for Kansas. The original SSURGO and STATSGO version 1 have different data structures and classifications of attributes (NRCS, 1997; NRCS, 2008b), but the newly upgraded STATSGO version 2 (General Soil Map) has a data structure similar to SSURGO (NRCS, 2008b; NRCS, 2008c). However, certain watershed modeling tools were originally designed for the old STATSGO soil dataset, making it necessary to develop a program or geoprocess model to convert and tailor the soil data source to fit the required soil properties format of watershed modeling tools. In Figure 5-6, both SSURGO and STATSGO data structures were included. As with the landuse data sets, they could be replaced by any soil data source.

The datasets in “Watershed Model” and “Economic Model” categories include the necessary parameters for modeling processes, the lookup tables, management scenario designs, and some empirical information or previous modeling estimates like implementation costs, transaction costs, or farmer willingness. These two categories should provide a variety of modeling scenarios for WQT that would help researchers and stakeholders to see potential modeling results under different management scenario pairs. Figure 5-6 shows the necessary datasets and their data structures for the watershed model, SWAT2005 (Neitsch et al., 2005), and the economic model, the econometric model developed by Peterson et al. (2007) and trading simulation model developed by Smith (2004).

The “Monitoring” category includes two measures: the historical climate data in the study watershed and water quality in the stream network. All information was collected from verified gages. Different watershed models, using different hydrology hypotheses and methods, need different climate data. For example, SWAT2005 needs precipitation and maximum and minimum temperatures for its default model simulation method. Extra historical climate data such as solar radiation, wind speed, or relative humidity are only necessary when applying different infiltration or evaporation methods (Neitsch et al., 2005). Therefore, the designs of data structure in this category must include all required information. Figure 5-6 shows the datasets of daily precipitation and temperature, acquired from NOAA NCDC, and the required relationship classes.

The “Pollution Source” category includes both potential PS and NPS information. For the potential PS, data could come from facilities in the National Pollutant Discharge Elimination System (NPDES) list or be collected from the field survey and government reports. Locating the exact outlets of pollution sources for the potential NPS would be difficult. Therefore, all agricultural lands were included in the potential NPS list. Figure 5-6 assumes each subbasin area represents one or more potential NPS, and the subbasin outlet is the presumable point of NPS.

Both the modeling outputs and post analyses for each design scenario were grouped into the “Estimation” category. Converting units or raw data of modeling outputs into readily available styles for analysis was necessary. Some external programs or scripts could be tailored for the final products of model simulations, such as water yield or pollutant loads, for statistical analyses like uncertainty ratio, delivery ratio, or TR. Moreover, most watershed outputs and analyzed results are time series data, estimated in yearly, monthly, or daily time steps. Thus, the time stamp for each record is an important attribute for these datasets.

For data visualization and presentation, other ancillary geospatial data (political boundaries, transportation elements, cartography annotations, or orthoimagery) are needed to present background information. All these layers are optional in basic design and could be added depending on the researcher's theme map design. In Figure 5-6, the "Basic Map" included political boundaries, transportation, map indexes, and ortho-imagery catalogs used in the study case. All of these data were acquired from government agency resources like the USDA NRCS Geospatial Data Gateway, National Atlas of the United States, or Geospatial-One-Stop from USGS (USGS, 2008a; USDA, 2009; USGS, 2009).

5.3.2 System Design and Implementation

Integrating WQT information with GIS involves two major tasks. The first is to implement WQTGDM with the spatial database application, a database management system with spatial functions. This spatial database application can be commercial software like ESRI ArcSDE with RDBMS, Oracle Spatial, or MS SQL Server 2008, or an open source database such as PostgreSQL with PostGIS spatial extension. All the georeferenced and non-georeferenced data of WQT can then be managed by the geospatial database. The second task is to integrate a GIS map service to visualize the WQT information. As with the database applications, several commercial and open source GIS map service applications are available, such as ESRI ArcIMS, ESRI ArcGIS Server, Autodesk MapGuide, or Google Maps. With these two tasks complete, a GIS-based web interface system can be designed with three-tier architecture.

The three-tier architecture uses the presentation tier, application tier, and data tier. The presentation tier displays information related to such topics as browsing potential pollutant loads, estimating benefits, or searching for potential trading partners. It may also visualize georeferenced information with the GIS map service. This tier communicates with other tiers by outputting results to the web browser or the other tiers in the network. The application tier, the Business Logic or the Logic Tier, pulls out the user inputs from the presentation tier and then parses the information with one or several application functions through detailed processing. The tier might query data from the data tier or just feed the processing results back to the presentation tier. The data tier usually consists of a database server and several data storage units. The system information is stored and retrieved in this tier, keeping all the data outside the other two tiers and making data management highly scalable and high performance.

To create easy access to the WQT program, the presentation tier was implemented with a web browser environment as a client-side, end-user interface. The internet GIS map service application, ESRI ArcIMS 9, is the intermediate application in application tier to process spatial query requests and to provide geospatial visualization. The web server, Microsoft Internet Information Service (IIS), also handles data queries and transactions in the application tier. In the data tier, an RDBMS, Microsoft SQL Server 2005, and the spatial database application, ESRI ArcSDE 9, were integrated to provide data storage and database core functions. Figure 5-7 illustrates the system design of WQTIPS. To the left in Figure 5-7 are the necessary system elements for the three-tier design. And to the right in Figure 5-7 are the applications that implement WQTIPS in this study.

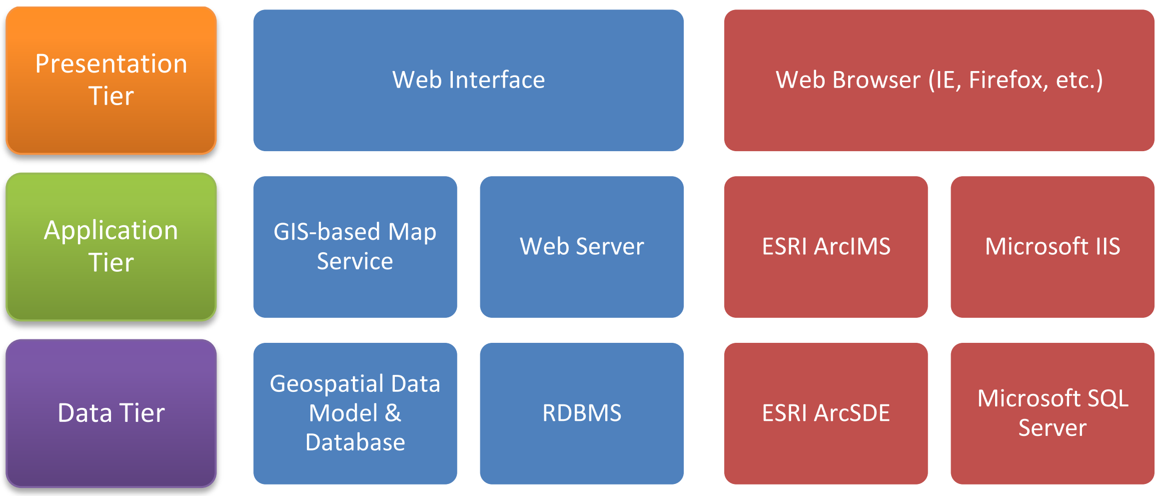


Figure 5-7 Three-Tier System Design and Implement for WQTIPS

Based on this system design and these applications, a GIS-based web interface WQT assessment tool, WQTIPS, was implemented. Users with any compatible web browser and an internet connection can access WQTIPS. Moreover, a GIS-based web interface system is easy to use with no download of client side applications and no installation of any GIS software on the client side.

5.3.3 End-User Interface

The client-side, end-user interface design uses the general webpage and the GIS map to maximize data presentation and visualization. There are two major page styles for the end-user interface. The first is the data query page style, and the other is the geospatial information visualization page style. The data query page style focuses on selecting and listing data, and as such, has an input box, drop-down list, and tables. Data query page design has several variant styles. Figure 5-8 illustrates one concept for data query page style. In Figure 5-8, the top panel provides quick access links for functions that help users access other system functions quickly and easily. The left panel allows users to select inquiry conditions. The center section presents the information resulting from queries.

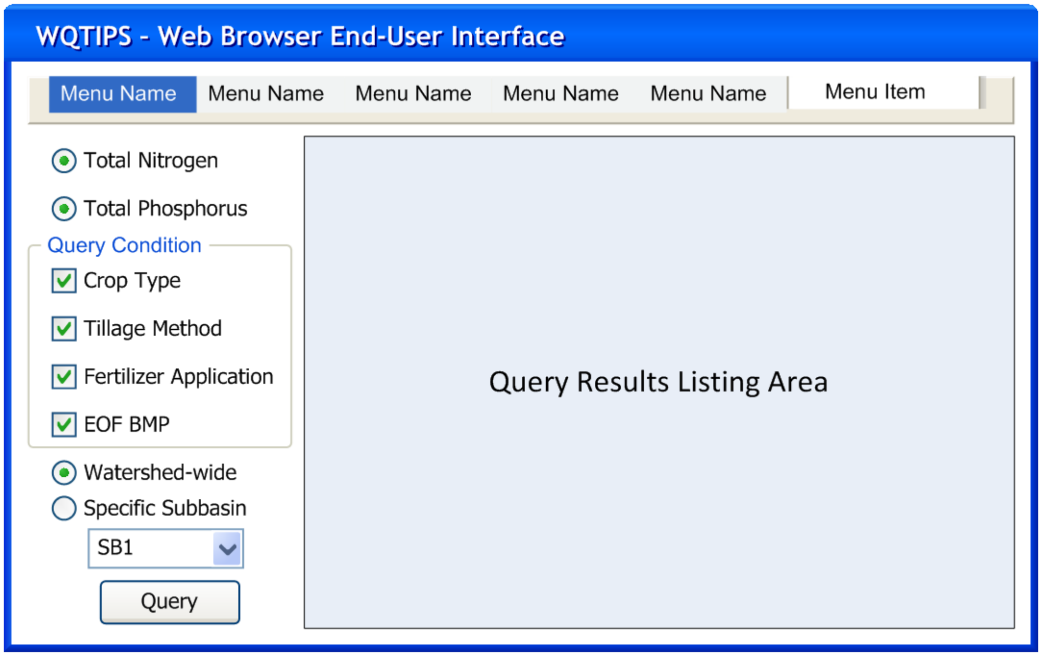


Figure 5-8 Conceptual Design for Data Query Page Style of WQTIPS

To provide geospatial visualization of WQT information in the geospatial information visualization page style, design concepts maximize the map presentation area and integrate other data analyzing functions in several small toolbars. Figure 5-9 illustrates a general design for a geospatial information visualization page style. The general map presentation area occupies the center of page. It presents visualized geospatial information and an optional overview of whole area. To the right of general map area is the control panel, which hosts the map layer control and legend. For each map layer listed in the map layer control, a user can decide to display or hide that layer in the general map area. By clicking the layer name, users also can query the spatial properties of that layer. For the general map, operations like zoom, pan, identify, or select are grouped in the top toolbar. For layer control, the relative functions are arranged in a control toolbar on the top of the Control Panel. Some advanced data analysis or query functions, such as SQL queries, buffer selection, or hyperlinks, are placed in the function bar at the bottom of the general map area. The Data Query Panel, which hosts the data query results and displays some important information, lies below the function bar. Figure 5-10 and Figure 5-11 are screen captures of these WQTIPS pages.

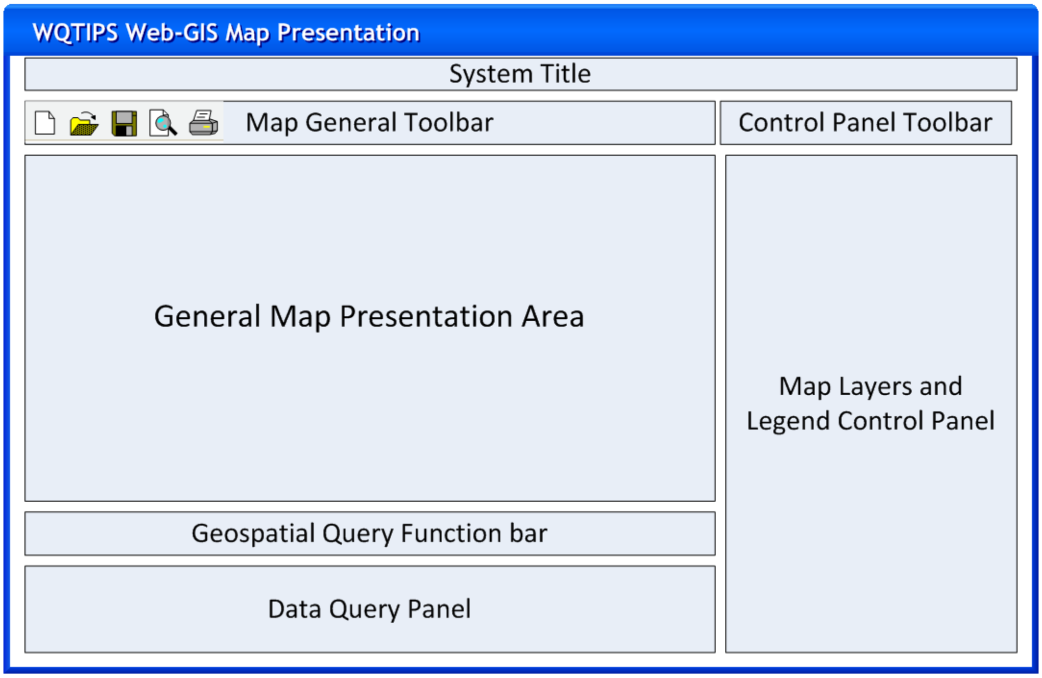


Figure 5-9 Conceptual Design for Geospatial Information Visualization Page Style of WQTIPS

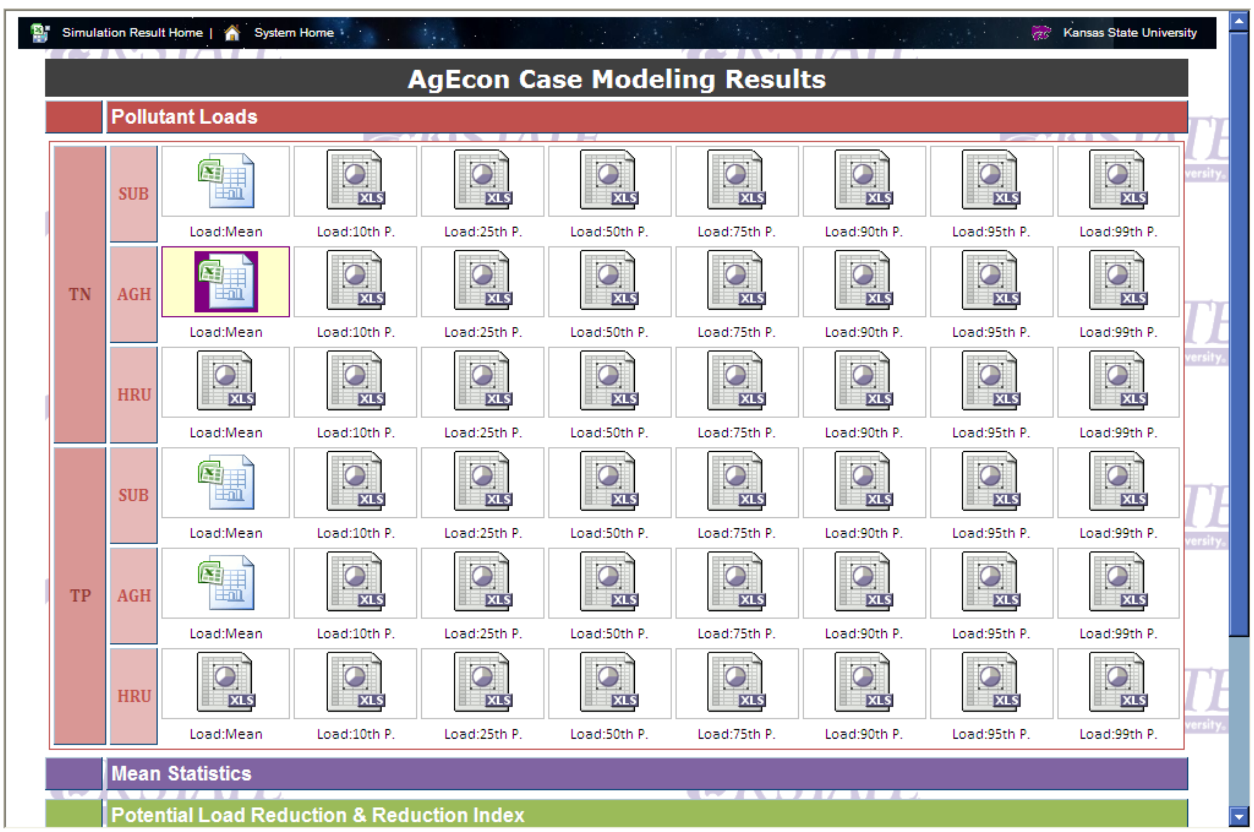


Figure 5-10 Snapshot for the Modeling Results Page in WQTIPS

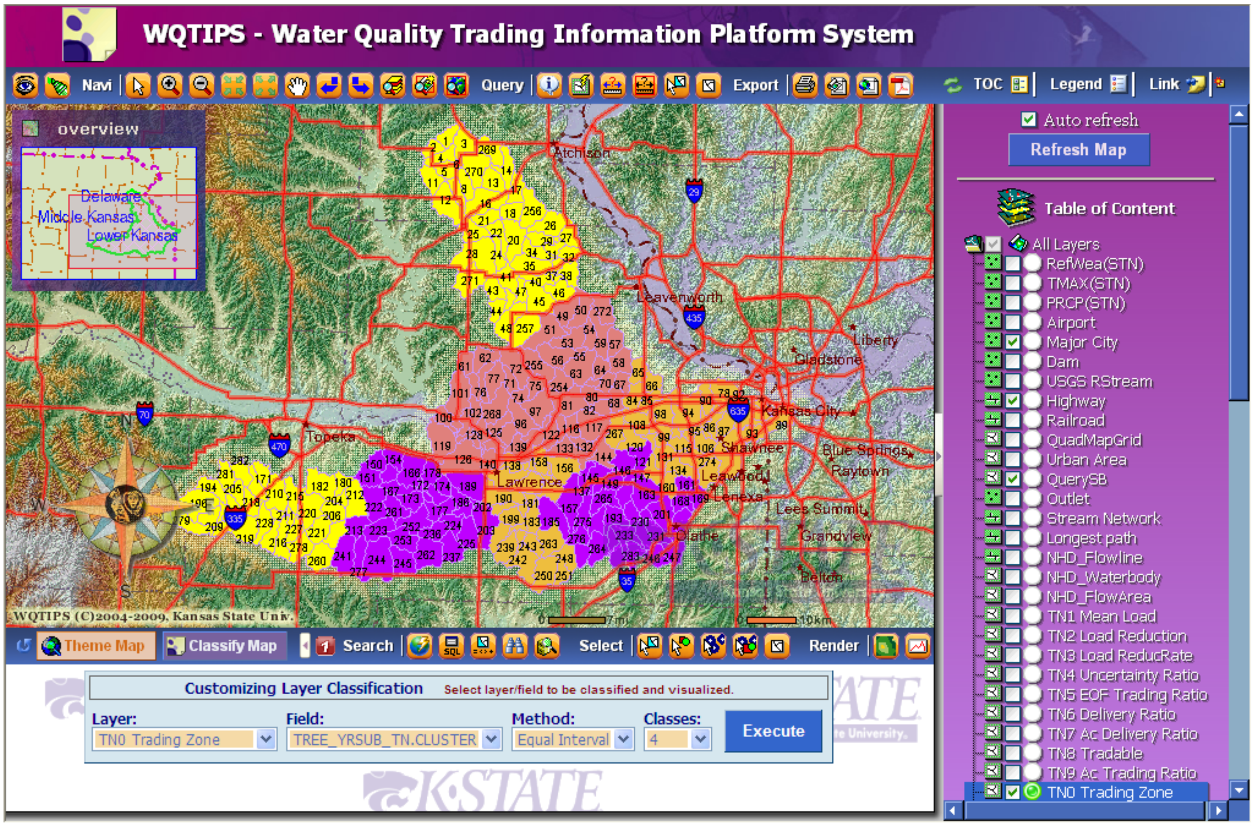


Figure 5-11 Snapshot for Geospatial Information Visualization Function in WQTIPS

5.3.4 Assessment Function

Based on the end-user interface design, several functions in WQTIPS were developed as major assessment tools so stakeholders can assess potential WQT benefits. The first function provides stakeholders the ability to evaluate potential pollutant loads for each scenario or selected groups like crop rotation and tillage method. The second function allows stakeholders to choose the current scenario and alternative scenario from a list to evaluate potential pollutant load reduction or an uncertainty ratio within the management scenario changed. The third function allows stakeholders to select the location of trading partners from the subbasin list to see potential delivery effects. The fourth function helps stakeholder understand the potential TR in the trade while choosing location and alternative scenario from the list. The fifth function helps stakeholders visualize the selected scenario with its potential pollutant load or TR across the watershed, and then helps stakeholders understand the patterns of potential benefits within the area. The conceptual processes of these assessment functions are illustrated in Figure 5-12.

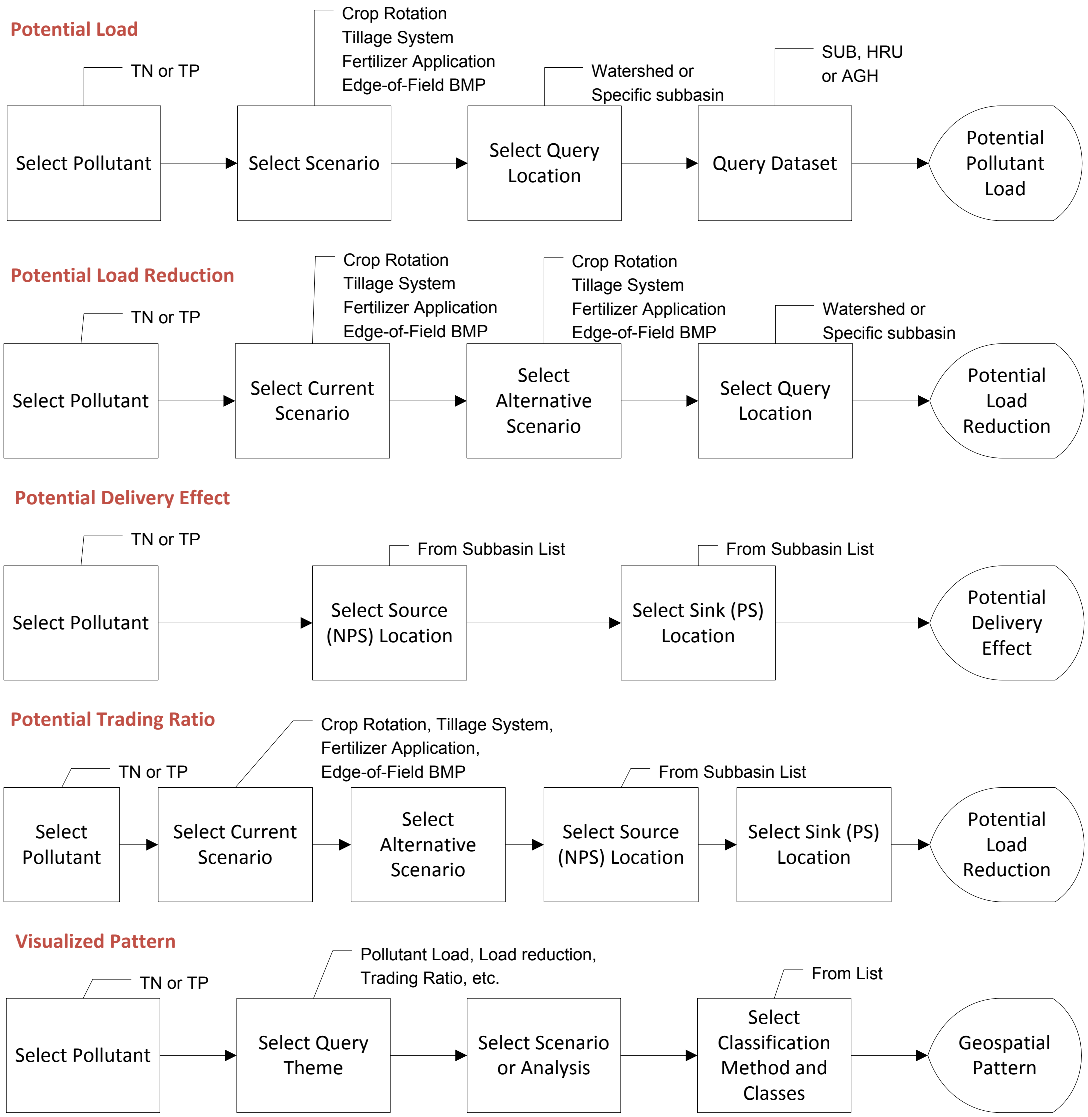


Figure 5-12 Conceptual Processes for the Assessment Function of WQTIPS

Using the conceptual processes illustrated in Figure 5-12, the user interfaces were implemented. Figure 5-13 illustrates the end-user interface for querying potential pollutant load, and Figure 5-14 illustrates the interface for querying the TR of a specified alternative scenario pair. In Figure 5-13, users first decide which pollutant and then select scenario characteristics that interest them: crop, tillage, fertilizer application, or edge-of-field BMP. Users then either query the watershed-wide information or focus on a specific subbasin by selecting the subbasin number from the drop-down list. An optional selection for those interested in the other data subsets can be applied in Query Dataset section. As in Figure 5-14, users first choose the characteristics of the current and alternative scenarios and then decide the query area and dataset; query results will be listed in the returning pages.

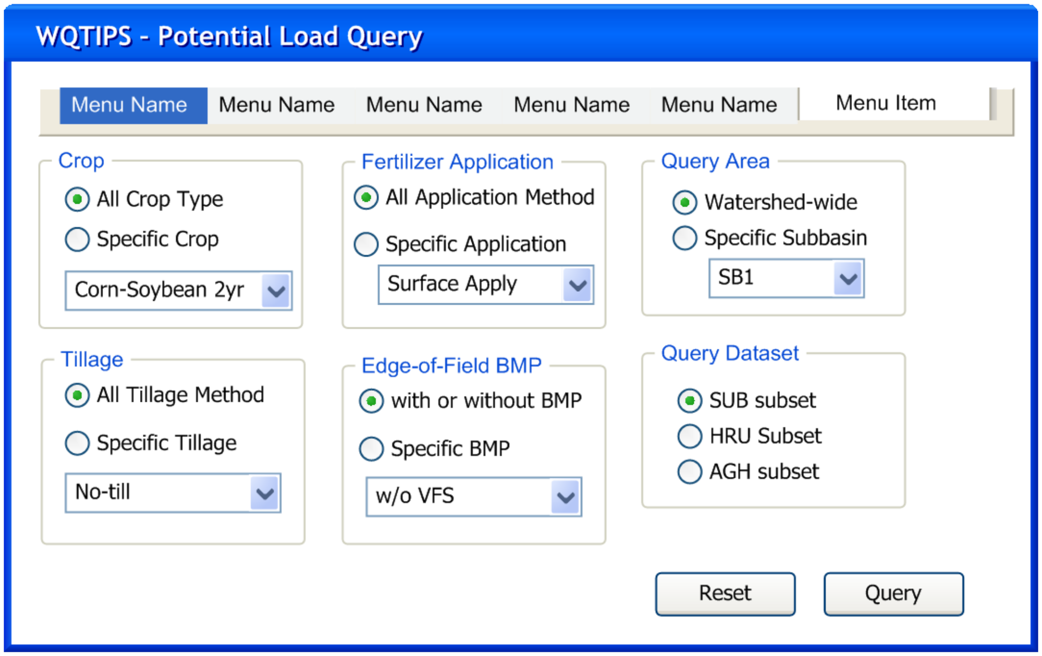


Figure 5-13 Interface Design for Querying Potential Pollutant Load

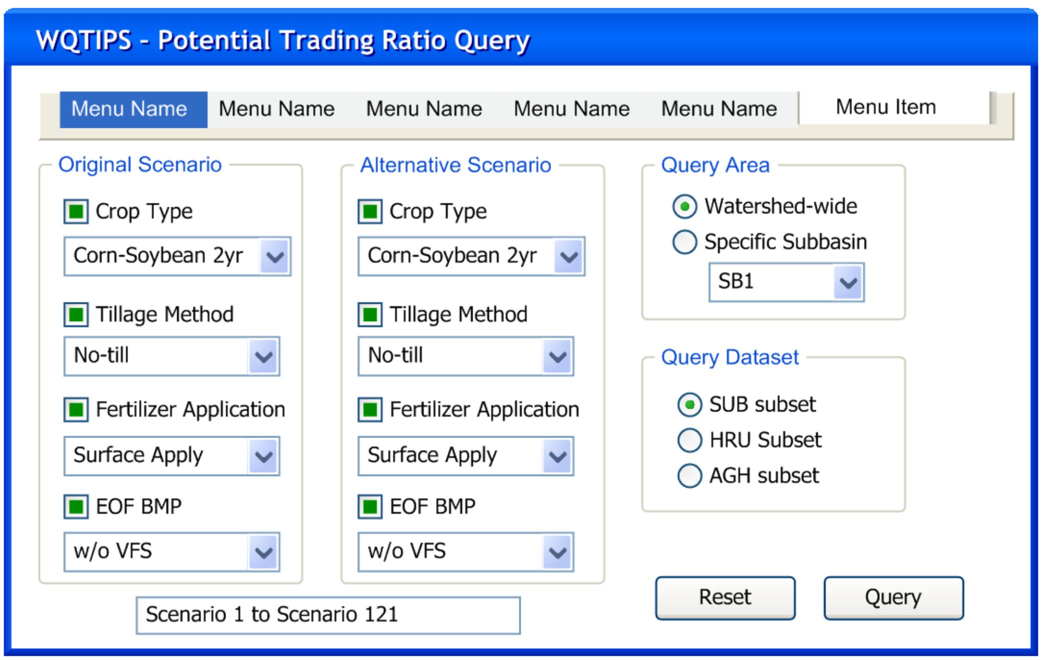


Figure 5-14 Interface Design for Querying TR of the Specified Alternative Scenario Pair

With the design and criteria, WQTIPS was then developed. Figure 5-15 shows the main page of WQTIPS in this study. It provides a portal for users to access topics of interest like Model Simulation or System Scenario Design, or interactively queries the WQT information in Thematic Map Viewer or WQT Assessment Tool sections. Figure 5-16 shows the interface design of the interactive map querying for the potential load reduction for specific alternative scenarios. Other than these assessment functions and the design criteria mentioned above, several other minor functions and detail designs not listed here were also developed to assist the WQT assessment processes. All design details and functions can be seen by visiting the WQTIPS demonstration website via our research webpage.

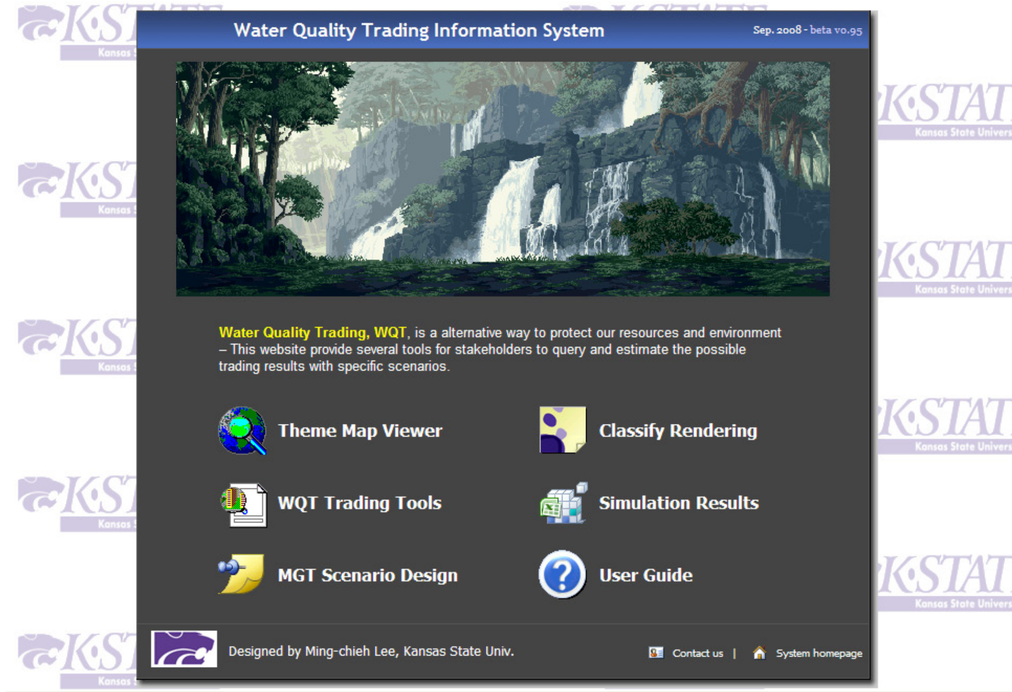


Figure 5-15 Main Page of WQTIPS

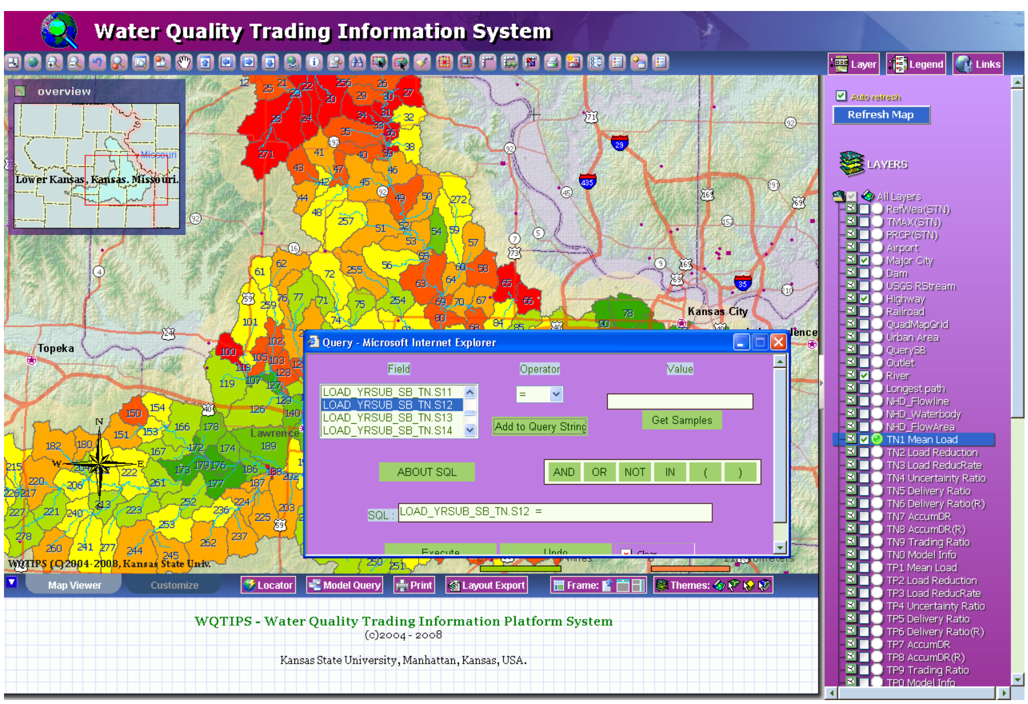


Figure 5-16 Data Query Interface Design in WQTIPS

5.4 Case Study

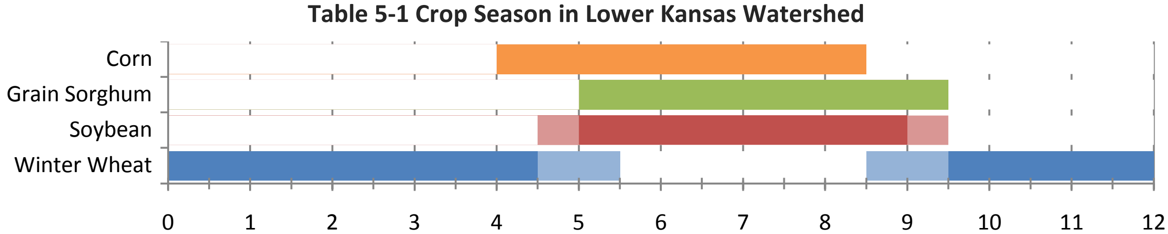
5.4.1 Study Area

To test and verify WQTIPS, we used a case study to illustrate the methodology. As in previous WQT studies, the Lower Kansas watershed (HUC8: 10270104) was used to asses tool system implementation (Lee and Mankin, 2007a; Lee and Mankin, 2007b; Lee et al., 2007a). The watershed is in the Kansas and Delaware River Basin (HUC6: 102701) in northeastern Kansas. It encompasses a large proportion of the Kansas population within its 429,000 ha (1,060,000 ac) drainage basin, which also includes many and diverse PS and NPS pollutant contributors. Nearly all (99.6%) of the basin lies in Atchison, Douglas, Jefferson, Johnson, Leavenworth, Osage, Shawnee, Wabaunsee, Wyandotte, and Wyandotte counties of northeastern Kansas, with only 0.4% in Jackson County, Missouri. Grassland and woodland cover approximately 46% of this area, with 18% in crop land, 17% in forest, and 2% in water classes. The maximum elevation is 424 m and the minimum elevation is 220 m, with an average of 301 m. The watershed was delineated into 286 subbasins in previous modeling research (Lee and Mankin, 2007a; Lee and Mankin, 2007b; Lee et al., 2007a). Figure 5-17 presents the environment of the watershed.

Corn and soybeans are the major corps in this area, with some alfalfa, wheat, and grain sorghum. Corn and soybeans are sometimes rotated but are planted continuously in some fields. In the valley upland, more wheat and grain sorghum is planted. The crop season in this watershed is shown in Table 5-1. Most tillage in this area is conventional (disk, chisel, and field cultivated). More no-till and reduced till is used in the upland area. Most land under conventional tillage is disked and chiseled soon after harvest. In the upland, most farmers pasture cattle during the winter after corn or grain sorghum harvest and do no tillage until the following March.

From this information and the publications of Kansas State University Agricultural Experiment Station, the crop seasons in this area are corn (April to September), soybeans (May to September), grain sorghum (mid-June to late-October), and winter wheat (mid-October to the following June) (Shroyer et al., 1993; Shroyer et al., 1996; Fjell et al., 1997; Shroyer et al., 1997; Fjell, 1998; Fjell et al., 2007). Table 5-1 lays out the general crop season for the four major crops in northeastern Kansas.

Table 5-1 Crop Season in Lower Kansas Watershed



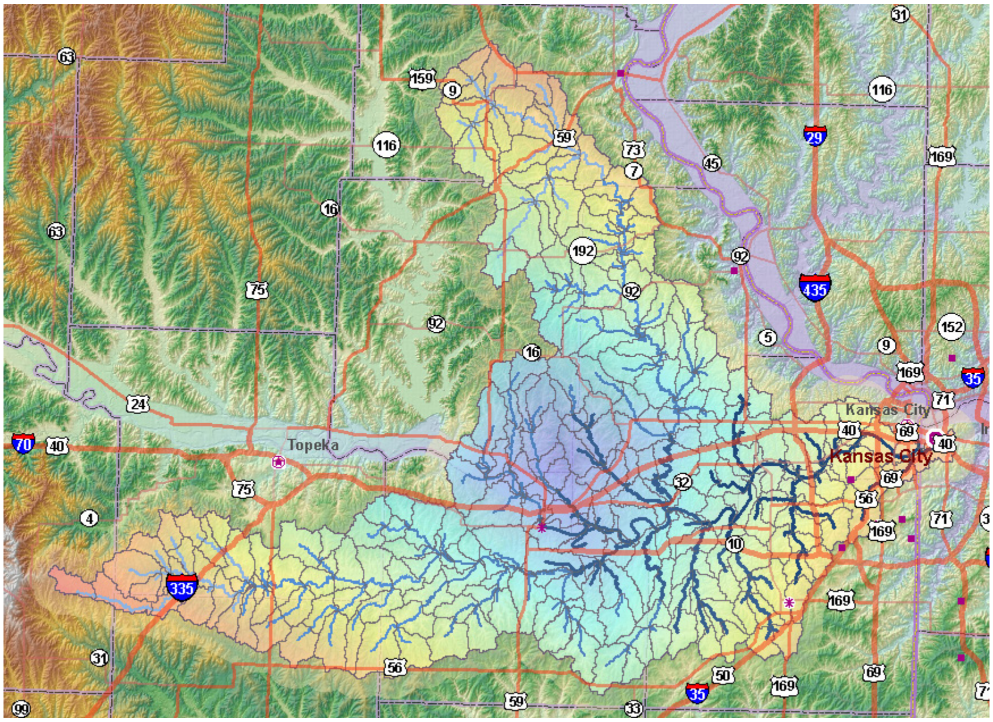


Figure 5-17 Lower Kansas Watershed, Northeastern Kansas

5.4.2 Data Collection and Preparation

The geospatial referenced data which describe watershed topography, landuse/cover, soil types and attributes, and climate were collected from several government agencies. The 30-m resolution DEM dataset of the study area was downloaded from USGS National Elevation Dataset (NED) (USGS, 2006). The quality landuse and landcover data, NLCD 2001 (2001 National Land Cover Data) dataset, were acquired from the MRLC website (MRLC, 2008). One of most widely used soil survey databases, the 1:24,000 Soil Survey Geographic Database (SSURGO), was preprocessed with a customized application for the SWAT model (NRCS, 2008b). Digital stream network information, historical stream discharge from available gauging stations within the watershed, and upstream ponds and reservoirs storage data were collected from NHD (USGS, 2008b) and manipulated. The long term daily climate data included precipitation and maximum and minimum daily temperature were also downloaded from NCDC Daily Surface Data webpage for the period from 1960 to 2006 (NCDC, 2009).

Potential land management practices, plant/crop growing information, field operations, and fertilizer applications were collected from watershed specialists and professionals of the Kansas State University Extension Service as well as from a literature review, the USDA NRCS field office, and the USDA NRCS electronic field office technical guides (eFOTGs) website (Barnes, 2006; Boyer, 2006; KSU, 2006; Maddux, 2006; NRCS-Kansas, 2006; NRCS, 2008d). This information was applied to provide potential alternative land management practices and the appropriate inputs for the model. Geospatial referenced digital data were re-projected to a Universal Transverse Mercator (UTM) coordinate system (NAD 1983 UTM Zone 15N [spheroid = GRS80, NAD 1983]).

Currently, WQT is not implemented in the study watershed. Qualitative and quantitative data from stakeholders were then collected from field surveys and interviews. The two major stakeholder groups for WQT are agricultural producers or NPSs of nutrient pollution, who would be potential sellers of water quality credits in WQT, and municipal WWTPs or PSs, who would be potential buyers. The data from the BMP/Water Quality Survey for agricultural producers was collected from 136 producers between August 2006 and January 2007 at several state and regional conferences hosted in Kansas (Smith et al., 2007). The survey elicited data on BMPs, participation/awareness of conservation programs, perceptions of water quality issues and policies, and demographics. A parallel survey of WWTP managers was developed and pilot tested with engineering consultants. Interview and surveys were conducted during on-site visits to more than 50 WWTPs in Kansas (Smith et al., 2007). Like the producer survey, the WWTP survey obtained information on plant characteristics, operator demographics, and operator perceptions of water quality issues.

5.4.3 Model Simulation

To integrate the potential nutrient load in-field uncertainty and in-stream delivery effect within the watershed stream network, we first used both the SWAT and EUTROMOD models to simulate load response for each alternative scenario for every subbasin and stream section. To coordinate with the testing scenarios from the field survey of “choice experiments of producers (NPS)” in the study watershed (Peterson et al., 2007; Smith et al., 2007), which compared the farmers’ willingness to participate in WQT programs using different land management practices, 13 specific alternative land management scenarios were arranged and simulated. Table 5-2 lists the details of the modeling parameters for these 13 scenarios. To explicate the relationship between cropping field and original undisturbed prairie, big bluestem with SWAT built-in parameters was modeled to represent prairie grasses in a restoration scenario. Switchgrass, modified from SWAT default Alamo Switchgrass parameters, was simulated as a typical bio-energy plant to assess the potential benefits with other cropping scenarios. Tall fescue, a common Kansas cool season grass for vegetative filter strip (VFS), was also simulated. Although big bluestem, switchgrass, and tall fescue were modeled for different reasons, all of them were classified as the typical grass scenarios in later comparisons.

The other 10 land management scenarios were based on a corn-soybean, two-year rotation with either surface or sub-surface fertilizer application. For each fertilizer application method, the baseline case was the traditional minimum tillage system without VFS and/or grazing at the edge of the field. Case1 and Case2 have similar modeling designs but the tillage system differs. Case1 used no-till, and Case2 combined baseline and Case1 as rotational tillage system, which is with 50% of time or area in no-till and the other 50% in minimum tillage. Case3 also used the baseline setting but added an edge-of-field VFS. Case4 followed the Case3 design but added fall haying and grazing events on the VFS.

Table 5-2 Major SWAT Parameters for Modeling Scenarios

Scenario#[1]	Crop Rotation	Till[2]	Abbrev.[3]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
SBase	CORN-SOYB (2-yr)	MT	CS4SB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.2	72	80	86	89	0.18	---
SCase1		NT	CS1SB			0.27	67	77	84	88	0.09	2x
SCase2		OT	CS2SB			0.27	67	77	84	88	0.12	1.5x
SCase3		MT	CS4SBFS			0.2	72	80	86	89	0.18	---
SCase4		MT	CS4SBFSGZ			0.2	72	80	86	89	0.18	---
DBase		MT	CS4DB			0.2	72	80	86	89	0.18	---
DCase1		NT	CS1DB			0.27	67	77	84	88	0.09	2x
DCase2		OT	CS2DB			0.27	67	77	84	88	0.12	1.5x
DCase3		MT	CS4DBFS			0.2	72	80	86	89	0.18	---
DCase4		MT	CS4DBFSGZ			0.2	72	80	86	89	0.18	---
BBLS	Big bluestem	n/a	NP_BBLS	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
SWCH	Switchgrass	n/a	NP_SWCH	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
FESC	Fescue (1-yr)	n/a	NP_FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---

Note: 1. S: surface fertilizer application (surface broadcast); D: sub-surface fertilizer application (deep band). **2.** NT: no-till; OT: rotational tillage (50% No-till). Apply no-till with corn and minimum tillage with soybean; MT: minimum tillage; n/a: not a cropland. **3.** C: corn; S: soybean; CS: two-year corn-soybean rotation; BBLS: big bluestem; SWCH: switchgrass; FESC: tall fescue; SB: surface fertilizer application (surface broadcast); DB: sub-surface fertilizer application (deep band); FS: with VFS at the edge of field; FSGZ: with the grazing on VFS at the edge of field. **4.** CN2: Curve Number for moisture condition II or antecedent moisture condition II (AMC II); HSG: Hydrologic Soil Group.

Using the 30 m DEM acquired from NED, the study watershed was divided into 286 subbasins with a stream definition threshold area of 990 hectares (2450 acre). Individual HRU delineation was done by overlaying NLCD 2001 landuse database on the Natural Resources Conservation Service (NRCS) SSURGO soil database with the thresholds in 4% landuse over a subbasin area and 7% soil class over each landuse area. Therefore, a total of 5395 HRUs in 286 subbasins were developed.

Historical daily precipitations as well as maximum and minimum daily temperatures from 1960 to 2006 were collected from NOAA NCDC SOD for weather stations within a 20 mile buffer zone around the watershed (NCDC, 2009). Data from 41 precipitation and 20 temperature gage stations were used. Two extra USGS weather simulation data sites were used in the model works to estimate any missing data. Values for solar radiation, wind speed, and relative humidity were generated by the model. To stabilize model responses, all scenarios used weather data from 1968 to 2006 for simulations with SWAT, but the modeling outputs from only 1971 to 2006 were analyzed for potential effects on trading. Annual values were simulated for pollutant load and load reduction for both TN and TP in daily time step.

5.4.4 Results and Discussion

5.4.4.1 *WQT Assessment Method*

Designing a WQT program requires sufficient knowledge and understanding of the targeted pollutant in the given watershed (Kerr et al., 2000). Either PS or NPS may produce these pollutants (for example, TN and TP), but pollutants affect a watershed differently depending on pollutant origins, discharge timing, or pollutant fate and transport (Wood and Bernknopf, 2003). Most of time, PSs discharge a relatively consistent concentration of pollutants except for flow situations with excessive flows resulting in temporary by-pass operation. For WWTPs, the total pollutant load depends on the amount of inflow wastewater concentration and flow rate and treatment dynamics. In contrast, NPS pollution, a by-product of storm water runoff, is event based with widely varying daily pollutant loads. The amount of NPS load depends on climate conditions, precipitation amounts and timing, soil factors, topographic factors, and landcover.

Applying an alternative management scenario to replace the current management scenario could potentially reduce pollutant loads from the same area in the watershed. Similarly, climate, soil, landuse, and topography also affect how much reduction in pollution loads actually occur. For a long term study, the potential pollutant load of a management scenario and potential load reduction in shifting from one to another of a specific scenario pair vary. Therefore, the mean value of pollutant load reduction for a specific scenario pair is simply an indicator of the potential amount of pollutant abatement under an average situation. This value cannot describe the potential that the pollutant load will actually be higher (or lower) due to environmental variants like climate changes, soil, landuse or topography difference. We quantify these load reduction risks or deviations with an uncertainty ratio (R_U) to describe the variations in potential load reduction at the edge of field, and delivery ratio (R_D) to quantify the variation via stream transportation. To simplify WQT indicators, the R_U and R_D can be combined as the TR, which becomes a single indicator to explain the potential trading risk of a trade between NPS and PS with specific management scenarios.

Assuming a potential load of current scenario (LMP_1) is P_{LMP1}, and an alternative scenario (LMP_2) is P_{LMP2}, the potential load reduction of this scenario pair can be explained as $P_{AVG(1-2)}$ with Eq. 5-1. For the potential trading risk of a specific scenario pair, the R_U can be explained with the means and standard deviations of the load reduction with 95% confidence level (Eq. 5-2). Within an individual sub-watershed, the R_D is the ratio of the amount of pollutant load transported at the downstream sub-watershed outlet to the original amount of same pollutant load at the inlet (see Eq. 5-3). Delivery ratio also can be defined as the ratio of the amount of pollutant load transported at PS to its original amount of the load at edge of field from NPS. Combining the R_U and R_D with Eq. 5-4, the TR can be calculated for a specific management scenario pair.

Therefore, for assessment in WQT, the potential load reductions of specific scenario pairs and the risks are the two major indicators of the benefits from a trade. Integrating these WQT indicators, WQTIPS would provide a systematic method for stakeholders to evaluate scenario pairs of land management changes or assess the benefit of a potential trade in watershed with spatially variable, quantifiable pollutant loads, load reductions, uncertainty ratio, delivery ratios, and TRs.

$$P_{AVG(1-2} = \frac{1}{n}\sum_{i=1}^{n} w_i\left(P_{LMP_1} - P_{LMP_2}\right)_i \qquad \text{Eq. 5-1}$$

$$R_U = \frac{t_{(1-\alpha),v} \cdot \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}{\bar{X}_1 - \bar{X}_2} \qquad \text{Eq. 5-2}$$

$$R_{D_i} = \frac{N_{OUT_i}}{N_{IN_i}} \qquad \text{Eq. 5-3}$$

$$TR = \frac{1}{(1 - R_U)R_D} \qquad \text{Eq. 5-4}$$

5.4.4.2 *Potential Pollutant Load*

The potential pollutant load of a management scenario varies across the watershed. We analyzed TN and TP loads from 1971 to 2006 for all thirteen scenarios listed in Table 5-2. To simulate the general querying processes, the analyses were focused on the subbasin level of both pollutants. Figure 5-18 presents the watershed scale annual TN and TP loads, which are the area weighted averages of all HRUs in each subbasin. Figure 5-19 shows the potential deviations of TN and TP loads. In Figure 5-19, the differences between the annual means of 36-year loads and their 25th percentiles (P25) are in green. Similarly, the differences between the annual means and their 75th percentiles (P75) are in red. Therefore, the heights of the bars represent the potential load deviations for each scenario.

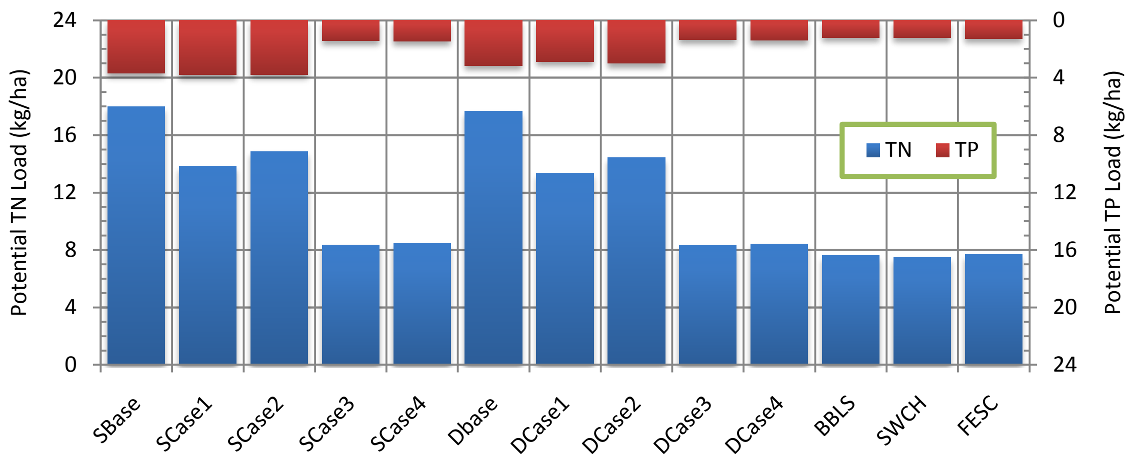


Figure 5-18 Potential Annual TN and TP Load for Each Scenario

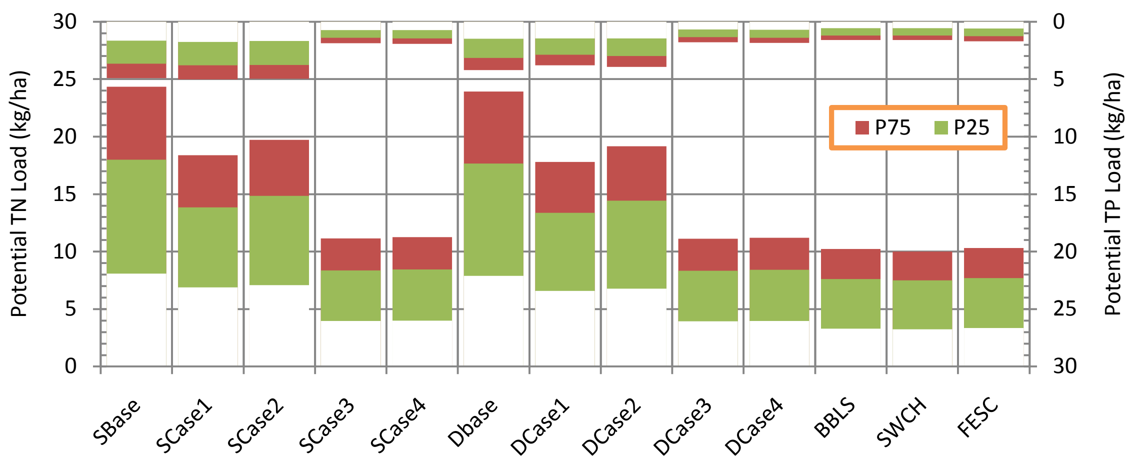


Figure 5-19 Potential Annual Loads and P25/P75 for Each Scenario

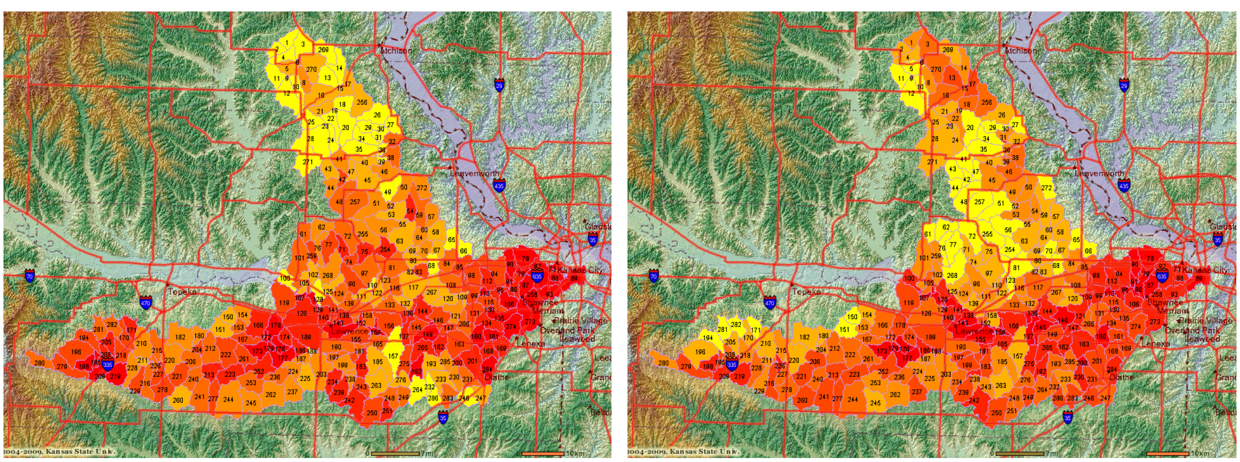
The WQTIPS arranged and ranked all scenarios based on their potential annual loads as Table 5-3. Both baseline scenarios showed maximum TN loads. Cases with VFS or native prairie grasses had the lowest TN loads. In contrast, the maximum TP load occurred in scenarios with surface fertilizer without VFS: SBase (minimum till), SCase1 (no-till), and SCase2 (rotational till). Even though the sub-surface fertilizer without VFS scenarios, Dbase (minimum till), DCase1 (no-till), and DCase2 (rotational till), still had higher TP loads than cases with VFS or native prairie grasses, the TP yields were still lower than SBase, SCase1, and SCase2. These trends show croplands implementing edge-of-field BMP methods such as VFS or native prairie grass restoration will dramatically reduce TN and TP loads. This result matches the trends of potential pollutant load in either Figure 5-18 or Figure 5-19

Table 5-3 Ranks of Potential Annual Load for Thirteen Scenarios

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
TN	SBase	DBase	SCase2	DCase2	SCase1	DCase1	SCase4	DCase4	SCase3	DCase3	FESC	BBLS	SWCH
TP	SCase1	SCase2	SBase	DBase	DCase2	DCase1	SCase4	SCase3	DCase4	DCase3	FESC	SWCH	BBLS

To visualize the spatial pattern of pollutant load with WQTIPS, each subbasin was rendered with its potential annual TN load for SBase (2-yr corn-soybean, minimum till, surface fertilizer, no VFS), which had the highest load, and DCase3 (2-yr corn-soybean, minimum till, sub-surface fertilizer, with VFS), which had the lowest cropland load, second only to BBLS (native prairie grasses), with the lowest load, in Figure 5-20. The subbasins with lower pollutant loads are in red color while subbasins with higher loads are in yellow. The distribution patterns in Figure 5-20 (a) and (b) are not similar. That means the potential annual TN load of each subbasin might behave differently in each scenario. With similar visualizing processes and color style, we rendered the potential annual TP load for SCase1 (highest load: no-till, surface fertilizer, no VFS) and BBLS (lowest load: native prairie grass, big bluestem) in Figure 5-21. The patterns of Figure 5-21 (a) and (b) also differ, as we saw in Figure 5-20, which implies that pollutant loads have strong site-specific effects within the study watershed.

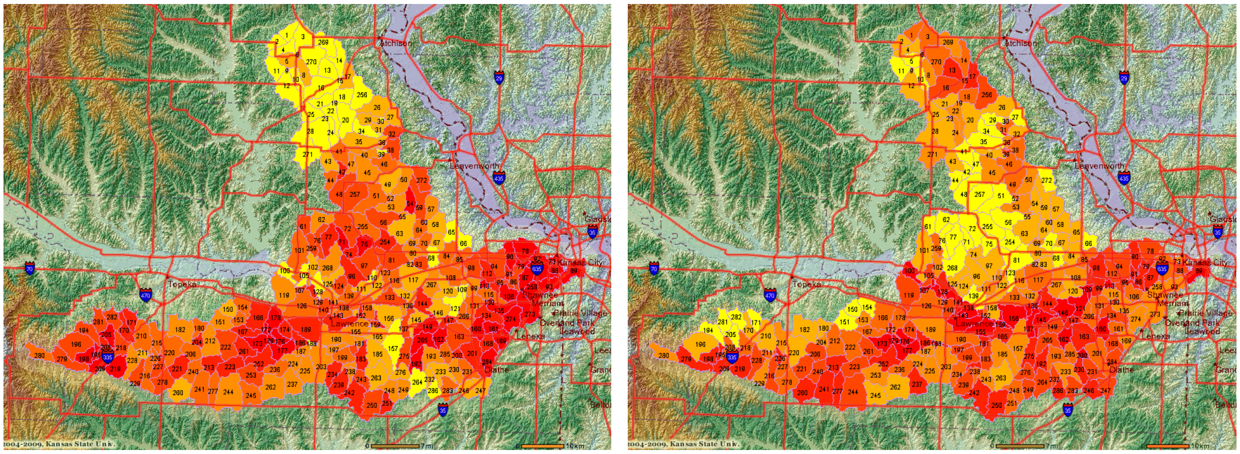
The strategy for stakeholders to assess and prioritize water-quality trades is first to prioritize the potential pollutant loads of alternative scenarios and then to assess regional trends by visualizing subbasin-level pollutant yields. However, a WQT program should assess not only the average potential pollutant load of a specific scenario but also the potential deviation, such as P25 or P75 in Figure 5-19. We need more indicators to describe these properties in WQT.



(a) TN Load for SBase Scenario **(b) TN Load for DCase3 Scenario**

Note: SBase: 2-yr corn-soybean, minimum till, surface fertilizer, no VFS; DCase3: 2-yr corn-soybean, minimum till, sub-surface fertilizer, with VFS.

Figure 5-20 Potential Annual TN Load Distribution within Study Watershed



(a) TP Load for SCase1 Scenario **(b) TP Load for BBLS Scenario**

Note: SCase1: 2-yr corn-soybean, no-till, surface fertilizer, no VFS; BBLS: native prairie grass, big bluestem.

Figure 5-21 Potential Annual TP Load Distribution within Study Watershed

5.4.4.3 *Potential Load Reduction*

The pollutant load reduction for a specific scenario pair is simply an indicator of the potential amount of pollutant abatement under an average situation. Based on the potential annual pollutant load statistics above, the potential load reduction between any two scenarios can be calculated (Table 5-4). The number in each block represents the potential annual TN load after changing the chosen (current) scenario in the top row to the selected (alternative) scenario in the first column. The negative value for the current scenario shows it has a lower potential load than the alternative scenario. In other words, this change would not reduce the potential load, but actually increase it instead. The blocks with scenario pairs with the maximum load reduction are in red, and the top 10 pairs are in cyan blocks. Similar symbols and color styles were used in Table 5-5 to show potential TP load reduction.

Table 5-4 Potential Annual TN Load Reduction among Study Scenarios

(Kg/ha)	SBase	SCase1	SCase2	SCase3	SCase4	DBase	DCase1	DCase2	DCase3	DCase4	BBLS	SWCH	FESC
SBase		-4.145	-3.147	-9.636	-9.555	-0.328	-4.625	-3.567	-9.671	-9.590	-10.385	-10.501	-10.311
SCase1	4.145		0.999	-5.491	-5.410	3.817	-0.480	0.578	-5.526	-5.445	-6.240	-6.355	-6.166
SCase2	3.147	-0.999		-6.489	-6.408	2.819	-1.479	-0.421	-6.524	-6.444	-7.239	-7.354	-7.164
SCase3	9.636	5.491	6.489		0.081	9.308	5.011	6.069	-0.035	0.046	-0.750	-0.865	-0.675
SCase4	9.555	5.410	6.408	-0.081		9.227	4.930	5.988	-0.116	-0.035	-0.830	-0.946	-0.756
DBase	0.328	-3.817	-2.819	-9.308	-9.227		-4.297	-3.239	-9.343	-9.262	-10.057	-10.173	-9.983
DCase1	4.625	0.480	1.479	-5.011	-4.930	4.297		1.058	-5.046	-4.965	-5.760	-5.875	-5.686
DCase2	3.567	-0.578	0.421	-6.069	-5.988	3.239	-1.058		-6.104	-6.023	-6.818	-6.933	-6.744
DCase3	9.671	5.526	6.524	0.035	0.116	9.343	5.046	6.104		0.081	-0.714	-0.830	-0.640
DCase4	9.590	5.445	6.444	-0.046	0.035	9.262	4.965	6.023	-0.081		-0.795	-0.910	-0.721
BBLS	10.385	6.240	7.239	0.750	0.830	10.057	5.760	6.818	0.714	0.795		-0.115	0.075
SWCH	10.501	6.355	7.354	0.865	0.946	10.173	5.875	6.933	0.830	0.910	0.115		0.190
FESC	10.311	6.166	7.164	0.675	0.756	9.983	5.686	6.744	0.640	0.721	-0.075	-0.190	

Table 5-5 Potential Annual TP Load Reduction among Study Scenarios

(Kg/ha)	SBase	SCase1	SCase2	SCase3	SCase4	DBase	DCase1	DCase2	DCase3	DCase4	BBLS	SWCH	FESC
SBase		0.133	0.107	-2.257	-2.211	-0.519	-0.782	-0.680	-2.313	-2.266	-2.472	-2.461	-2.399
SCase1	-0.133		-0.025	-2.390	-2.343	-0.651	-0.915	-0.813	-2.446	-2.399	-2.605	-2.594	-2.532
SCase2	-0.107	0.025		-2.365	-2.318	-0.626	-0.890	-0.787	-2.420	-2.374	-2.579	-2.569	-2.507
SCase3	2.257	2.390	2.365		0.047	1.738	1.475	1.577	-0.056	-0.009	-0.215	-0.204	-0.142
SCase4	2.211	2.343	2.318	-0.047		1.692	1.428	1.530	-0.102	-0.056	-0.261	-0.251	-0.189
DBase	0.519	0.651	0.626	-1.738	-1.692		-0.264	-0.161	-1.794	-1.748	-1.953	-1.943	-1.881
DCase1	0.782	0.915	0.890	-1.475	-1.428	0.264		0.102	-1.531	-1.484	-1.690	-1.679	-1.617
DCase2	0.680	0.813	0.787	-1.577	-1.530	0.161	-0.102		-1.633	-1.586	-1.792	-1.781	-1.719
DCase3	2.313	2.446	2.420	0.056	0.102	1.794	1.531	1.633		0.047	-0.159	-0.149	-0.087
DCase4	2.266	2.399	2.374	0.009	0.056	1.748	1.484	1.586	-0.047		-0.206	-0.195	-0.133
BBLS	2.472	2.605	2.579	0.215	0.261	1.953	1.690	1.792	0.159	0.206		0.010	0.072
SWCH	2.461	2.594	2.569	0.204	0.251	1.943	1.679	1.781	0.149	0.195	-0.010		0.062
FESC	2.399	2.532	2.507	0.142	0.189	1.881	1.617	1.719	0.087	0.133	-0.072	-0.062	

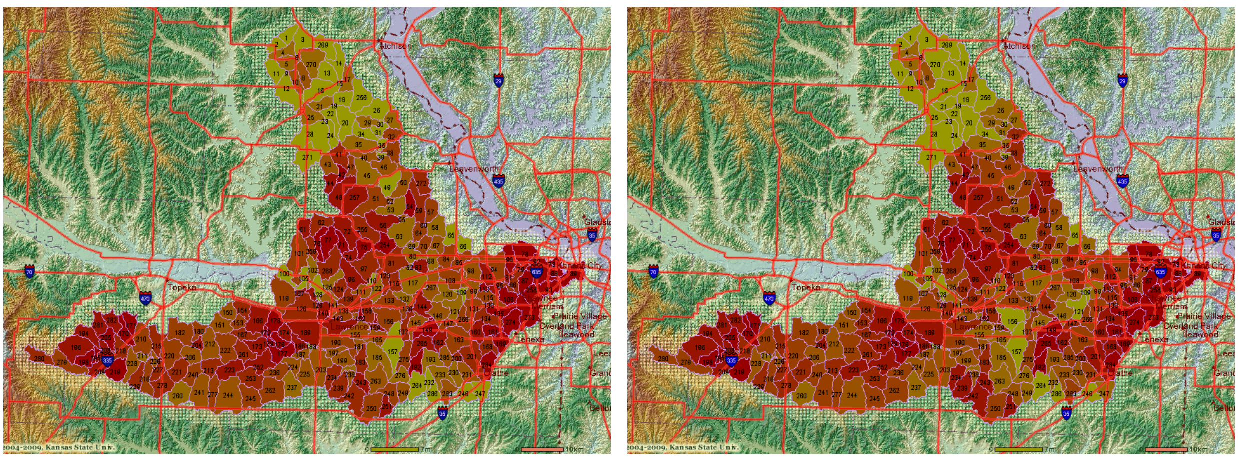
Assessing the potential pollutant load reduction, WQTIPS arranged and ranked the top eight alternative scenario pairs based on their potential load reductions (Table 5-6). The most common current scenarios for the scenario pairs with top TN load reduction are baseline scenarios with alternative scenarios of major grasses and SCase3 (2-yr corn-soybean, minimum till, surface fertilizer, with VFS). For the top TP load reduction, the most common "current" scenarios were SCase1, SCase2, and SBase combined with alternative scenarios of major grasses. These trends are identical to what we saw in Table 5-4 and Table 5-5.

Table 5-6 Top Pollutant Load Reduction Scenario Pairs in Study Watershed

Rank	1	2	3	4	5	6	7	8
TN	SBase-SWCH	SBase-BBLS	SBase-FESC	DBase-SWCH	DBase-BBLS	DBase-FESC	SBase-DCase3	SBase-SCase3
TP	SCase1-BBLS	SCase1-SWCH	SCase2-BBLS	SCase2-SWCH	SCase1-FESC	SCase2-FESC	SBase-BBLS	SBase-SWCH

To evaluate site-specific effects on potential load reduction with WQTIPS, the maximum load reduction of pollutant loads, the SBase to SWCH scenario for TN and SCase1 to SWCH (native prairie grass, switchgrass) for TP, were rendered for each subbasin in Figure 5-22 (a) and (b). The subbasins with lower pollutant load reductions are in maroon while subbasins with higher load reductions are in olive green. The patterns of TN and TP load reductions in Figure 5-22 (a) and (b) also show a strong site-specific effect across the study watershed.

Thus, the strategy for stakeholders selling NPS WQT credits (e.g., farmers or NPS producers) to assess potential load reduction is to first define the subbasin in which the farm (or NPS source) is located and then query the potential annual load reduction for potential alternative scenario pairs in this subbasin. By sorting the scenario pairs by potential load reduction, the scenario pairs can be ranked from best to worst. Alternatively, a WQT credit purchaser (e.g., WWTP manager) can set the alternative scenario pair first and then rank all subbasins with their potential load reductions to see which areas have higher potential for pollutant abatement. For example, Table 5-7 lists the top 20 subbasins for potential load reduction while applying the SBase to SWCH scenario pair for TN and SCase1 to SWCH scenario pair for TP. In these lists, the subbasins #271, #188, and #30 might have maximum TN load reduction with implementing SBase-SWCH scenario while subbasins #188, #100, and #271 might have maximum TP load reduction with applying SCase1-SWCH scenario pair. However, without information on the potential risks or deviations of the load reduction from the annual average value, it would be difficult to estimate the potential benefit of a trade.



(a) Potential TN Load Reduction for SBase to SWCH **(b) Potential TP Load Reduction for SCase1 to SWCH**

Figure 5-22 Annual Potential Pollutant Load Reduction for Specific Scenario Pairs

Table 5-7 Top Pollutant Load Reduction Subbasins for Specific Scenario Pairs

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SBase-SWCH	271	188	30	33	28	100	20	39	1	65	269	13	3	286	24	246	128	18	22	31
SCase1-SWCH	188	100	271	109	1	28	128	3	20	269	33	13	65	2	24	16	105	23	22	30

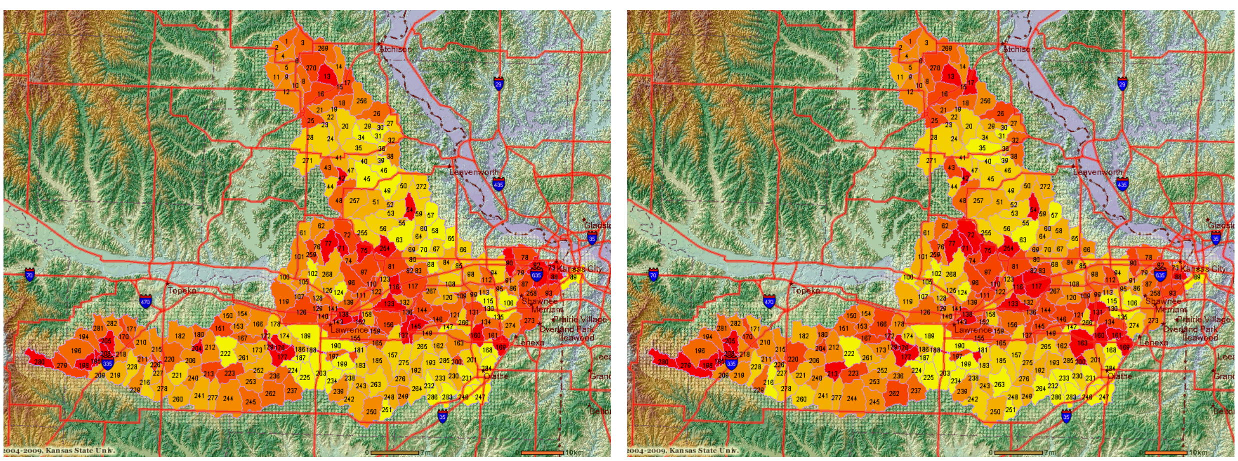
5.4.4.4 *Uncertainty Ratio*

As previously described, the RU analyses determined the potential trading risk associated with changes in management. The 36-year average annual nutrient loads for 286 subbasins were tested to determine the significance of load reductions using the t-test method at 95% confident level. For scenario pairs with significant load reductions, additional t-tests checked for the significance of any deviation in load reduction based on Eq. 5-2. For each alternative scenario pair, its R_U represents the statistical deviation from the mean of potential load reduction at 95% confidence level; higher values represent higher deviations, representing higher variability in potential load reduction. To show the values in Table 5-6 with R_Us, Table 5-8 lists the R_U for the top pollutant load reduction scenario pairs.

Table 5-8 R_U for Each Top Pollutant Load Reduction Scenario Pairs in Study Watershed

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
TN	0.0221	0.0224	0.0226	0.0226	0.0229	0.0231	0.0242	0.0242
TP	0.0187	0.0188	0.0195	0.0196	0.0193	0.0202	0.0190	0.0191

The geospatial patterns of RUs are also strongly site specific. Figure 5-23 (a) illustrates the R_Us for potential annual TN load reduction for the SBase-SWCH scenario pair, and Figure 5-23 (b) portrays the R_Us for potential annual TP load reduction for SCase1-SWCH scenario pair. In both figures, with R_Us ranging from 0.1 to 0.9, some subbasins were classified as non-tradable areas (in red). The non-tradable areas are those where either the potential load reduction of this scenario pair is too small or the risk of potential load reduction is too large to be traded. Therefore, the same scenario pair applied in a different subbasin might have a different degree of load reduction deviation, a properly chosen location to apply alternative scenarios is important. In WQT assessment, R_U provides the potential deviation of in-field load reduction of each alternative scenario pair. Stakeholders can use R_U to understand the trading risk of in-field load reduction within the watershed.



(a) R_U of TN Load Reduction for SBase-SWCH Scenario **(b) R_U of TP Load Reduction for SCase1-SWCH Scenario**

Note: SBase: 2-yr corn-soybean, minimum till, surface fertilizer, no VFS; SCase1: no-till, surface fertilizer, no VFS; SWCH: native prairie grass, switchgrass.

Figure 5-23 R_U of Potential Load Reduction in Study Area

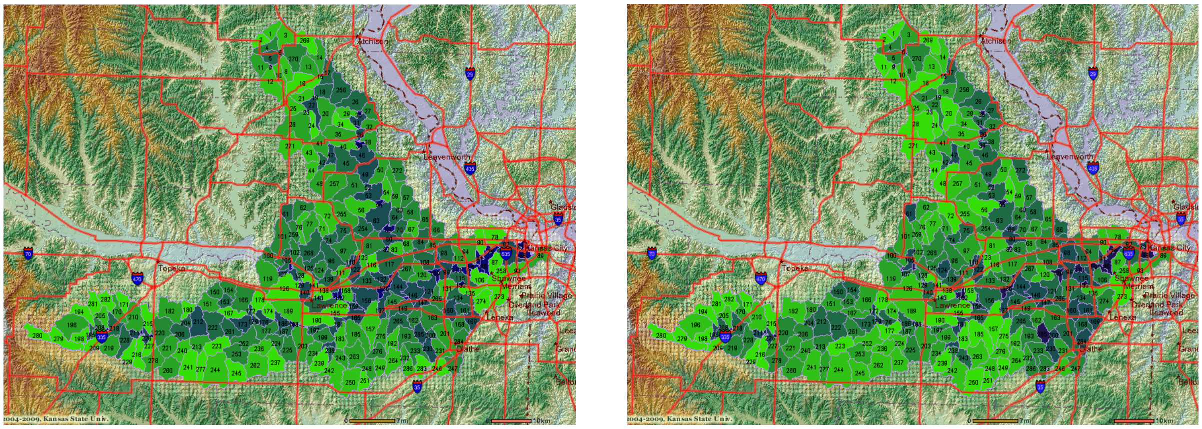
5.4.4.5 *Delivery Ratio*

As discussed previously, because of site-specific effects, the pollutant source subbasin and trading partner location are very important for estimating the potential load reduction and its risk. Pollutants transported via stream network might show some loss due to physical deposition or bio-chemical degradation. These phenomena are affected by stream length, travel time, and/or water temperature. Understanding the potential delivery effect between any two points or areas in watershed is very important to estimate the delivery effects within a WQT system.

To determine the in-stream delivery effect, we analyzed the potential TN and TP loads from 1971 to 2006 for each stream section within all 286 subbasins. Following Eq. 5-3 and modeling simulations, the R_D for each individual subbasin was then calculated. To see the difference of R_D among scenarios and subbasins, the ANOVA method was applied.

ANOVA for the differences in nutrient load R_D among modeling scenarios showed a p-value of main effect at scenario level was 0.0556 for the TN load R_D and 0.7935 for TP load R_D. Both p-values were larger than the 0.05 necessary to accept the test null hypothesis, which was the differences in R_D among the scenarios was not statistically significant. Furthermore, Tukey's Studentized Range (HSD) and Fisher's Least Significant Distance (LSD) tests for the R_D grouped all scenarios into a single group. In other words, scenarios did not differ significantly in R_D. However, the p-value of the ANOVA main effect at the subbasin level was less than 0.0001 (<0.0001) for both TN and TP load R_Ds. The HSD and LSD tests for both R_Ds also showed significant differences among subbasins. In other words, each river section still had its own specific R_D, and the ratios were statistical significantly different. Therefore, the means of R_D of all scenarios were calculated for every river section in the study watershed. To simplify the process of estimating potential load reduction risk in WQT, the means of R_D of all scenarios were calculated for every river section (subbasin), and all scenarios shared a single R_D for the same river section.

Figure 5-24 illustrates the R_D for each Individual subbasin in the watershed. The lower R_D in lime color means more pollutant degradation might occur; the higher R_D in dark blue means less degradation. The TN load R_D in Figure 5-24 (a) ranges from 0.9625 to 1.0, and the TP load R_D in Figure 5-24 (b) ranges from 0.9871 to 1.0. The patterns for both TN and TP load R_D are similar but not identical. This implies the site-specific effect of TN and TP load R_D might differ. Therefore, for WQT assessment, different pollutant loads should have an individual R_D to estimate the trading risk of pollutant delivery.

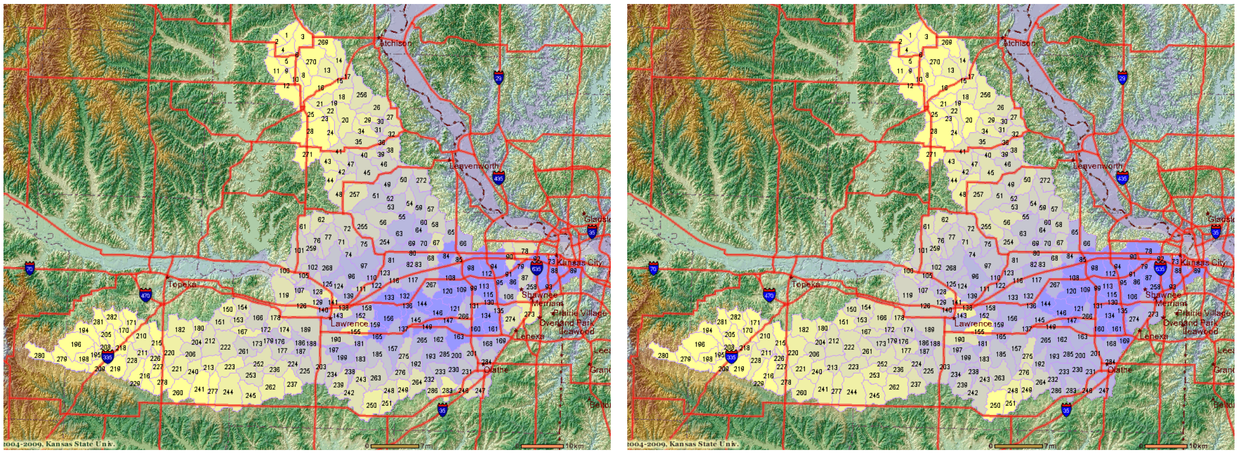


(a) Potential TN Load **(b) Potential TP Load**

Figure 5-24 R_D of Potential Pollutant Loads within each Subbasin in Study Watershed

During pollutant transport from the source subbasin to a specific point or outlet downstream, the pollutant load degradation is cumulative, so to estimate the pollutant load transported via stream network required adding up the delivery effects of all stream sections within the subbasin along the stream path. Hence, the cumulative R_D equals the product of all individual subbasin R_Ds of the river sections along the stream network from source to sink. Figure 5-25 illustrates the geospatial pattern of the cumulative R_D of TN and TP loads for each subbasin to watershed outlet. The lower R_D in yellow means more pollutant degradation might occur; the higher R_D in purple-blue shows less degradation.

As addressed previously, the cumulative R_D between any two points or areas in watershed is the indicator to present the potential delivery effect and an important parameter to estimating the potential delivery loss of a trade. With this querying process, stakeholders can visualize better or worse locations to search for trading partners. However, R_D is only based on the in-stream load delivery and did not include the potential uncertainty or site-specific effect of in-field load. To assess the trading risk of WQT, an integrated indicator, TR, which includes both in-field uncertainty and in-stream delivery effect, is needed.



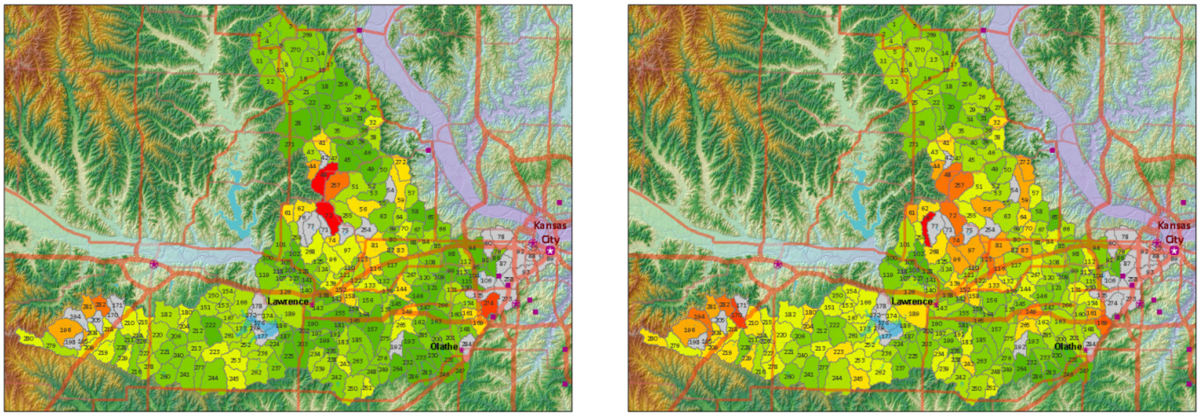
(a) Cumulative R_D of TN Load (b) Cumulative R_D of TP Load

Figure 5-25 Cumulative R_D of Potential Pollutant Load for Each Subbasin to Watershed Outlet

5.4.4.6 *Trading Ratio*

As discussed previously, TR, which integrated the in-field R_U and in-stream R_D, is an indicator for assessing the potential load reduction deviation or trading risk of a trade. A higher TR represents the higher deviation among all annual load reductions, which means the differences of yearly load reduction is significant. In other words, a higher TR represents a higher cost for stakeholders to lower the potential risk of a trade.

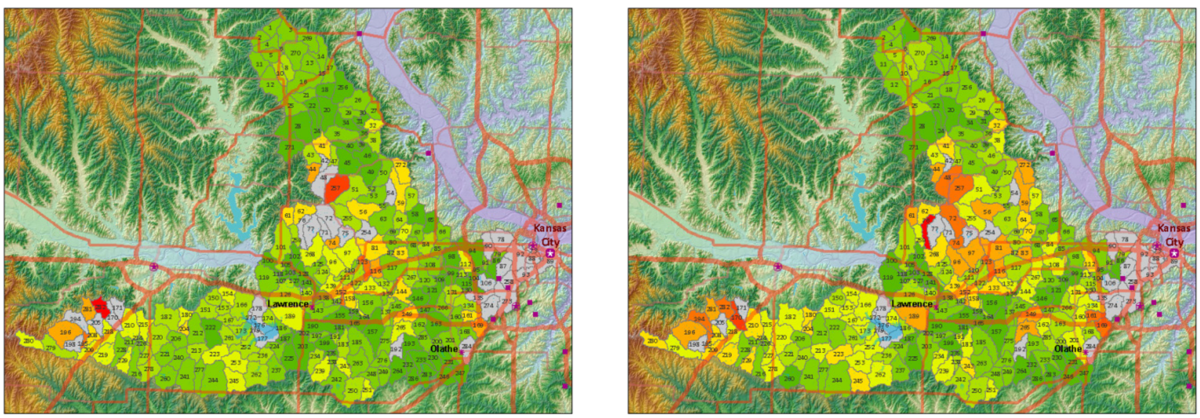
To estimate the TR for each subbasin in the watershed, the in-field R_U for each alternative scenario pair and the R_D for each individual river section within a subbasin were pulled into Eq. 5-4 and tabulated as series matrices for pollutant load reductions. Thus, assuming all sources of pollutants in each subbasin trade their pollutant load reduction with buyer at the watershed main outlet, Figure 5-26 (a) illustrates the TR for potential TN load reduction of SBase-SWCH scenario pair, which has the maximum TN load reduction. The greenish blocks in Figure 5-26 (a) represent a lower TR or trading risk, and the reddish blocks mean a higher TR or trading risk. The gray blocks represent non-tradable areas where either the potential load reduction is not significant or the trading risk is too high. Similarly, Figure 5-26 (b) maps the TR for potential TP load reduction of SCase1-BBLS scenario pair, which had the maximum TP load reduction of all the tested scenarios. If we look at the alternative edible crop scenarios, the SBase-DCase3 has maximum potential TN load reduction, and SCase1-DCase3 has the maximum potential TP load reduction. Figure 5-27 (a) illustrates the TR of potential TN load reduction for each subbasin to watershed outlet for SBase-DCase3 scenario pair, and Figure 5-27 (b) shows the TR of TP load reduction for each subbasin to watershed outlet for SCase1-DCase3 scenario pair.



(a) TN Load Reduction TR for SBase-SWCH **(b) TP Load Reduction TR for SCase1-BBLS**

Note: SBase: 2-yr corn-soybean, minimum till, surface fertilizer, no VFS; SCase1: no-till, surface fertilizer, no VFS; BBLS: native prairie grass, big bluestem; SWCH: native prairie grass, switchgrass.

Figure 5-26 TR for Maximum Load Reduction Scenario Pairs to Watershed Outlet



(a) TN Load Reduction TR for SBase-DCase3 **(b) TP Load Reduction TR for SCase1-DCase3**

Note: SBase: 2-yr corn-soybean, minimum till, surface fertilizer, no VFS; SCase1: no-till, surface fertilizer, no VFS; DCase3: minimum till, sub-surface fertilizer, with VFS.

Figure 5-27 TR of Edible Crop Scenario Pairs with Max Load Reduction to Watershed Outlet

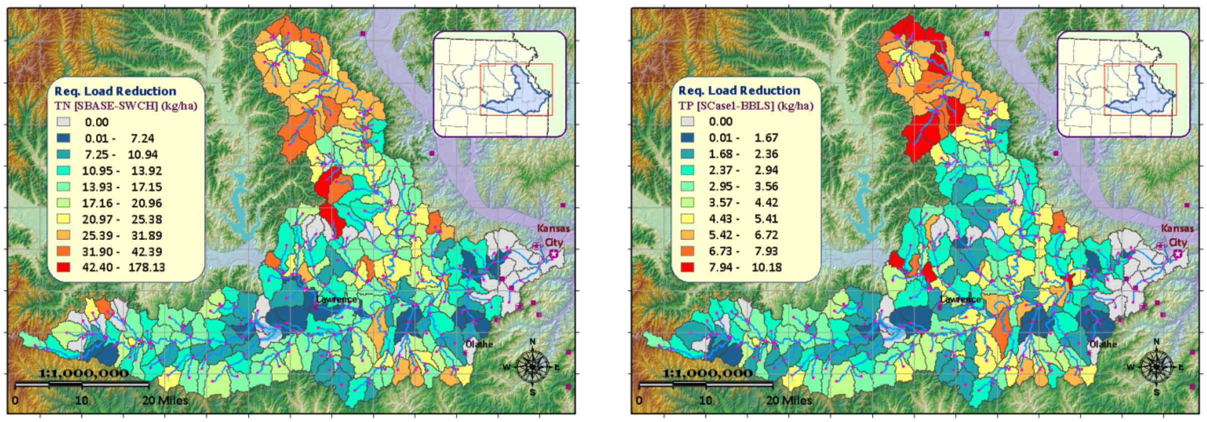
The maximum TR for TN load reduction was as high as 48.0 and for TP load reduction reached approximately 20.0 in these figures. However, more than 85% of the TRs ranged from 1.0 to 2.0. Obviously, the fixed 2:1 TR would likely overestimate the trading risks of TN and TP load reductions from NPS for more than 85% of the subbasins in the study watershed. Furthermore, the highest TR did not occur in the subbasin most remote to the watershed outlet. In fact, it occurred in the middle of the watershed and varied by pollutant and scenario pair. This suggests both load reduction uncertainty and load delivery effect dominate the calculation of TRs. With this process, stakeholders have a simple method of calculating TRs and getting more concise information for WQT.

5.4.4.7 *Overall Assessment for WQT*

For WQT assessment, the potential load reductions of specific scenarios and the risks are the two major indicators of assessing the environmental benefits from a trade. With the potential pollutant load reductions of all alternative scenario pairs ranked in WQTIPS, stakeholders can determine which crop, tillage system, fertilizer application and edge-of-field BMP combination would be the better or best scenarios for producing maximum reduction at specific area. Alternatively, choosing an alternative scenario pair and ranking all subbasins based on their load reductions would locate the hot-spots for pollution abatement or the high priority trading partner for a trade. Likewise, TR tells the potential load reduction deviation or trading risk in each alternative scenario pair or subbasin for stakeholders.

The nominal trading benefit of a trade would be the potential load reduction of selected current-alternative scenario pair. However, the total amount of pollutant load reduction that trading buyer needs to purchase from trading seller to guarantee that replacement at a specific confidence level would be equal to the potential load reduction multiplied by its TR. A higher confidence level, a higher TR, or higher trading risk will increase the total purchases required to meet a given load reduction. Moreover, the price of each unit load reduction would vary subbasin to subbasin. The exact total cost of a WQT trade must be analyzed with an economic model.

For example, if we want to assess which subbasin in the study watershed is the best area for the farmer, or seller, to trade, the best alternative management scenarios to maximize tradable credits would be the top load reduction scenario pairs, e.g., SBase-SWCH for TN and SCase1-BBLS for TP in Table 5-6. Buyers in the watershed can maximize their benefits by purchasing the potential load reduction with a lower trading risk and price. Assuming the price of a unit pollutant load reduction is the same throughout the study watershed and everyone within a subbasin will trade their load reductions to a buyer at the watershed outlet, Figure 5-28 illustrates how much a buyer would have to purchase in each subbasin. Figure 5-28 (a) shows the required TN load reduction purchased is 2.25 kg/ha to 178 kg/ha for SBase-SWCH scenario pair. In Figure 5-28 (b), the required TP load reduction purchased is 0.82 kg/ha to 10.2 kg/ha for SCase1-BBLS scenario pair. As we know, to maintain the same water quality at watershed outlet, the total purchasing would vary depending on where the trade occurs. Therefore, Table 5-9 lists the top 8 subbasins with lowest trading risks in the study watershed. In Table 5-9, each cell represents the subbasin number with their TR in parentheses after the subbasin number. Thus, for a TN load reduction trade, subbasin #33, SBase-SWCH scenario, might be good for both seller and buyer. Similarly, for a TP load reduction trade, subbasin #246 would be the best trade for the SCase1-BBLS scenario.



(a) SBase to SWCH **(b) SCase1 to BBLS**

Note: SBase: 2-yr corn-soybean, minimum till, surface fertilizer, no VFS; SCase1: no-till, surface fertilizer, no VFS; BBLS: native prairie grass, big bluestem; SWCH: native prairie grass, switchgrass.

Figure 5-28 Load Reduction Requirement of Specific Scenario Pairs to Watershed Outlet

Table 5-9 Top 8 Lowest Trading Risk Subbasins

Rank	1	2	3	4	5	6	7	8
TN [SBase-SWCH]	33 (1.163)	246 (1.173)	286 (1.179)	247 (1.187)	232 (1.191)	188 (1.193)	39 (1.199)	114 (1.200)
TP [SCase1-BBLS]	246 (1.143)	286 (1.152)	107 (1.158)	247 (1.158)	33 (1.164)	100 (1.168)	118 (1.173)	232 (1.181)

5.5 Conclusion

Although it still has some issues and people might not recognize its usability on solving water quality problems, WQT, which supported by EPA and USDA, is still a potential alternative method to achieve water quality goals in the rural watersheds of Kansas. Recent studies have shown that the major problems with the WQT program is that it failed to address environmental uncertainties and could not achieve a lower reduction cost with fixed trading ratios (Nelson and Keeler, 2005). Consequently, stakeholders have been unwilling to participate in the WQT program. Moreover, the transaction costs, the costs for collecting information for trading, are also another impediment. A web-based information platform with geospatial data structure and watershed modeling tools, as introduced in this study, may solve these WQT issues.

WQT information sharing and decision support, an information platform system, the Water Quality Trading Information Platform System (WQTIPS) were developed in this study. The information platform provides a dataset repository, transforming data into readily accessible information. It offers services other than a data repository: data visualization and assessment support tool to capture information online. In this study, the WQT Geodatabase Data Model (WQTGDM) was introduced to standardize data format and inputs for WQT processes, analyzing the potential trading benefits in a geospatial scale. The geoprocessing model is an important element of WQTGDM. Traditional designs of geodatabase data models mainly focus on the database element arrangement and data structure normalization. However, this geoprocessing model provides a linkage between datasets and their geospatial properties to trigger GIS functions and geospatial analyses. In other words, a geoprocessing model provides a GIS enabled template in WQTGDM.

Three-tier GIS-based web interface architecture was used for WQTIPS. The application tier was based on the potential pollutant load reduction and its trading ratio (Lee and Mankin, 2007a; Lee and Mankin, 2007b; Lee et al., 2007a). Both parameters were analyzed for 13 selected alternative scenarios, which were modeled with SWAT watershed modeling tools in Lower Kansas watershed, northeastern Kansas. The data tier, a geospatial database which is the system data repository, was implemented with ESRI ArcSDE and Microsoft SQL Server based on WQTGDM schema. The presentation tier, a WQT assessment tool with a GIS-based web interface, was then developed by incorporating the other two tiers with a GIS internet map service, ESRI ArcIMS.

In previous researches, the potential pollutant load reductions and their site-specific TRs were addressed to estimate potential trading benefits in Kansas (Lee et al., 2005; Lee and Mankin, 2007a; Lee and Mankin, 2007b; Lee t al., 2007a). In our case study, based on WQTGDM, the GIS-based web interface WQTIPS, which was implemented with a web user interface and internet map service, provided these functions for stakeholders inquiring about the potential benefits. Sellers, or upstream farmers, could use the system to prioritize alternative scenarios with their potential loads and load reductions to gain maximum trading credits; buyers, or interested downstream pollution sources, could use the system to search for lower trading risk sources and thus decrease their costs.

These processes can help stakeholders to quantify the potential load reduction and its TR changes from the land management shifts using a simple interface. For specific alternative scenario pairs, the potential pollutant load reductions vary by subbasin. The TRs of potential pollutant load reductions also show similar trends, indicating the best alternative scenario pair might change from one subbasin to another, and scenarios with higher potential load reductions may or may not produce a lower TR. To assess the potential WQT benefit of a trade, the potential load reduction of selected scenario pairs and the TRs would have to be individually evaluated for a trading partner's subbasin. Therefore, WQTIPS provides an easily accessible way to assess WQT benefits with systematic, spatially variable, quantifiable load reductions and TRs. This system demonstrates that it is possible to automate these trades, use models to minimize trading risk, and prioritize among possible trades both spatially and by BMP.

The case study with thirteen selected management scenarios in the study watershed demonstrated the processes for assessing WQT benefit with WQTIPS are feasible. WQTIPS could provide an information system essential for developing a WQT program. In future research, integrating WQTIPS with public geospatial map services like Google Map or Microsoft Virtual Earth may simplify the construction process and cost of WQTIPS, provide users a friendlier user interface, and use a more powerful internet map engine and data service. Furthermore, although the geospatial site-specific phenomena have been visualized in WQTIPS, rendering subbasins in different color schemes, the monthly and seasonal effect of WQT were not covered in this study. Therefore, including WQT time-series information into the next version of WQTIPS is a challenge for WQT researchers.

Acknowledgements

The authors gratefully acknowledge Dr. J.M. Shawn Hutchinson, associate professor of Geography, for his comments and instructions on geospatial analysis and geospatial data model design. Appreciation is also extended to Drs. Jeffrey M. Peterson and John Leatherman, professors of Agricultural Economics, and Mr. Craig Smith, watershed specialist and research assistant for their expertise in the field survey of WWTP and water quality trading program in Kansas.

We are grateful for the partial financial supports from the U.S. EPA Section 319 grant and Kansas Water Plan funds provided by the Kansas Department of Health and Environment (KDHE) (Project #: 2004-0017), and U.S. EPA, the National Center for Environmental Research (NCER) Science to Achieve Results (STAR) Program Grant #R831774. Although the research described in the article has been funded in part by KDHE project and the U.S. EPA's STAR program grant, it has not been subjected to any KDHE or EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

5.6 References

Arctur, D. and M. Zeiler. 2004. *Designing Geodatabases*. Redlands, CA: ESRI Press.

Atzeni P., Ceri S., Paraboschi S. and Terlone R. 1999. *Database System*. Boston, MA: McGraw-Hill.

Autodesk. 2009. Autodesk MapGuide. San Rafael, CA: Autodesk, Inc. Available at: usa.autodesk.com/adsk/servlet/index?siteID=123112&id=2995478. Accessed April 30, 2009.

Barnes, P. L. 2006. Personal communication. Manhattan, KS.

Borah, D.K., and M. Bera. 2003. Watershed-Scale Hydrologic and Nonpoint-Source Pollution Models: Review of Mathematical Bases. *Trans. ASAE* 46(6): 1553-1566

Boyer, W. R. 2006. Interview by author. E-mail communication. Manhattan, KS.

Breetz, H. L., K. Fisher-Vanden, L. Garzon, H. Jacobs, K. Kroetz, and R. Terry. 2004. Water quality trading and offset initiatives in the U.S.: a comprehensive survey. Hanover, NH: Dartmouth College. Available at: www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf. Accessed April 30, 2009.

Chapra, S. C. 1997. *Surface Water-Quality Modeling*. Boston, MA: McGraw-Hill.

Di Luzio, M., J. G. Arnold, and R. Srinivasan. 2004. Integration of SSURGO maps and soil parameters within a geographic information system and nonpoint source pollution model system. *J. Soil and Water Conserv.* 59(4):123-133.

Di Luzio, M., R. Srinivasan, J. G. Arnold, and S. L. Neitsch. 2002. ArcView Interface for SWAT2000: User's Guide. Report TR-193. College Station, TX: Texas Water Resources Institute.

Environomics. 1999. A summary of U.S. Effluent trading and offset projects. Bethesda, MD: Environomics. Available at: www.epa.gov/OWOW/watershed/trading/traenvrn.pdf. Accessed April 30, 2009.

ESRI. 2006. Network Analyst. in ArcGIS 9.2 Desktop Help. Redlands, CA: Environmental Systems Research Institute (ESRI), Inc. Available at: webhelp.esri.com/arcgisdesktop/9.2/. Accessed April 30, 2009.

ESRI. 2009a. Hydro Data Model. Redlands, CA: Environmental Systems Research Institute (ESRI), Inc. Available at: support.esri.com/index.cfm?fa=downloads.datamodels.filteredgateway&dmid=15. Accessed April 30, 2009.

ESRI. 2009b. Overview of ArcIMS. Redlands, CA: Environmental Systems Research Institute (ESRI), Inc. Available at: www.esri.com/software/arcgis/arcims. Accessed April 30, 2009.

Fischer, M. M. 2006. GIS and Network Analysis. Selected essays *in Spatial Analysis and Geocomputation* 43-60. New York: Springer.

Fjell, D. L. 1998. *Grain Sorghum Production Handbook*. C-687 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., D. Peterson, D. A. Whitney, 1997. *Soybean Production Handbook*. C-449. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., R. L. Vanderlip, K. L. Roozeboom, 2007. *Corn Production Handbook*. C-560 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

GREAT-ER, 2003. Geography - Referenced Regional Exposure Assessment Tool for European Rivers. Available at: www.great-er.org. Accessed April 10, 2007.

HYMAPS-OWL, 2004. Hydrologic MAP Server - On-line Watershed Delineator, HYMAPS-OWL. Programmed by Jin-Yong Choi & Bernard A. Engel. Ag. & Bio. Engg., Purdue University. Available at: pasture.ecn.purdue.edu/~watergen. Accessed April 10, 2007.

Kansas GIS Policy Board. 2007. Kansas Geospatial Community Commons (KGCC) Data Access & Support Center (DASC). Lawrence, KS: Kansas GIS Policy Board & Kansas Geological Survey. Available at: www.kansasgis.org/catalog. Accessed April 10, 2009.

KDHE. 2004. *Surface Water Nutrient Reduction Plan*. Topeka, KS: Kansas Department of Health and Environment (KDHE).

Kerr, R. L., S. J. Anderson, and J. Jaksch. 2000. Crosscutting analysis of trading programs: case studies in air, water, and wetland mitigation trading systems. Washington, D.C.: National Academy of Public Administration. Available at: www.napawash.org/pc_economy_environment/epafile06.pdf. Accessed April 30, 2009.

Kimball, R. 2002. The Data Warehouse Toolkit, 2nd Ed.. Wiley Computer Publishing.

KSU. 2006. Common Kansas Crop Rotations. Unpublished technical note. Manhattan, KS: Extension Agronomy, Kansas State University (KSU).

Leatherman, J., J. M. Peterson, and K. R. Mankin. 2005. Is Water Quality Trading a Policy Option for Kansas? In *Proc. 22nd Annual Water and the Future of Kansas Conference.* Topeka, KS: Kansas State University.

Lee, M. and K. R. Mankin. 2007a. A Site-Specific Water Quality Trading Ratio: Using GIS and Watershed Modeling to Account for Spatial and Temporal Variability. In *Proc: Watershed Management to Meet Water Quality Standards and TMDLs (Total Maximum Daily Load)*) ASAE Pub #701P0207. A. McFarland and A. Saleh ed. St. Joseph, MI: ASABE.

Lee, M., and K. R. Mankin. 2007b. Site-specific Water Quality Trading Ratio Analysis. 2007 ASABE Annual Meeting Paper No. 72179. St. Joseph, MI: ASABE.

Lee, M., K. R. Mankin, and J. M. Peterson. 2007a. Evaluation of Potential Water Quality Trading Sites with Network Analysis. 2007 ASABE Annual Meeting Paper No. 071091. St. Joseph, MI: ASABE.

Lee, M., K. R. Mankin, and J.M. S. Hutchinson. 2007b. WQTIPS: Water Quality Trading Information Platform System. 2007 ASABE Annual Meeting Paper No. 072021. St. Joseph, MI: ASABE.

Lee, M., K. R. Mankin, J. M. Peterson, and J. Leatherman. 2005. Water Quality Trading Issues in Kansas. ASABE Paper No. MC05-306. St. Joseph, MI.: ASABE.

Maddux, L. D. 2006. Interview by author. E-mail communication. Manhattan, KS. February 23.

Maidment, D. R. 2002. *Arc Hydro: GIS for water resources*. Redlands, CA: ESRI Press.

Miller H.J. and Shaw S. L. 2001. *Geographic Information System for Transportation. Principles and Applications.* Oxford, U.K.: Oxford University Press.

MRLC. 2008. National Land Cover Database 2001 (NLCD 2001). Washington, D.C.: Multi-Resolution Land Characteristics Consortium (MRLC). Available at: www.mrlc.gov. Accessed April 30, 2009.

NCDC. 2009. Daily surface data. Climate Data Online (CDO), National Climatic Data Center (NCDC). NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and U.S. Department of Commerce. Available at: cdo.ncdc.noaa.gov. Accessed March 31, 2009.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, and J. R. Williams. 2005. *Soil and Water Assessment Tool Theoretical Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS & Blackland Research and Extension Center, Texas A&M University.

Nelson, N. and A. Keeler. 2005. Water Quality Trading in Georgia: Addressing Two Potential Impediments to Success. In *Proc. 2005 Georgia Water Resources Conference*. Kathryn J. Ed. Athens, Georgia: Institute Ecology, University of Georgia. Available at: www.uga.edu/water/GWRC/Papers/NelsonN-GWRCpaper%20April13.pdf. Accessed April 30, 2009.

NRCS. 1997. State Soil Geographic (STATSGO) Database. Fort Worth, TX: USDA-NRCS, National Cartography and GIS Center. Available at: www.ncgc.nrcs.usda.gov/products/datasets/statsgo/. Accessed April 30, 2009.

NRCS. 2008a. Soil Data Availability Status Map. USDA-NRCS. Available at: soildatamart.nrcs.usda.gov/StatusMap.aspx. Accessed April 30, 2009.

NRCS. 2008b. Soil Survey Geographic (SSURGO) Database. USDA-NRCS. Available at: soils.usda.gov/survey/geography/ssurgo/. Accessed April 30, 2009.

NRCS. 2008c. U.S. General Soil Map (STATSGO2) Database. USDA-NRCS. Available at: soils.usda.gov/survey/geography/statsgo/. Accessed April 30, 2009.

NRCS. 2008d. Electronic Field Office Technical Guides. USDA-NRCS. Available at: www.nrcs.usda.gov/technical/efotg. Accessed April 30, 2009.

NRCS-Kansas. 2006. Crop field management record (dry land). Unpublished technical note. Lyndon, KS: USDA-NRCS, Kansas Division, Osage County Field Office.

Peterson, J. M., J. A. Fox, J. C. Leatherman, and C. M. Smith. 2007. Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market. In *Proc: 2007 Annual Meeting,* July 29-August 1, 2007, Portland, OR: American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association).

Renschler, C.S. 2003. Designing geo-spatial interfaces to scale process models: The GeoWEPP approach. Hydrological Processes 17, 1005-017.

Shaffer, M.J. 1995. Fate and Transport of Nitrogen What Models Can and Cannot Do. RAC III Working Paper No.11, USDA ARS. Available at: www.nrcs.usda.gov. Accessed May 4, 2005.

Shroyer, J. P., D. Whitney, and D. Peterson. 1997. *Wheat Production Handbook*. C-529. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Shroyer, J. P., C. Thompson, R. Brown, P. D. Ohlenbush, D. L. Fjell, S. Staggenborg, S. Duncan, G. L. Kilgore. 1996. *Kansas Crop Planting Guide*. L-818. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Shroyer, J. P., D. L. Fjell, K. C Dhuyvetter, L. N. Langemeier, G. L. Kuhl, J. O. Fritz. 1993. *Wheat Pasture in Kansas*. C-713 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Smith, C. M. 2004. A Water Quality Trading Simulation for Northeast Kansas. MS Thesis. Manhattan, KS: Kansas State University, Department of Agricultural Economics.

Smith, C. M., J. M. Peterson, and J. C. Leatherman. 2007. Attitudes of Great Plains Producers about Best Management Practices, Conservation Programs, and Water Quality. *J. Soil and Water Conserv.* 62: 97A-103A.

Streeter, H. W. and E. B. Phelps. 1925. A Study of the pollution and natural purification of the Ohio River, III. Factors concerned in the phenomena of oxidation and re-aeration. Public Health Bulletin No.146. Washington, D.C.: Treasury Department, U.S. Public Health Service.

USDA. 2009. Geospatial Data Gateway. USDA. Available at: datagateway.nrcs.usda.gov/, Accessed April 30, 2009.

USEPA. 2004. *Water Quality Trading Assessment Handbook*. Washington, D.C.: Office of Water. USEPA.

USGS. 1999. National Land Cover Dataset 1992 (NLCD 1992). USGS. Available at: landcover.usgs.gov/mapping_proc.php. Accessed April 30, 2009.

USGS. 2006. National Elevation Dataset (NED). USGS. Available at: ned.usgs.gov. Accessed April 30, 2009.

USGS. 2008a. National Atlas of the United States. Reston, VA: USGS. Available at: nationalatlas.gov. Accessed April 30, 2009.

USGS. 2008b. National Hydrography Dataset (NHD). USGS. Available at: nhd.usgs.gov, Accessed April 30, 2009.

USGS. 2009. Geospatial One Stop. Reston, VA: USGS. Available at: gos2.geodata.gov/wps/portal/gos. Accessed April 30, 2009.

Wang, X., C. Du, M. Homer, S.D. Dyer, C. White-Hull. 2002. GIS-ROUT: Integration of ArcIMS and a River Water Quality Model, gis.esri.com/library/userconf/proc02/pap1259/p1259.htm. Accessed May 4, 2005

Wang, X., M. Homer, S.D. Dyer, C. White-Hull, and C. Du. 2005. A river water quality model integrated with a web-based geographic information system. *J. of Environmental Management* 75(3): 219-228.

Wood, A. and R. Bernknopf, 2003. Preliminary Review for a Geographic and Monitoring Program Project: A review of point source-nonpoint source effluent trading /offset systems in watersheds. Open file report 03-79. Washington, D.C.: USGS.

Woodward, R. T., and R. A. Kaiser, 2002. Market Structures for U.S. Water Quality Trading. *Rev. Agr. Econ.* 24: 366-383.

WRI, 2007. NutrientNet. World Resources Institute (WRI), Available at: www.nutrientnet.org. Accessed April 30, 2009.

Zeiler, M. 1999. Modeling *our world: the ESRI guide to geodatabase design*. Redlands, CA: ESRI Press.

Chapter 6 Summary and Conclusions

Water quality trading (WQT) is a market-based approach to improve water quality. It is an innovative, voluntary tool that connects industrial and municipal facilities, or point sources (PSs), with agricultural producers, the nonpoint sources (NPSs), to economically achieve water quality improvements in a watershed. It is a flexible and cost-effective approach for maintaining, restoring, or enhancing water quality. However, the design of a WQT program requires sufficient knowledge and understanding of the targeted pollutant and the watershed it affects. The candidate pollutants can be produced from either PSs or NPSs, but the pollution processes can be quite different depending upon its source and location. Most PS pollutant loads are almost consistent on a day-to-day basis, but NPS loads, the by-product of storm water runoff, are event-based with widely variant. For specific cases, the potential pollutant loads vary by subbasin. Due to these differences in measurement scale, pollutant origins and source locations may cause significant disparity of load reduction, load uncertainty and transport effect for trades between PSs and NPSs. Therefore, the goal of this study was to quantify uncertainties of pollutant load reduction and delivery effects for potential trades, estimating spatiotemporal variations of potential trades, and providing rich WQT information for stakeholders to reduce intangible costs of WQT.

From an engineering perspective, the best practice for evaluating the risk of a trade in WQT is to develop a floating trading-ratio system of pollutant load reduction with its in-field uncertainty ratio and in-stream delivery ratio with sound scientific watershed model and geospatial analyses. In this dissertation, a method is demonstrated to estimate the tradable pollutant load reductions and potential trading risks resulting from specific changes in land management, locations of trading partners, processes that attenuate downstream delivery of pollutants, and time frame of the trade. A spatiotemporally specific trading ratio then was calculated to represent the statistical uncertainty (or trading risk) that accounts for spatiotemporal variability in pollutant load reductions and delivery. The hypothesis was that a system that better quantified trading risk would also reduce the required trading ratio, thus providing more tradable credits per unit cost. Based on above analysis results, a GIS-based web interface, termed the 'Water Quality Trading Information Platform Service' (WQTIPS), was demonstrated as an assessment tool to provide systematic structure to allow incorporation of a site-specific trading ratio into a WQT system and rich information for stakeholders.

In Chapter 2, we developed a method to quantify the uncertainty of tradable load reduction with statistical analysis and watershed modeling. Preliminary results for TN and TP load, load reduction, uncertainty ratio, and trading ratio (TR) for each scenario pair were then calculated. The variation of potential pollutant load reductions and TRs for specific scenarios vary by subbasin, which indicates that the best alternative scenario pair might change from one subbasin to another

In Chapter 3, we applied the framework to 225 alternative scenarios of land management practice with combinations of crop rotations, tillage systems, fertilizer application methods, and edge-of-field BMPs to simulate the nutrient yields and potential load reduction between each pair of alternative scenarios in the Lower Kansas watershed, Kansas. With the variations in potential nutrient load reduction, the R_U and TR were then calculated. The main effects and cross effects showed significant differences among the design criteria. With the variation of potential nutrient load reduction in each subbasin and time period, the analyses of site-specific effects in both geospatial and temporal aspects were also applied to subbasin level WQT parameters. The results strongly supported that site-specific phenomena exist in the study watershed.

In Chapter 4, we used several approaches to quantify the in-stream uncertainties of WQT in the Lower Kansas watershed. The delivered effects of subbasin-level TN and TN nutrient loads were simulated using the SWAT model, and impacts of lakes/reservoirs in the trading risk analysis simulated using the EUTROMOD loading functions. The results show a significant delivery effect within the subbasins: the delivery ratio ranged from 0.8882 to 0.9997 excluding lake effects and from 0.388 to 0.791 including lake effect. These phenomena suggest geospatial site-specific effects also apply to the delivery ratio for each subbasin across the watershed. The overall TR for both nutrients ranged from 1 to 2.2 or more in different scenarios, suggesting that a floating TR system would be more suitable than fixed 2:1 TR in study watershed. Another alternative that was analyzed was cluster analysis, which splits a watershed into several sub-regional trading zones with TR being constant within each zone. This eliminates the issues involved in fixed TRs while keeping the method simpler than floating TR system.

In Chapter 5, a GIS-based web interface information platform system, the Water Quality Trading Information Platform System (WQTIPS) was developed. WQTIPS offers services other than a common data repository: information sharing, data visualization and assessment support tool to capture information online. The WQT Geodatabase Data Model (WQTGDM) was introduced to standardize the procedure and structure of WQT in data collecting and in maintaining and synchronizing WQT. In our case study, a three-tier GIS-based web interface WQTIPS provided for WQT information querying and assessment functions for stakeholders inquiring about the potential benefits. Sellers, or upstream farmers, could use the system to prioritize alternative scenarios with their potential loads and load reductions to gain maximum trading credits; buyers, or interested downstream pollution sources, could use the system to search for lower trading risk sources and thus decrease their costs. The case study demonstrated that the processes for assessing WQT benefit with WQTIPS are feasible.

WQT incorporating watershed model and GIS techniques to estimate the potential trading benefit and risk was demonstrated to be a feasible approach of pollution reduction in a watershed and a potential method to conduct the TMDLs or the water quality goal. Although methods for calculating trading parameters were demonstrated in this study, the community acceptance, government policy and stakeholders' willingness, all keys for success of WQT program, were not evaluated.

The application of incorporating watershed model with GIS techniques to estimate the potential, spatiotemporally varying load reductions, environmental benefits, or site-specific trading parameters is not limited to surface water quality from agricultural watersheds. Changing the watershed model with the another model in other disciplines, such as air pollutant emission model for air pollution or crop growth model for greenhouse gas emission, the WQT processes and analysis methods demonstrated in this study are also feasible to apply to these fields, with some minor tailoring. The GIS-based web interface WQTIPS demonstrates that it is possible to automate water-quality trades and prioritize among possible trades both spatially and by land management practice in this study. It also provides an information platform template for the other discipline to follow.

Although we used more than 30 years historical climate data to simulate the potential pollutant loads in our study watershed, the severe global climate changes in recent years might significantly affect the reliability of the estimation of TR and pollutant load reduction in this study. Introducing advanced climate forecast methods or modeling with the weather changes adjustment will be one of the future tasks of WQT research. In future research, integrating WQTIPS with public geospatial map services like Google Map or Microsoft Virtual Earth may simplify the construction process and cost of WQTIPS, provide users a friendlier user interface, and use a more powerful internet map engine and data service. Furthermore, although the geospatial site-specific phenomena have been visualized in WQTIPS, rendering subbasins in different color schemes, the monthly and seasonal effect of WQT were not covered in this study. Therefore, including WQT time-series information into the next version of WQTIPS is a challenge for WQT researchers.

Appendix A Design of Modeling Scenario

Introduction

The primary goal of using watershed modeling tools in this study is to assess the impact among land management practices on the given area and also maximize the potential water-quality benefits within a given trade. Central to the modeling works is the itemization of the management practices and field operations taking place within the watershed. The design and evaluation of these itemizations for WQT is the major goal of this chapter.

A.1 Scenario Designs

As described previously, the efforts to alleviate the impact of agriculture on water quality have focused primarily on the abatement of soil erosion and proper management of chemical fertilizers. The broader designs of agricultural BMPs demonstrably provided alternative management for croplands to reduce in-field pollutant load and stream contaminant levels. Referring to SWAT documents (Neitsch et al., 2004; Neitsch et al., 2005), four categories and balanced scenario designs were chosen for the different scenarios in this study: crop type (CROP), tillage system (TILL), edge-of-field BMP (BMPS), and fertilizer application (FERT). By changing one of these four categories at a time, a balanced alternative management scenario can be implemented. These four variable categories are also the most important factors for modeling field operation in land management practices in SWAT.

To analyze and compare the model results from SWAT outputs, the scenarios with un-regulated varied parameters will result an obscure consequence. The balanced design could minimize cross effects from other static variable categories and provide a clearer comparison at the dynamic variable category levels. Moreover, some plants other than common food or feed crops were also interested in their nutrient load reduction abilities to replace other crops in WQT assessment. Hence, the native prairie grass, alternative energy source or bio-fuel plant, and general VFS cover grass were simulated in this study.

The modeling scenario designs in this study were included the five specific alternative scenarios of pilot study in Chapter 2, the 225 scenarios simulated annually and 65 scenarios monthly on agricultural cropland for estimating in-field load reduction uncertainty in Chapter 3, and the 35 scenarios for simulating in-stream load delivery effect in Chapter 4 and for the demonstration of WQTIPS in Chapter 5. Although the number of modeling scenarios and applied soil/landuse datasets might different in each chapter, the design concept for the scenarios is similar.

A.1.1 Scenario Design for Pilot Study, In-Stream Delivery and WQTIPS

To coordinate the economic analysis scenarios, which are the comparison scenarios in the field survey of "choice experiments of producers (NPS)" in the study watershed (Peterson et al., 2007; Smith et al., 2007); five specific alternative land management practices have been simulated in Chapter 2 for pilot study. As described in Session:2.4.2, Table A-1 (same as Table 2-2) lists the details of the five cases, one for baseline and the others for four alternatives, which were simulated with SWAT and will integrate with economic estimations. These five land management practices are based on a two-year corn-soybean rotation with surface-broadcast fertilizer application. Even though there are only five cases needed in pilot study, to have a balanced design of modeling simulation, more extra scenarios were modeled in practice. Table A-2 (same as Table 4-1) explains the levels of variables for a balanced design in Chapter 2. In order to simulate the fall grazing event on VFS for Case4 in Table A-1, two extra scenarios were modeled for analyzing the potential load and load reduction differences between with and without grazing. Based on these analyzing results, another 10 scenarios were developed to approximate the scenario for grazing on VFS, which is 4% of total area.

Based on the Table A-2 and simulating grazing effect on VFS, the total 35 scenarios were needed. Table A-3 displays the major parameters of all 35 scenarios for SWAT modeling. The scenarios in Table A-3 which number ranges from 1 to 20 are balanced design scenarios. These scenarios were directly simulated with SWAT. For scenario's number ranges from 21 to 30 are the scenarios for simulating grazing on VFS. The other scenarios are the major grasses or the grazing event simulation scenarios. These 35 scenarios were also the modeling scenario in Chapter 4 and Chapter 5.

Table A-4 presents the three subsets of Table A-3. The first subset is the scenarios used in pilot study. The second subset is similar to the first subset but with a sub-surface fertilizer application. The scenarios in second subset were modeled and analyzed for comparison on the method of fertilizer application. The third subset includes native grasses, VFS grass and simulation for grazing event on VFS. All the scenarios in Table A-3 were modeled and analyzed, but the analyses and discussions were more focused on the scenarios in Table A-4 in Chapter 2, Chapter 4 and Chapter 5. The descriptions for the scenario design can be found in Section: 2.4.2 for Chapter 2, Section: 4.4.3 for Chapter 4, and Section: 5.4.3 for Chapter 5. The full modeling scenarios and their descriptions can be found in Table A-18 and Table A-19.

Table A-1 Major SWAT Parameters for Modeling Scenario in Pilot Study

Case	Crop Rotation	Till[1]	Abbrev.[2]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[3] A	B	C	D	Manning's n	K_{SAT}
Baseline	CORN-SOYB (2-yr)	MT	CS4SB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.27	67	77	84	88	0.12	---
Case1		NT	CS1SB			0.12	77	84	88	90	0.24	2x
Case2		OT[2]	CS2SB			0.2	72	80	86	89	0.18	1.5x
Case3		MT	CS4SB/FS			0.27	67	77	84	88	0.12	---
Case4		MT	CS4SB/FS-GZ			0.27	67	77	84	88	0.12	---

Note: **1. NT**: no-till; **OT**: rotational tillage, which is the tillage system with halftime no-till (NT) with corn and halftime minimum tillage (MT) with soybean; **MT**: minimum tillage. **2. SB**: general surface fertilizer application (surface broadcast); **C** corn; **S** soybean; **CS**: 2-yr corn-soybean rotation; **FS** with edge-of-field VFS; **FS-GZ** implementing edge-of-field VFS with fall grazing event on it. **3. CN2**: curve number for moisture condition II or antecedent moisture condition II (AMC II); **HSG**: hydrologic soil group.

Table A-2 Variable and Level for Scenario Design in Pilot Study

Variable	Attribute	Level
CROP[1]	Growing crops or rotation	BBLS, SWCH, FESC, CORN-SOYB
TILL[2]	Tillage system on the field	NT, OT, RT, MT, CT
BMPS[3]	Edge-of-field BMPs	Blank, FS; FSGZ
FERT[4]	Fertilizer application method	SB, DB

Note: 1. BBLS: big bluestem, used to simulate native prairie grass with SWAT default Big Bluestem parameters; **SWCH**: switchgrass, used to simulate alternative energy source (bio-fuel) with SWAT default Alamo Switchgrass parameters; **FESC**: tall fescue, used to simulate a Kansas cool season grass for vegetative filter strip with SWAT default Tall Fescue parameters; **CORN-SOYB**: two-year corn-soybean rotation. **2. NT**: no-till; **OT**: rotational tillage, which is a tillage system with halftime no-till (NT) and halftime minimum tillage (MT); **RT**: reduced tillage; **MT**: minimum tillage; **CT**: conventional tillage. **3.** Blank: without any BMP at the edge of field; **FS**: with VFS at the edge of field; **FSGZ**: with the grazing actives on VFS at the edge of field. **4. SB**: general surface fertilizer application; **DB**: general sub-surface fertilizer application.

Table A-3 Major SWAT Parameters for Modeling Scenarios in Chapters 2, 4, and 5

Scen#	Case#[1]	Crop Rotation	Till[2]	Abbrev.[3]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
S1		CORN-SOYB (2-yr)	CT	CS5SB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.27	67	77	84	88	0.09	---
S2				CS5SBFS									
S3				CS5DB									
S4				CS5DBFS									
S5	SBase		MT	CS4SB			0.27	67	77	84	88	0.12	---
S6	SCase3			CS4SBFS									
S7	DBase			CS4DB									
S8	DCase3			CS4DBFS									
S9			RT	CS3SB			0.27	67	77	84	88	0.14	---
S10				CS3SBFS									
S11				CS3DB									
S12				CS3DBFS									
S13	SCase2		OT	CS2SB			0.2	72	80	86	89	0.18	1.5x
S14				CS2SBFS									
S15	DCase2			CS2DB									
S16				CS2DBFS									
S17	SCase1		NT	CS1SB			0.12	77	84	88	90	0.24	2x
S18				CS1SBFS									

Scen#	Case#[1]	Crop Rotation	Till[2]	Abbrev.[3]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
S19	DCase1	CORN-SOYB (2-yr)		CS1DB									
S20				CS1DBFS									
S21			CT	CS5SBFSGZ	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.27	67	77	84	88	0.09	---
S22				CS5DBFSGZ									
S23	SCase4		MT	CS4SBFSGZ			0.27	67	77	84	88	0.12	---
S24	DCase4			CS4DBFSGZ									
S25			RT	CS3SBFSGZ			0.27	67	77	84	88	0.14	---
S26				CS3DBFSGZ									
S27			OT	CS2SBFSGZ			0.2	72	80	86	89	0.18	1.5x
S28				CS2DBFSGZ									
S29			NT	CS1SBFSGZ			0.12	77	84	88	90	0.24	2x
S30				CS1DBFSGZ									
S31	BBLS	Big Bluestem	n/a	BBLS	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
S32	SWCH	Switchgrass	n/a	SWCH	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
S33	FESC	Fescue	n/a	FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
S34	FESC	Fescue	FS	FSGZ0	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
S35			GZ	FSGZ1									

Note: 1. NT: no-till; OT: rotational tillage (50% No-till). Apply no-till on corn and minimum tillage on soybean; RT: reduced tillage; MT: minimum tillage; CT: conventional tillage. **2.** C: corn; S: soybean; CS: two-year corn-soybean rotation; BBLS: big bluestem; SWCH: switchgrass; FESC: tall fescue; FSGZ0: without grazing event; FSGZ1: with grazing event; SB: surface fertilizer application (surface broadcast); DB: sub-surface fertilizer application (deep band application); FS: with VFS at the edge of field; FSGZ: with the grazing on VFS at the edge of field. **3.** CN2: Curve Number for moisture condition II or antecedent moisture condition II (AMC II); HSG: Hydrologic Soil Group.

Table A-4 Subsets for Modeling Scenarios in Chapters 4

Surface Fertilizer Subset

Scen#	Econ#[1]	Crop Rotation	Till[2]	Abbrev.[3]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
S5	SBase	CORN-SOYB (2-yr)	MT	CS4SB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.27	67	77	84	88	0.12	---
S17	SCase1		NT	CS1SB			0.12	77	84	88	90	0.24	2x
S13	SCase2		OT	CS2SB			0.2	72	80	86	89	0.18	1.5x
S6	SCase3		MT	CS4SBFS			0.27	67	77	84	88	0.12	---
S23	SCase4		MT	CS4SBFSGZ			0.27	67	77	84	88	0.12	---

Sub-surface Fertilizer Subset

Scen#	Econ#[1]	Crop Rotation	Till[2]	Abbrev.[3]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
S7	DBase	CORN-SOYB (2-yr)	MT	CS4DB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.27	67	77	84	88	0.12	---
S19	DCase1		NT	CS1DB			0.12	77	84	88	90	0.24	2x
S15	DCase2		OT	CS2DB			0.2	72	80	86	89	0.18	1.5x
S8	DCase3		MT	CS4DBFS			0.27	67	77	84	88	0.12	---
S24	DCase4		MT	CS4DBFSGZ			0.27	67	77	84	88	0.12	---

Native Prairie Grass and Vegetative Filter Strip Subset

Scen#	Econ#[1]	Crop Rotation	Till[2]	Abbrev.[3]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[4] A	B	C	D	Manning's n	K_{SAT}
S31	BBLS	Big Bluestem		BBLS	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
S32	SWCH	Switch Grass		SWCH	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
S33	FESC	Fescue		FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
S34	FESC2	Fescue	FS	FSGZ0	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
S35	FESC3		GZ	FSGZ1									

A.1.2 Scenario Design for In-Field Uncertainty and Temporal Effect Analysis

As described in Section: 3.4, in order to estimate the water-quality benefit among possible land management practices in study watershed, the 14 levels on CROP, five tillage system on TILL, with or without VFS at the edge of the field for BMPS, and surface and sub-surface two fertilizer on FERT were listed in Table A-5 (same as Table 3-3). Based on Table A-5, there are 225 scenarios were modeled and estimated their annual nutrient loads in Chapter 3. The major parameters for these scenarios were listed in Table A-6. The listed parameters in Table A-6 are the general modeling settings for the similar scenarios. There are some minor fine-tunes required before modeling each scenario. To analyze the temporal effects of pollutant load and load reduction among alternative scenarios in study watershed, the first 60 and last five scenarios of the annual 225 scenarios were calculated in monthly basis. Table A-7, a subset of Table A-6, briefs the major parameters of SWAT for the 65 scenarios. All scenarios in either Table A-6 or Table A-7 were was simulated in daily time-steps with SWAT but analyzed in different duration. The full scenario lists can be found on Table A-20 and Table A-21.

Table A-5 Variable and Level for Scenario Design in Chapters 3

Variable	Attribute	Levels
CROP[1]	Growing crops or rotation	BBLS, SWCH, FESC, CORN, GRSG, SOYB, WWHT, WWHT-SOYB, CORN-SOYB, GRGS-SOYB, WWHT-FALW, WWHT-(FALW)-CORN, WWHT-(FALW)-GRSG, WWHT-GRSG-SOYB
TILL[2]	Tillage system on field	NT, OT, RT, MT, CT
BMPS[3]	Edge-of-field BMPs	Blank, FS
FERT[4]	Fertilizer application method	SB, DB

Note: **1.** BBLS: big bluestem, used to simulate native prairie grass with SWAT Big Bluestem parameters; SWCH: switchgrass, used to simulate alternative energy source (bio-fuel) with SWAT Alamo Switchgrass parameters; FESC: tall fescue, used to simulate a Kansas cool season grass for vegetative filter strip with SWAT default Tall Fescue parameters; CORN: continuous corn; GRSG: continuous grain sorghum; SOYB: continuous soybean; WWHT: continuous winter wheat; WWHT-SOYB: 1-year winter wheat-soybean double crops; CORN-SOYB: 2-year corn-soybean rotation; GRGS-SOYB: 2-year grain sorghum-soybean rotation; WWHT-FALW: 2-year winter wheat-fallow rotation; WWHT-(FALW)-CORN: 3-year winter wheat-fallow-corn rotation; WWHT-(FALW)-GRSG: 3-year winter wheat-fallow-grain sorghum rotation; WWHT-GRSG-SOYB: 3-year winter wheat-grain sorghum-soybean rotation. **2.** NT: no-till; OT: rotational till, a tillage system with 50% no-till and 50% minimum till; RT: reduced tillage; MT: minimum tillage; CT: conventional tillage. **3.** Blank: without any BMP; FS: with VFS. **4.** SB: surface fertilizer; DB: sub-surface fertilizer.

Table A-6 Major SWAT Parameters for Annual Modeling Scenarios in Chapters 3

Crop Rotation	Till[1]	Abbrev.[2]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[3]				Manning's n	K_{SAT}
						A	B	C	D		
Big Bluestem		BBLS	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
Switchgrass		SWCH	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
Fescue		FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
Fescue (1-yr)	FS GZ	FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
CORN (1-yr)	NT	C1 SB/DB			0.13	77	83	87	89	0.3	2x
	OT	C2 SB/DB			0.22	72	80	85	88	0.22	1.5x
	RT	C3 SB/DB	05/01/01	09/15/01						0.14	
	MT	C4 SB/DB			0.31	67	77	83	87	0.12	---
	CT	C5 SB/DB								0.09	
GRSG (1-yr)	NT	G1 SB/DB			0.13	77	83	87	89	0.3	2x
	OT	G2 SB/DB			0.22	72	80	85	88	0.22	1.5x
	RT	G3 SB/DB	06/01/01	10/15/01						0.14	
	MT	G4 SB/DB			0.31	67	77	83	87	0.12	---
	CT	G5 SB/DB								0.09	
WWHT (1-yr)	NT	W1 SB/DB			0.03	73	81	84	86	0.2	2x
	OT	W2 SB/DB			0.03	68	77	82	85	0.17	1.5x
	RT	W3 SB/DB	09/15/01	06/15/02						0.15	
	MT	W4 SB/DB			0.03	62	73	81	84	0.14	---
	CT	W5 SB/DB								0.12	
SOYB (1-yr)	NT	S1 SB/DB			0.11	78	85	89	91	0.19	2x
	OT	S2 SB/DB			0.17	72	81	87	90	0.16	1.5x
	RT	S3 SB/DB	05/15/01	10/07/01						0.14	
	MT	S4 SB/DB			0.23	67	78	85	89	0.12	---
	CT	S5 SB/DB								0.09	
WWHT-SOYB (1-yr) (Double Crop)	NT	WS1 SB/DB			0.07	75	83	86	88	0.2	2x
	OT	WS2 SB/DB			0.1	70	79	84	87	0.17	1.5x
	RT	WS3 SB/DB	W: 10/01/01 S: 06/01/01	W: 05/22/01 S: 09/15/01						0.15	
	MT	WS4 SB/DB			0.13	65	76	83	87	0.13	---
	CT	WS5 SB/DB								0.11	
CORN-SOYB (2-yr)	NT	CS1 SB/DB			0.12	77	84	88	90	0.24	2x
	OT	CS2 SB/DB			0.2	72	80	86	89	0.18	1.5x
	RT	CS3 SB/DB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02						0.14	
	MT	CS4 SB/DB			0.27	67	77	84	88	0.12	---
	CT	CS5 SB/DB								0.09	
GRGS-SOYB (2-yr)	NT	GS1 SB/DB			0.12	77	84	88	90	0.24	2x
	OT	GS2 SB/DB			0.2	72	80	86	89	0.18	1.5x
	RT	GS3 SB/DB	G: 06/01/01 S: 05/15/02	G: 10/15/01 S: 10/07/02						0.14	
	MT	GS4 SB/DB			0.27	67	77	84	88	0.12	---
	CT	GS5 SB/DB								0.09	
WWHT-FALW (2-yr)	NT	WF1 SB/DB			0.03	73	81	84	86	0.2	2x
	OT	WF2 SB/DB			0.03	68	77	82	85	0.17	1.5x
	RT	WF3 SB/DB	W: 09/15/01	W: 06/15/02						0.15	
	MT	WF4 SB/DB			0.03	62	73	81	84	0.14	---
	CT	WF5 SB/DB								0.12	

Crop Rotation	Till[1]	Abbrev.[2]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[3]				Manning's n	K_{SAT}
						A	B	C	D		
WWHT-CORN (3-yr)	NT	WC1 SB/DB	W: 09/15/03 C: 05/01/02	W: 06/15/01 C: 09/15/02	0.08	75	82	85	87	0.25	2x
	OT	WC2 SB/DB			0.12	70	79	84	86	0.2	1.5x
	RT	WC3 SB/DB								0.15	
	MT	WC4 SB/DB			0.17	64	75	82	85	0.13	---
	CT	WC5 SB/DB								0.1	
WWHT-GRSG (3-yr)	NT	WG1 SB/DB	W: 09/15/03 G: 06/01/02	W: 06/15/01 G: 10/15/02	0.08	75	82	85	87	0.25	2x
	OT	WG2 SB/DB			0.12	70	79	84	86	0.2	1.5x
	RT	WG3 SB/DB								0.15	
	MT	WG4 SB/DB			0.17	64	75	82	85	0.13	---
	CT	WG5 SB/DB								0.1	
WWHT-GRSG-SOYB (3-yr)	NT	WGS1 SB/DB	W:10/01/03 G: 06/01/02 S:05/15/03	W: 06/15/01 G: 10/15/02 S: 09/15/03	0.1	76	83	86	88	0.25	2x
	OT	WGS2 SB/DB			0.16	71	79	84	87	0.2	1.25x
	RT	WGS3 SB/DB								0.15	
	MT	WGS4 SB/DB			0.22	66	76	83	87	0.13	---
	CT	WGS5 SB/DB								0.1	

Note: **1.** NT: no-till; OT: rotational tillage, which is a tillage system applied halftime with no-till (NT) and another half with minimum tillage (MT); RT: reduced tillage; MT: minimum tillage; CT: conventional tillage. **2.** C: corn; S: soybean; G: grain sorghum; W: winter wheat; WS: 1-yr winter wheat-soybean double crop; CS: 2-yr corn-soybean rotation; GS: 2-yr grain sorghum-soybean rotation; WF: 2-yr winter wheat-fallow rotation; WC: 3-yr winter wheat-fallow-corn rotation; WG: 3-yr winter wheat-fallow-grain sorghum rotation; WGS: 3-yr winter wheat-grain sorghum-soybean rotation; BBLS: big bluestem; SWCH: switchgrass; FESC: tall fescue; SB: surface fertilizer application (surface broadcast); DB: sub-surface fertilizer (deep band). **3.** CN2: curve number for moisture condition II or antecedent moisture condition II (AMC II); HSG: hydrologic soil group.

Table A-7 Major SWAT Parameters for Monthly Modeling Scenarios in Chapters 3

Crop Rotation	Till[1]	Abbrev.[2]	Plant Date	Harvest Date	USLE C	CN2/(HSG)[3]				Manning's n	K_{SAT}
						A	B	C	D		
CORN-SOYB (2-yr)	NT	CS1 SB/DB	C: 05/01/01 S: 05/15/02	C: 09/15/01 S: 10/07/02	0.12	77	84	88	90	0.24	2x
	OT	CS2 SB/DB			0.2	72	80	86	89	0.18	1.5x
	RT	CS3 SB/DB								0.14	
	MT	CS4 SB/DB			0.27	67	77	84	88	0.12	---
	CT	CS5 SB/DB								0.09	
CORN (1-yr)	NT	C1 SB/DB	05/01/01	09/15/01	0.13	77	83	87	89	0.3	2x
	OT	C2 SB/DB			0.22	72	80	85	88	0.22	1.5x
	RT	C3 SB/DB								0.14	
	MT	C4 SB/DB			0.31	67	77	83	87	0.12	---
	CT	C5 SB/DB								0.09	
SOYB (1-yr)	NT	S1 SB/DB	05/15/01	10/07/01	0.11	78	85	89	91	0.19	2x
	OT	S2 SB/DB			0.17	72	81	87	90	0.16	1.5x
	RT	S3 SB/DB								0.14	
	MT	S4 SB/DB			0.23	67	78	85	89	0.12	---
	CT	S5 SB/DB								0.09	
Big bluestem		BBLS	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
Switchgrass		SWCH	03/15/01	12/01/01	0.003	31	59	72	79	0.1	---
Fescue (1-yr)		FESC	03/01/01	12/01/01	0.003	31	59	72	79	0.1	---
	FS	FESC0									
	GZ	FESC1									

A.2 Major Variables for Scenario Design

Summarized the field experiences and prior researches in Lower Kansas watershed (Barnes, 2006; Boyer, 2006; KSU, 2006; Maddux, 2006), four categories and balanced scenario designs were chosen for the different scenarios in this study: crop type (CROP), tillage system (TILL), edge-of-field BMP (BMPS), and fertilizer application (FERT). The crop types included the major field crops and some potential plants, which might be the alternatives, in study area. The tillage systems included both current and potential methods, which were suggested by watershed professionals (Barnes, 2006; Boyer, 2006; Maddux, 2006). Either surface (surface broadcast) or sub-surface (deep band) fertilizer applications are common in study watershed (Barnes, 2006). Therefore, the fertilizer application was defined as these two methods. For the edge-of-field BMPs, the vegetative filter strips (VFSs) is common in study area (Maddux, 2006). In order to incorporate the comparison scenarios in the field survey of "choice experiments of producers (NPS)" in the study watershed (Peterson et al., 2007; Smith et al., 2007), extra discussions for approximating fall grazing on VFSs were included.

A.2.1 Crop Type

A.2.1.1 *Major Crop Rotation and Native Prairie Grasses*

Kansas is the first place of wheat production in United States. Its wheat acreage is almost 16% of whole United States (NASS, 2008). However, in study watershed area, Lower Kansas watershed, the dominant crops are corn, soybean, grain sorghum and some rotated winter wheat following the harvest of corn or soybeans (Barnes, 2006; Boyer, 2006; Maddux, 2006; NRCS, 2008b). In terms of the information summarized by the watershed specialists in study watershed, the continuous corn, grain sorghum, and soybeans as well as the rotated corn-soybeans or corn-soybeans-winter wheat are common crop operations in northeastern Kansas (KSU, 2006). Table A-8 depicts the common crop rotations in different area of Kansas. Nelson et al. (2006) used corn-soybean, corn-soybean-wheat, grain sorghum-soybean, and grain sorghum-soybean-wheat as modeling crop rotations in Delaware watershed to simulate water quality with SWAT and to estimate the environmental benefits among these scenarios to alternative switchgrass, a bio-energy crop.

Beside the common food and feed crops, some other alternative plants/crops, which might reduce soil erosion and also improve water quality, were interested in this study. The first one is the bio-energy plant. Babcock et al. (2007) in their study on environmental impacts of alternative energy crops suggested switchgrass as the energy plant in Great Prairie. Nelson et al. (2006) also used switchgrass as the bio-energy crop to compare its environmental and economic benefit with other traditional crop rotations in Delaware watershed, northeastern Kansas. Another interesting plant, which used for agricultural cropland restoration, is native prairie grass. Due to the most of non-point source (NPS) pollution came from the agricultural cropland, restoring cultivated fields back to original prairie plain can be a baseline scenario for comparing pollutant load to other human activities. One of the common prairie grasses, big bluestem, is selected as the representative of native grasses in the restored prairie scenario. For the study of VFS grazing effects, the tall fescue (*Festuca arundinacea*), which is a deep rooted, cool season perennial grass, is the common plant for the VFS and pastures land in northeastern Kansas. Although these three grasses were assigned different meaning on the modeling scenarios, switchgrass, big bluestem and tall fescue are the common grass scenarios in the study watershed.

Table A-8 Common Crop Rotations in Kansas (KSU, 2006)

North-East Kansas	South-Central Kansas	South-West Kansas
Continuous Corn	Continuous Wheat	Corn-Wheat-Fallow
Corn-Soybean	Corn-Soybean	Grain Sorghum-Wheat-Fallow
Corn-Soybean-Wheat	Corn-Soybean-Wheat	Wheat-Fallow
Corn-Soybean-Wheat-3Alfalfa	Corn-Soybean-Wheat-3Alfalfa	
Continuous Grain Sorghum	Continuous Grain Sorghum	
Grain Sorghum-Soybean	Grain Sorghum-Soybean	
Grain Sorghum-Soybean-Wheat	Grain Sorghum-Soybean-Wheat	
Grain Sorghum-Soybean-Wheat-3Alfalfa	Grain Sorghum-Soybean-Wheat-3Alfalfa	
Continuous Soybean	Continuous Soybean	
	Grain Sorghum-Wheat	

A.2.1.2 *Crop Season*

Following the major crop types in study watershed, the planting dates can be acquired from the literatures and watershed specialists. Figure A-1 illustrates the zone divisions for the general crops in Kansas (Shroyer et al., 1996). Table A-9 shows the suggested crop planting dates for each zone which excerpted from "Kansas Crop Planting Guide" published by Kansas State University Agricultural Experiment Station and Cooperative Extension Service (Shroyer et al., 1996). Generally, the earlier planting dates of the planting range are for spring-planted crops in eastern and southern Kansas, while for fall-planted crops, they apply to northern and western Kansas. A similar date and schedule of each major crop types with common tillage systems are also acquired from watershed specialists in study area (Maddux, 2006; Boyer, 2006). Table A-10 tabulated the planting and harvesting dates for each crop in study area.

Summarized the crop growing information from field operations and the publications from Kansas State University Agricultural Experiment Station, the crop seasons in this area are: corn (April to September), soybeans (May to September), grain sorghum (mid-June to late-October), and winter wheat (mid-October to next June) (Shroyer et al., 1993; Shroyer et al., 1996; Fjell et al. 1997; Shroyer et al., 1997; Fjell, 1998; Fjell et al. 2007;). Table A-11 illustrates the general crop planting and harvesting dates for major four crops in northeastern Kansas.

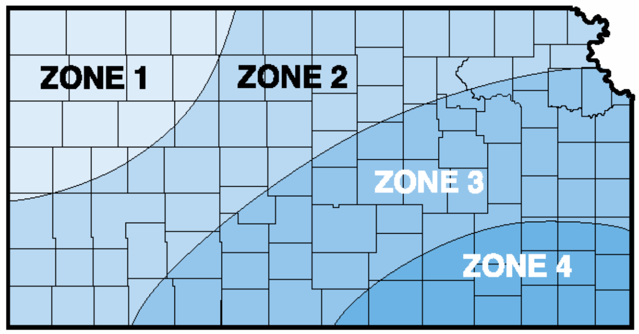


Figure A-1 General Zone Division of Kansas Crop Planting Dates (Shroyer et al., 1996)

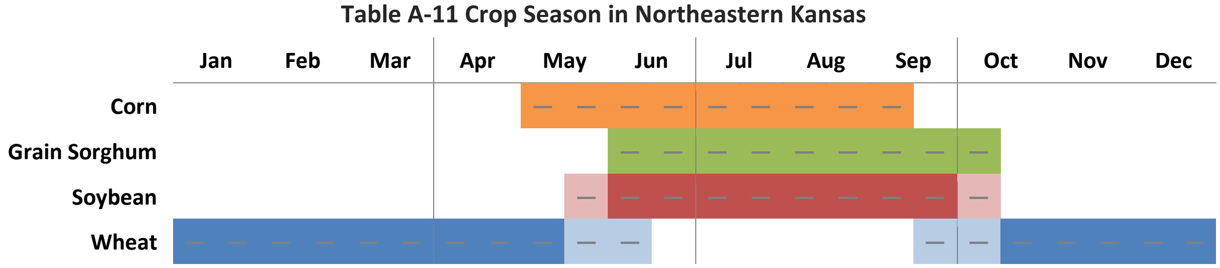
Table A-9 Suggested Planting Dates for Kansas Crops (Shroyer et al., 1996)

Crop/Plant	Zone 1	Zone 2	Zone 3	Zone 4
Corn	Apr. 20 - May 20	Apr. 15 - May 20	Apr. 1 - May 10	Mar. 25 - Apr. 25
Soybean	May 10 - June 1 (*Irr.*)	May 5 - June 10	May 5 - Jun 10 (*West*) May 15 - June 15 (*East*)	May 10 - June 25 (*West*) June 1 - June 30 (*East*)
Grain Sorghum	May 15 - June 10	May 15 - June 20	May 15 - June 20	May 1-15 / June 5-25
Wheat	Sept. 10 - Sept. 30	Sept. 15 - Oct. 20	Sept. 25 - Oct. 20	Oct. 5 - Oct. 25
Major Grasses	Mar. 15 - May 15	Mar. 15 - May 15	Mar. 15 - Apr. 30	Mar. 1 - Apr. 30
Cool Season Grasses (spring)	Mar. 1 - Apr. 1	Feb. 15 - Mar. 15	Feb. 15 - Mar. 15	Feb. 15 - Mar. 15

Table A-10 Planting and Harvesting Dates of Crops with Major Tillage System in Kansas

		Corn		Soybean		Grain Sorghum		Wheat	
		Planting	Harvesting	Planting	Harvesting	Planting	Harvesting	Planting	Harvesting
Conventional Till	**CT**	4/16	10/1	5/16	10/1				
Minimum Till	**MT**	4/16	10/1	5/16	10/1	5/25	9/25	10/16	7/1 (next)
No-till	**NT**	4/16	10/1	5/5	10/1	5/25	9/25	10/16	7/1 (next)

Table A-11 Crop Season in Northeastern Kansas



A.2.1.3 *Crop Rotation*

There are seven different crops/plants and 14 crop rotations were modeled in this study. Table A-12 briefed the planting and harvesting dates for each crop rotation. In practice, the planting and harvesting dates might vary depending on climate condition, geospatial location, crop types, and tillage systems. The dates in Table A-12 provide the general dates for each crop rotation simulated in this study. The dates for each modeling scenario had been fine-tuned with its characteristics and field operations such as cultivating or fertilizer application method.

Table A-12 Modeling Crop Rotation and Planting/Harvesting Dates

Crop Rotation	Period	Pre-LULC	CORN		GRGS		WWHT		SOYB		Grass	
			Plant	Harvest	Plant	Harvest	Plant	Harvest	Plant	Harvest	Plant	Harvest
BBLS	Multi.	n/a									03/15/01	12/01/01
SWCH	Multi.	n/a									03/15/01	12/01/01
FESC	Multi.	n/a									03/01/01	12/01/01
CORN	1 yr	n/a	05/01/01	09/15/01								
GRSG	1 yr	n/a			06/01/01	10/15/01						
WWHT	1 yr	WWHT					09/15/01	06/15/01				
SOYB	1 yr	n/a							05/15/01	10/07/01		
WWHT-SOYB	1 yr	WWHT					10/01/01	05/22/01	06/01/01	09/15/01		
CORN-SOYB	2 yr	n/a	05/01/01	09/15/01					05/15/02	10/07/02		
GRGS-SOYB	2 yr	n/a			06/01/01	10/15/01			05/15/02	10/07/02		
WWHT-FALW	2 yr	n/a					09/15/01	06/15/02				
WWHT-(FALW)-CORN	3 yr	WWHT	05/01/02	09/15/02			09/15/03	06/15/01				
WWHT-(FALW)-GRSG	3 yr	WWHT			06/01/02	10/15/02	09/15/03	06/15/01				
WWHT-GRSG-SOYB	3 yr	WWHT			06/01/02	10/15/02	10/01/03	06/15/01	06/01/03	09/15/03		

Note: Plant: planting date; Harvest: harvesting date. BBLS: native prairie grass (big bluestem); SWCH: alternative energy source - bio-fuel (switchgrass); FESC: general VFS cover plant (tall fescue); CORN: continuous corn; GRSG: continuous grain sorghum; SOYB: continuous soybean; WWHT: continuous winter wheat; WWHT-SOYB: one-year winter wheat-soybean double crop; CORN-SOYB: two-year corn-soybean rotation; GRGS-SOYB: two-year grain sorghum-soybean rotation; WWHT-FALW: two-year winter wheat-fallow rotation; WWHT-(FALW)-CORN: three-year winter wheat-fallow-corn rotation; WWHT-(FALW)-GRSG: three-year winter wheat-fallow-grain sorghum rotation; WWHT-GRSG-SOYB: three-year winter wheat-grain sorghum-soybean rotation.

A.2.2 Tillage System

A.2.2.1 *Common Tillage System*

As described previously in Section: 3.4.2, several potential tillage systems are used in Lower Kansas watershed. The five tillage systems (no-till, rotational tillage, reduced tillage, minimum tillage, and conventional tillage) were selected as alternative tillage methods for SWAT scenario design. The definitions of each tillage system are in Table 3-4. Although the traditional definition of conservation tillage included various tillage systems such as reduced till, mulch-till, eco-fallow, ridge-till, and no-till, the difference among these tillage involves the number of cultivating operations such as a mold board plow, disk, or chisel plow and timing to leave different percentage of crop residue on the ground.

The major advantage of conservation tillage is surface residues will slow down runoff water movement, reduce rainfall drop energy and then minimize the potential soil erosion. With conservation tillage, the sheet and rill erosion are normally controlled by the surface cover of residues. Moreover, the stream water quality, soil moisture, soil compaction as well as labor or fuel consumption could be additional benefits. Therefore, different conservation tillage systems might have different ability to reduce soil erosion while maintaining or increasing crop productivity (Staggenborg et al., 2004), to improve soil conditions, and to realize economic benefits (Whitney et al., 1999). However, ephemeral gully or gully erosion may increase due to conservation tillage might cause higher storm water runoff especially for clay pan soil area (Whitney et al., 1999). Moreover, conservation tillage may reduce soil erosion, but nutrient loads may or may not be reduced.

In this study, these five tillage systems were modeled with eleven common edible crop rotations and three native prairie grasses, with or without edge-of-field BMPs and two fertilizer application methods. Although, some of tillage methods may not be suggested applied under specific conditions in practices, they were modeled and analyzed for comparison purpose. The brief schedule of field cultivating operations for each tillage systems and crop rotations were listed in Table A-24 through Table A-27.

A.2.2.2 *Tillage Depth and Mixed Efficiency*

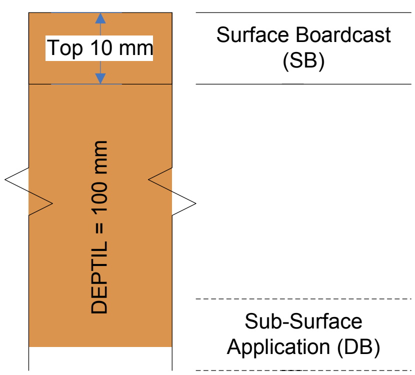
The tillage depth and mixed efficiency will affect the vertical fertilizer distribution in soil profile. The FRT_SURFACE parameter, the fraction of fertilizer applied to top 100 mm of soil, is a very important setting for SWAT modeling the fertilizer application operation (Neitsch et al., 2005). No matter what kind of tillage or application method used, the default value for FRT_SURFACE is set as 0.20, which meant 20% fertilizer applied on the top 10 mm soil and the others are in the deeper soil layer (Neitsch et al., 2005). In real field operations, most of fertilizers are applied with tillage events with either surface broadcast or deep band application method. So that the portion of fertilizer remains on the top 10 mm soil will depend on the tillage and its application method. Table A-13 show the suggest value of FRT_SURFACE parameters for each tillage methods applied on this study. The different tillage method has its specific mixing efficiency and mixing depth. These mixing efficiency and mixing depth parameters were provided by SWAT built-in tillage database. However, some tillage systems may not suitable for utilizing surface broadcasting or deep band fertilizer application. The information in Table A-13 was fine-tuned with reviewing the literatures published by Kansas State University Agriculture Extension (Fjell et al. 1997; Shroyer et al., 1997; Fjell, 1998; Fjell et al. 2007). An Example of the processes for calculating FRT_SURFACE parameter is demonstrated in Box A-1.

Table A-13 Mixing Efficiency and Tillage Depth for Each Cultivating Operation

Tillage Method		Tandem Disk Reg Ge 19ft	Chisel Plow Gt15ft	Moldboard Plow Reg Ge7b	Tandem Disk Reg 14-18ft	Field Cultivator Lt15ft	No-till Mixing	Row Cultivator Lt15ft	Blade 10 ft
Code		**TANDEMRG**	**CHISPLOW**	**MLDBOARD**	**TANDEMRG**	**FLDCULT**	**ZEROTILL**	**ROWCULT**	**BLADE10**
EFTMIX		0.75	0.30	0.95	0.40	0.30	0.05	0.25	0.25
DEPTIL(mm)		100	150	150	75	100	25	25	25
Top 10mm Fertilizer	SB	0.33	0.72	0.11	0.65	0.73	0.97	0.85	0.85
	DB	0.08	0.02	0.06	0.05	0.03	0.02	0.10	0.10
FRT_SURFACE	SB	0.35	0.75	0.15	0.70	0.70	0.90	0.85	0.85
	DB	0.10	0.05	0.10	0.10	0.10	0.10	0.10	0.10

Note: **EFTMIX**: Mixing Efficiency; **DEPTIL**: Mixing Depth; data extracted from SWAT2005 tillage database (Neitsch et al., 2005). **SB**: General surface fertilizer application; **DB**: general sub-surface fertilizer application.

Box A-1 Example of Calculating Processes for FRT_SURFACE Parameter



For calculating the FRT_SURFACE value for a tillage system, the mixing depth and efficiency play very important part. For example, if the tillage system's EFTMIX = 0.30 and DEPTIL = 100.00 mm, the fertilizer still remain in top 10 mm layer is:

1. For surface fertilizer application (SB): 30% fertilizer will be mixing through the whole soil profile and the other 70% fertilizer will be placed on the surface. Thus, the fertilizer remain on the top 10 mm of soil will be that 70% fertilizer plus the portion of mixing processing on top 10 mm of soil:

$$(1.00 - 0.30) + 0.30 \text{ x } (10 / 100) = 0.73$$

2. For sub-surface fertilizer application (DB): 30% fertilizer will be mixing through the whole soil profile and the other 70% fertilizer will be placed on the deep layer. Thus, the fertilizer remain on the top 10 mm of soil will only be the portion of mixing processing on top 10 mm of soil:

$$0.30 \text{ x } (10 / 100) = 0.03$$

3. For Tandem Disk with Reg. 14-18ft tillage system, the tillage EFTMIX = 0.40 and DEPTIL= 75, the FRT_SURFACE parameter will be:

For SB: $(1.00 - 0.40) + 0.40 \text{ x } (10 / 75) = 0.653$

For DB: $0.40 \text{ x } (10 / 75) = 0.053$

4. For Blade 10ft tillage system, the tillage EFTMIX = 0.25 and DEPTIL= 25, the FRT_SURFACE parameter will be:

For SB: $(1.00 - 0.25) + 0.25 \text{ x } (10 / 25) = 0.85$

For DB: $0.25 \text{ x } (10 / 25) = 0.10$

In order to simplify the input parameter, the final modeling FRT_SURFACE numbers were rounded in 0.05 steps.

A.2.3 Edge of Field BMP

As described in Section: 3.4.3, VFS is one of the edge-of-field BMPs to store the storm water, slow runoff velocity, and filter the particles carried by the runoff. In this study, the scenarios designated to implement VFSs were defined as the buffer strips: an area at the edge of the field along a ditch, gully, or stream that is covered permanently by tall fescue *(Festuca arundinacea)* (Regehr et al., 1996; Harner et al., 2000).

A.2.3.1 *Vegetative Filter Strip*

VFSs are uniformly graded and densely vegetated section of land, designed to treat surface runoff and remove pollutants through vegetative filtering and infiltration. VFS relies on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from storm water. The larger particles in the runoff tend to settle out readily, the finer particles will remain suspended much longer. It could significant reduce finer particle by retaining water for a period of time. While retaining the surface runoff, it also can increase the infiltration to reduce the volume of runoff. To design an effective VFS, however, the sheet flow must be maintained across the entire VFS. Once surface runoff concentrates, it cannot effectively passing through whole VFS area and act as the channel flow, would reduce either the trapping efficiency or the life of VFS. Moreover, to keep an effective VFS without losing its performance, it also required a regular maintenance. Mowing and/or trimming vegetation must be performed on a regular schedule (NJDEP, 2004).

The VFS shall be established to permanent herbaceous vegetation consisting of a single species or a mixture of grasses adapted to the soil and climate of the area (NRCS-Kansas, 2003). VFS generally planted to sod-forming grasses that help to hold the soil in place, slow the runoff velocity, and also provide the filtering and infiltration abilities. In this study, the vegetation will need to be hayed to remove accumulated nutrients; the species selected should have good hay quality at the time of year the hay is harvested. Tall Fescue (*Festuca arundinacea,* FESC), one of the cool season grasses for vegetative filter strip in northeastern Kansas, designated as the cover plant of VFS in this study (Harner et al., 2000). It is a deep rooted, cool season perennial, bunch-type grass even though it has short rhizomes (Leeds et al., 1994). Tall fescue is adapted to a wide range of soil and climatic conditions. The plant grows in the spring and fall with an extensive root system. A thick stand produces an even sod if kept mowed or grazed. Mowing height requirements for tall fescue is at least a height of 1.5 inches or more. Tall fescue should not be used where mowing heights are below 1.5 inches during summer months (Harner et al., 2000).

A.2.3.2 *Trapping Efficiency of Vegetative Filter Strip*

VFS, in conjunction with sediment basins, are recognized by the Kansas Department of Health and Environment (KDHE) as an effective system for controlling and reducing nutrient runoff into surface water from the field (Harner et al., 2000). As described in Section: 3.4.3, the efficiency of VFSs in trapping pollutants relates to the local topography, soil property, climate condition, and management. Studies have shown no simple answer for estimating removal efficiency of VFSs.

SWAT 2005 cannot directly simulate landscape components processes and VFS systems geospatially either in the complex watershed and/or subbasin (Bosch et al., 2007); SWAT simply uses several empirical equations developed by Moore et al. (1988) to simulate the VFS trapping efficiency for bacteria (Eq. A-1), sediment and nutrient (Eq. A-2) yield (Neitsch et al., 2005).

$$E(t)_{bacteria} = \frac{(11.8 + 4.3 \times w)}{100} \qquad \text{Eq. A-1}$$

$$E(t)_{nutrient} = 0.367 \times w^{0.2967} \qquad \text{Eq. A-2}$$

The relationship between potential trapping efficiency and VFS width for equations Eq. A-1 and Eq. A-2 were portrayed in Figure A-2. In default, while increasing the width of VFS, the removal rate will increase. However, as long as the width beyond 70 feet (bacteria) or 100 feet (the others), the efficiency will theoretically exceed the 100% caps. That indicates SWAT will not tell any significant difference in pollutant load while the modeling VFS with width more than 70 feet for bacteria or 100ft for sediment or nutrient. This might be an issue for some literatures suggest utilizing more than 100 feet strip in practice.

Therefore, In this study, following the VFS instructions published by the NRCS Kansas subdivision (NRCS-Kansas, 2003), a uniform, 20 m (66 ft) wide VFS was applied as an edge-of-field BMP for scenarios that simulate VFSs as a management operation. The calculated global VFS trapping efficiency ($E(t)_{nutrient}$) in this study would be around 90%, which is close to what the literature and previous field experience reveals (Barnes, 2006).

Eq. A-1 and Eq. A-2 imply that SWAT model VFSs are well designed, maintained, and effective at all times in trapping and removing soil sediments from surface runoff as well as infiltrating runoff water into the soil. However, these assumptions may not hold in practice given such field circumstances as soil saturation under VFSs. Without any other tool to modify SWAT, Eq. A-1 and Eq. A-2 remain a useful way to estimate the trapping efficiency of VFSs in this study. However, these equations still need further research.

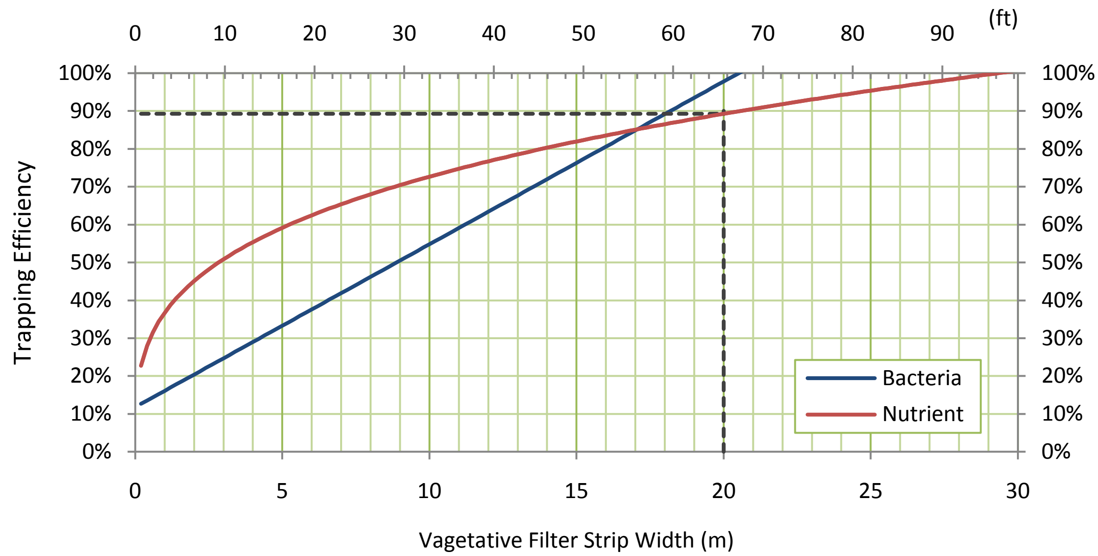


Figure A-2 VFS Trapping Efficiency versus Its Width in SWAT 2005

A.2.3.3 *VFS Area*

Based on Universal Soil Loss Equation (USLE), SWAT used a similar but revised equation to estimate soil erosion and sediment yield: Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977). RUSLE, Revised Universal Soil Loss Equation is another modified version of USLE developed by Wischmeier and Smith (Wischmeier and Smith, 1965; 1978). All of these equation used similar factors and parameters to estimate the soil detached or movement from source area.

The RUSLE R factor (rainfall and runoff) is based on the erosive power of rainfall events common to the area. Sometimes called the "erosive index", R values for each region have been set using weather records of rainfall energy and maximum rainfall intensity (NRCS-Kansas, 2003). The ratio of the drainage area to the VFS area shall be less than 70:1 in regions with RUSLE-R factor values 0-35, 60:1 in regions with RUSLE-R factor values 35-175, and 50:1 in regions with RUSLE-R factor values of more than 175 (NRCS-Kansas, 2003). In Figure A-3, the RUSLE-R factor in north-eastern Kansas is larger than 180, thus, at least 2% of total farm area should be used to create an effective VFS.

The field survey of “choice experiments of producers (NPS)” in the study watershed (Peterson et al., 2007; Smith et al., 2007) indicated the general VFS acreage of a block of cropland is around 4% of total area. Based on this survey, the 4% of total farm area is assigned as VFS when scenario implement strip as edge-of-field BMP in this study. Figure A-4 (a) displays the scenario designs for without grazing event on VFS, which illustrates the field arrangement for scenario SCase3/DCase3, and Figure A-4 (b) displays the SCase4/DCase4 (see Table A-3), which are the scenarios with grazing event.

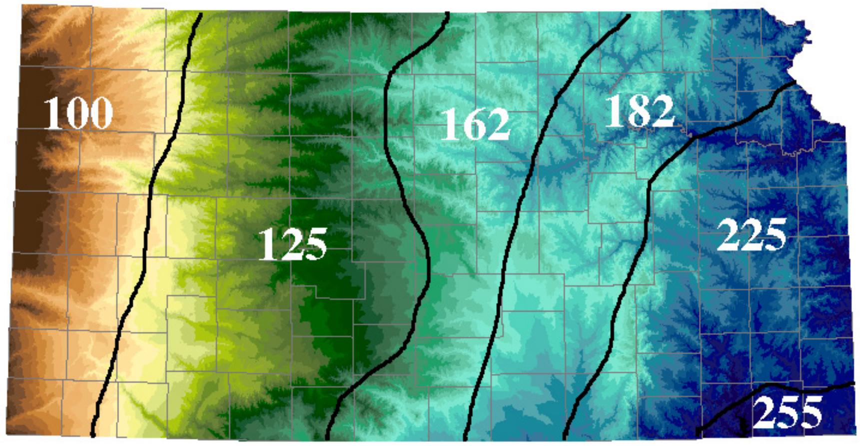


Figure A-3 The RUSLE R factor Distribution of Kansas (NRCS-Kansas, 2003)

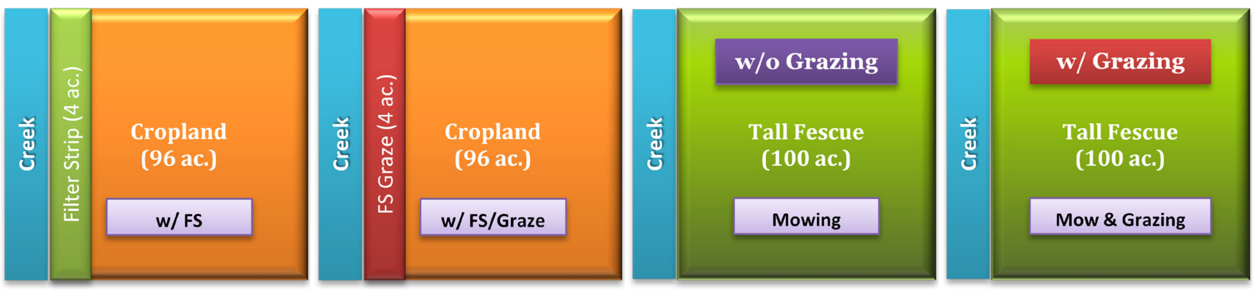


Figure A-4 Designed for Modeling VFS With or Without Grazing Scenarios

A.2.3.4 *Approximation of Grazing Event on VFS*

To coordinate the economic analysis scenarios, which are the comparison scenarios in the field survey of "choice experiments of producers (NPS)" in the study watershed (Peterson et al., 2007; Smith et al., 2007); the specific alternative land management practices: with grazing on VFS area needed to be simulated. SWAT could not directly simulate this management practice with simple subbasin and HRU delineation. The VFS area needs to be separated from the main cropland as an individual land management unit to simulate the processes of surface runoff through VFS and fall grazing. In practice, VFSs are built along the contour, which means to simulate VFS with SWAT, the subbasin need to split into smaller pieces based on its land slope, elevation or soil properties. These processes will become tedious processes for a large watershed or subbasins with an irregular shape. As described previously, SWAT uses empirical equations to estimate VFS's trapping efficiency. Bosch et al. (2007) also pointed out SWAT might geo-spatially simulate the physical processes of landscape component and management activities on VFS system with a modified version SWAT-L model, but the tedious processes might be still for a complex watershed. Therefore, simulating fall pasture beef cattle grazed on only VFS area instead the cropland of whole subbasin became a challenge.

Alternative way to simulate grazing on VFS with current SWAT version (SWAT2005) was modeling and comparing the difference between with and without grazing event on the study watershed. Based on the analyses of the difference, the grazing on VFS can be approximated. Figure A-4 (c) and (d) illustrate with and without fall grazing event on the tall fescue land. The difference between Figure A-4 (a) and (c) as well as Figure A-4 (b) and (d) were the 96% area in the design land management practices: SCase3/DCase3 or SCase4/DCase4 in Table A-3, and only 4% as VFS. These implied the unit pollutant load difference between Figure A-4 (c) and (d) might equal to the unit difference between Figure A-4 (a) and (b) while the other management practices fixed. This approximation process for estimating the pollutant load difference between with and without grazing on VFS can then be applied to scenarios with VFS and grazing events.

The following steps described the approximating processes:

1) Prepare and model all the scenarios with SWAT in Table A-14. The VFS was simulated with tall fescue land.

2) Analyze and calculate the unit load differences between FESC2 and FESC3xs in every subbasin, especially focus on the difference between scenario FESC2 and FESC3x1.

3) The unit load difference is actually the potential load difference between with and without grazing event on the ground. To approximate the potential load of the grazing on VFS scenarios, we used the modeling potential load of non-graze VFS scenarios add or substrate the load difference. These load differences can be calculated by multiply 4% subbasin area with the unit load difference at that subbasin.

Table A-14 Scenario Designs for Approximating VFS with Grazing Event

Case #	Scenario	Activity	Fertilizer	Grazing	Description
FESC1	Unmanaged grass	No	No	No	Unmanaged Grass without any field operation
FESC2	VFS cover plant	3 mowing	No	No	VFS cover (pasture) with 3 mowing per year
FESC3x1	VFS w/ grazing	2 mowing & 1 grazing	Beef cattle fresh manure	Yes	VFS with 2 beef cattle (1x) grazing for 120 day
FESC3x2	VFS w/ 2x grazing			Yes	VFS with 4 beef cattle (2x) grazing for 120 day
FESC3x3	VFS w/ 3x grazing			Yes	VFS with 6 beef cattle (3x) grazing for 120 day
FESC3x4	VFS w/ 4x grazing			Yes	VFS with 8 beef cattle(4x) grazing for 120 day

A.2.3.5 *Simulation of Fall Grazing on VFS*

The suggested cover plant of VFS in northeastern Kansas is tall fescue. To simulate the VFS, we assumed the pasture land with tall fescue was mowed every two month, three times per year with 90% harvest efficiency (HARVEFF) and 0.6 harvest index override (HI_OVR). To simulate the grazing event on VFS, the last mowing event was replaced by a fall grazing operation with the minimum plant biomass (BIO_MIN) at 1.0 kg/ha to prevent over grazing in SWAT.

Following the ASAE standard of animal manure production and characteristics, the fresh beef manure (total solids) is around 360 kg per finishing beef cattle within 153 day (ASAE Standard, 2003; ASAE Standard, 2005). The average dry weight of biomass consumed per beef cattle is 7.56 kg/day during the grazing season (Honeyman et al., 2006). The average dry weight of fresh beef manure production per beef cattle is 2.353 kg/day (ASAE Standard, 2003; ASAE Standard, 2005). Chandler (1998) suggested the suitable animal number for grazing on pasture is 2 cattle per acre. With this assumption, the total dry weight of biomass, which the grazing animals would consume, would be around 37.36 kg/ha per day; it would yield around 11.63 kg/ha beef fresh manure per day on pasture land (Moore et al., 2001; Honeyman et al., 2006). Moreover, the amount of animal tramp biomass was assumed as the same amount of consumed biomass, thus is 37.36 kg / ha-day (Moore et al., 2001; Honeyman et al., 2006). Box A-2 shows the details calculations and descriptions for grazing operation on the field.

Box A-2 SWAT Grazing Operation Parameters and Calculation

There are several different methods for grazing on the agricultural land. For grazing on VFS, the fall grazing method were adapted to meet the July 15th requirement. Following the ASAE Standard:

1. Fresh beef manure (total solids) is around 360 kg per finishing beef cattle within 153 day (ASAE Standard, 2003; ASAE Standard, 2005).
2. Average dry weight of biomass consumed: 18.5 lb/day * 0.454 kg/lb * 0.90 (dry matter %) = 7.56 kg/day, per beef cattle (Honeyman et al., 2006)
3. Average dry weight of fresh beef manure: 360 kg / 153 day = 2.353 kg/day, per beef cattle (ASAE Standard, 2005)
4. Animal grazing on pasture was assumed to be 2.0 cattle per acre (Chandler, 1998) so that the grazing animals would consume 37.36 kg/ha grass per day and add 11.63 kg/ha beef fresh manure to pasture each day (Moore et al., 2001; Honeyman et al., 2006).

For the real practices, grazing operation related to the cattle performance and carrying capacity that affected by forage production and quality. Carrying capacity and cattle performance are not simple to predict and will change from month to month. For example, during the month of June a field may be able to graze five, 500 pounds calves per acre and have them each gain 2 pounds/day. However, In August the same field may only be able to graze three, 500 pounds calves per acre and have them each gain 1 pound/day. The amount of beef cattle manure applied on the field would be also different. SWAT model use the plant growth model to estimate the available biomass on the field for grazing. Once the available biomass is less than pre-define “minimum biomass limit”, the grazing operation will stop and will not having any grazing until the biomass available again. More detail grazing operation mechanism can be found on SWAT2005 manual (Neitsch et al., 2005).

A.2.4 Fertilizer Application

Effective placement and timing of fertilizers can maximize crop yield. The detail attributes for designing a fertilizer operation include the timing of the application, the type of fertilizer/manure, the amount of fertilizer/manure application, and the depth of placement.

A.2.4.1 *Application Method*

As describe in Section: 3.4.4, the fertilizer application methods were simply classified as "surface broadcast" and "deep band application" to represent the surface and sub-surface fertilizer.

Research indicated the large difference in crop yield is generally not expected to be influenced by nitrogen application methods because nitrate is mobile in soils (Jones and Jacobsen, 2003). However, the storm runoff event might flush the surface fertilizer away just after fertilizer application.

A.2.4.2 *Amount and Type of Fertilizer*

Estimating the amount of fertilizer needed on the ground involves knowledge of a wide range of information. In practice, a soil test should be taken well ahead of planting to determine lime and fertilizer needs, but other factors such as soil moisture, cropping sequence, and other management practices are vital for the development. Therefore, fertilizing a field with a fixed amount fertilizer in SWAT would produce some biases. As described in Section: 3.4.4, the fertilizer application rates are tied to yield goals for crops. Table 3-5 summarized the potential yields and TN/TP fertilizer requirements for each crop in this study.

Nitrogen (N) fertilizer is the essential part for plant growth; too less or many fertilizers will decrease soil pH and crop yield. In Kansas, a large percentage of nitrogen fertilizer is used for agricultural purposes (Devlin et al., 1996). Common nitrogen fertilizers include: Anhydrous ammonia (82-0-0), Ammonium nitrate (34-0-0), Ammonium sulfate (21-0-0), Urea (46-0-0), Urea-ammonium nitrate solutions (UAN) nitrogen (NRCS, 2008a). Although animal manures, compost and other similar materials are excellent sources of nitrogen, commercially purchased nitrogen fertilizers are still the most common N sources used in agriculture (NRCS, 2008a). Whitney et al. (1991) also pointed out the commercial nitrogen applied in Kansas was 59% anhydrous ammonia, 18% urea-ammonium nitrate solution, 11% urea, and 3% ammonium nitrate in 1989 season. The research showed there is no significant difference in the effect on soil from these four sources of nitrogen fertilizer (Whitney et al., 1991). Thus, the nitrogen source selection in this study is based primarily on the form of nitrogen and potential application method.

Phosphorus (P) is an essential part of metabolic processes that occur within the plant such as photosynthesis and energy transfer (Whitney, 1988). If the soil level of available phosphorus is not adequate for these plant processes, then production will be reduced unless fertilizer phosphorus is added (Whitney, 1988). The common Phosphorus fertilizer sources are Ammonium Polyphosphate (POLY), Diammonium Phosphate (DAP), Monoammonium Phosphate (MAP), and Phosphoric Acid.

The different type of fertilizer chemical might be interchanged based on their N and P components (Whitney, 1988; Maddux, 2008). Table A-15 listed the common fertilizer and its chemical component. The price listed in Table A-15 was estimate by NRCS Energy Consumption Awareness Tool for Manhattan, Kansas at January 2009 (NRCS, 2008a).

Table A-15 Common Fertilizer and Its Chemical Components, Price

	Agricultural Chemical (SWAT Fertilizer Definition)	N %	P_2O_5 %	(\$/ton)
AHY	Anhydrous Ammonia (82-0-0)	0.82	0.00	731
DAP	Ammonium Phosphates (NH4)2HPO4 (18-46-0)	0.18	0.46	240
ELN	Elemental N (100-0-0)	1.00	0.00	
	Elemental P (0-100-0)	0.00	1.00	
ELP	Ammonium Nitrate (NH4NO3) (34-0-0)	0.34	0.00	465
	Urea (46-0-0)	0.46	0.00	537
UAN	Urea ammonium nitrate (UAN) (32-0-0)	0.32	0.00	375

Maddux (2008) studied the corn-soybean cropping sequence for the effects of fertilization in Topeka, KS. His results of a period from 1983 to 2005 showed no more than 180 kg/ha (160 lb/ac) TN was required to obtain optimum corn yield, and TP still maintained medium to high in soil test level during that period (Maddux, 2008). Following this suggestion and crop handbooks, Table A-23 lists the parameters for fertilizer application and the dates for SWAT modeling in this study (Fjell et al., 1997; Shroyer et al., 1997; Fjell, 1998; Fjell et al., 2007). To incorporate fertilizer application with major cultivating events, different tillage systems might recommend different type fertilizer. As described previously, different type of fertilizer chemical might be interchanged based on their own N and P components, but the application methods and/or dates need to be adjusted to fit the targeting tillage method of the tillage system.

A.2.4.3 *Application Date*

Timing fertilization with peak nutrient uptake demand is essential for optimizing both yield and quality. In general, nutrient uptake rates are highest from early to mid-growing season (Jones and Jacobsen, 2003). The timing for applying fertilizer in this study was categorized in three periods: prior to planting (pre-plant), at the time of planting (at planting), and after emergence (mid-growing season). Some periods may not suitable for both surface and sub-surface fertilizer (Jones and Jacobsen, 2003). The nitrogen fertilizer were designed to apply any period from pre-plant to after emergence, whereas the phosphorus fertilizer were designed to applied only in pre-plant or at planting operation due to its immobility in soil. Based on the literature reviews, USDA NRCS field office information and watershed specialist interviews, the designed modeling fertilizer application schedules were tabulated in Table A-28 through Table A-39 for each crop rotation and tillage system (Kilgore and Brazle, 1994; Fjell et al., 1997; Shroyer et al., 1997; Fjell, 1998; Jones and Jacobsen, 2003; Fjell et al., 2007).

A.3 Adjustment for SWAT Model Parameters

Based on the four categories of design variables in Table A-5 and Table A-6, the 220 scenarios were simulated for general purpose with food or feed crops; three native prairie grasses and another 5 additional scenarios for simulating grazing effects on VFS were also analyzed in this study. Each scenario were modeled with 39 years daily historical weather data (1968 to 2006) for 286 subbasins and 5395 hydrologic response units (HRUs) in daily time step and analyzed in either annual and/or monthly basis. Maski et al. (2007; 2008) calibrated and validated SWAT with measured data from field plots in the sorghum-soybean cropping sequence from 2001 to 2004 in northeastern Kansas. These WQT parameters, including USLE crop and cover management (C) factors, runoff curve numbers for moisture condition II (CN2), and soil saturated hydraulic conductivity (K_{SAT}), were modified for all annual and monthly scenarios. Moreover, Parajuli (2007) calibrated and validated flow, sediment with SWAT near Clinton Lake in study area. Three SWAT modeling parameters including CN2, soil evaporation compensation coefficient (ESCO), and USLE C factors, were selected (Parajuli, 2007). The detail parameters for each scenarios in this study can be found in the tables and charts in Appendix A.4.

A.3.1 Calibrated and Validated Parameters

A.3.1.1 *USLE Crop and Cover Management (C) Factor*

As described in Section: 3.4.6.1, the USLE-C factor is a ratio of soil loss from land cropping under specified conditions to the corresponding loss from clean-tilled, continuous fallow (Neitsch et al., 2005). In SWAT modeling processes, the cropping sequence and residue cover choices promotes selection of the C factor from SWAT default database (Neitsch et al., 2005). SWAT calculates the actual C factor based on the amount of soil cover and the minimum C factor determined for the plant/land cover (Neitsch et al., 2005). The minimum C factor quantifies the maximum decrease in erosion possible for the plant/ land cover (Neitsch et al., 2005). Table A-16 listed SWAT default and the calibrated USLE-C factors for each crops/plants under different tillage system.

Table A-16 Calibrated USLE Crop and Cover Management (USLE-C) Factor

Crop Type	SWAT Default	No-till (NT)	Rotational Tillage (OT)	Reduced Tillage (RT)	Minimum Tillage (MT)	Conventional Tillage (CT)
Native Prairie Grasses	0.003					
Agri. Land Row Crop (AGRR)	0.20					
Corn	0.20	0.13	0.22	0.31	0.31	0.31
Soybean	0.20	0.11	0.17	0.23	0.23	0.23
Grain Sorghum	0.20	0.13	0.22	0.31	0.31	0.31
Winter Wheat	0.03	0.03	0.03	0.03	0.03	0.03

Note: For crop rotation system or rotational tillage system, the values is used the intermediate value which based on the arithmetic mean of all elements.

A.3.1.2 *Runoff Curve Number (CN2)*

In this study, the NRCS runoff curve number (CN) method was used to calculate the infiltration and surface runoff during a precipitation event. As described in Section: 3.4.6.2, the NRCS runoff CN is an empirical parameter in the NRCS runoff equation that is widely used to determine the approximate amount of direct surface runoff from a rainfall event in a particular area (SCS, 1972; NRCS, 2004). The NRCS runoff equation is described as Eq. A-3. In the Eq. A-3, S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by Eq. A-4. The CN will be affected by the hydrologic soil group, surface cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious or pervious of surface (SCS, 1986; NRCS, 2004).

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{Eq. A-3}$$

Where

Q = runoff (in);
P = rainfall (in);
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$S = \frac{1000}{CN} - 10 \qquad \text{Eq. A-4}$$

Maski et al. (2008) suggested increasing CN2 by one hydrologic soil group when simulating no-till systems in northeastern Kansas. Based on this suggestion and HRU's hydrologic soil group, CN2 was adjusted by promoting one group of the stocked CN2 value for no-till. For simulating rotational tillage, the adjusted no-till values and original SWAT defaults of the other rotated tillage method (e.g., minimum tillage) were averaged for rotational tillage's CN2. Table A-17 lists the calibrated CN2 for each crops and tillage systems in this study.

Table A-17 Calibrated Runoff Curve Number of Soil Moisture Condition II (CN2)

Tillage System	SWAT Default				No-till (NT)				Rotational Till (OT)				Conventional Till (CT)			
Crop Type **HSG**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Agri. Row Crop (AGRR)	67	78	85	89												
Corn	67	77	83	87	77	83	87	89	72	80	85	88	67	77	83	87
Soybean	67	78	85	89	78	85	89	91	72	81	87	90	67	78	85	89
Grain Sorghum	67	77	83	87	77	83	87	89	72	80	85	88	67	77	83	87
Winter Wheat	62	73	81	84	73	81	84	86	68	77	82	85	62	73	81	84

Note: For crop rotation system or rotational tillage system, the values is used the intermediate value which based on the arithmetic mean of all elements.

A.3.1.3 *Saturated Hydraulic Conductivity*

Hydraulic conductivity (K) is defined by Darcy's law and is a measure of the soil's ability to transmit water on a hydraulic gradient. The saturated hydraulic conductivity (K_{SAT}) is the same quantitative measure but for a saturated soil, or the ease with which pores of a saturated soil permit water movement. In Darcy's law, K_{SAT} is a constant (or proportionality constant) affected by soil pore geometry as well as the fluid viscosity and density. In SWAT, the K_{SAT} parameter is used to estimate the time in which percolation drains water in excess of field capacity to the next soil layer; if percolation time for a layer exceeds 24 hours, soil water in excess of field capacity is carried forward to the next day (Neitsch et al., 2005). Maski et al. (2008) suggested doubling the K_{SAT} value to compensate for the consolidated soil surface effects due to no-till. Based on this suggestion, when modeling no-till, the K_{SAT} for each soil type was doubled. For modeling rotational tillage, the K_{SAT} of each soil type was roughly multiplied by 1.5 to compensate for half of the no-till effect.

A.3.2 Adjusted Parameters

A.3.2.1 *Manning's Roughness Coefficient*

SWAT uses Manning's equation to define the rate and velocity of either channel flow or overland flow (Neitsch et al., 2005). The roughness coefficient of Manning's equation represents the resistance to flow in surface, channels, and flood plains. It often denoted as "n" or "Manning's n". Manning's n values vary greatly in natural stream channels and will even vary in a given reach of a channel at different stages of flow. SWAT's default assigns Manning's roughness coefficient a value of 0.14 for overland flow on a row crop surface and 0.014 for channel flow in the whole stream network (Neitsch et al., 2005). However, this assumption may be suitable only for some types of tillage systems and channel conditions. The SWAT theory document (Neitsch et al., 2005) and other research (Wanielista et al., 1997) provide suggestions for Manning's n, tabulated according to factors that affect surface and channel roughness. Based on this research, the overland flow Manning's n is fine-tuned according to tillage system and crop rotation. Therefore, Manning’s n of overland flow was increased for no-till due to the impermeability of the surface. Moreover, channel flow Manning’s n was calculated with the channel conditional n equations provided by Wanielista et al. (1997). Hence, the global channel roughness coefficient is 0.05 for a tributary and 0.025 for the main channel.

A.3.2.2 *Fallow*

For scenarios with some specific crop rotations, a fallow operation is needed between two crops. Although the fallow did not really do anything on the ground, to simulate this operation with SWAT, it is necessary to insert a blank year in the management setting dialog. In other words, it needs to leave a blank line to represent a skipping year for the fallow in SWAT management operation setting file.

A.4 Table of Major SWAT Parameters for Design Scenarios

The major parameters for modeling each management scenario with SWAT are listed in following tables. Due to space limits, all scenarios are grouped by similar designs and only a representative parameter is listed. These tables include: (1) the serial number and definition for each modeling scenario; (2) the abbreviation or alias for each scenario; (3) amount of fertilizer application for all the crops and rotations; (4) the dates and schedule of cultivating operations for each scenario; (5) the dates of fertilizer application of each crop. In Table A-18 through Table A-21, the “Scenario” column represents the modeling sequence in this study. It used “S1” to represent simulation #1 or “sim1”, “S2” to represent simulation #2 or “sim2” and so on. This modeling sequence will be applied in the post analyses and used in the discussions. In “Abbrev.” column: C represents corn; S represents soybean; G represents grain sorghum; W represents winter wheat; WS represents one-year winter wheat-soybean double crops; CS represents two-year corn-soybean rotation; GS represents two-year grain sorghum-soybean rotation; WF represents two-year winter wheat-fallow rotation; WC represents three-year winter wheat-fallow-corn rotation; WG represents three-year winter wheat-fallow-grain sorghum rotation; WGS represents three-year winter wheat-grain sorghum-soybean rotation, and actually this rotation is the combination of WS and WG; BBLS represents big bluestem; SWCH represents switchgrass; FESC represents tall fescue.; SB represents surface fertilizer application (surface broadcast); DB represents sub-surface fertilizer application (deep band); FS represents the scenarios with VFS at the edge of field; FSGZ represents a similar scenario as FS but has a fall grazing event on VFS.

Table A-18 Scenario Number and Abbreviation for WQT Pilot Study

(a) Surface Fertilizer (Survey Scenarios)

Econ #	Scenario #	Abbrev.
SBase	S5	CS4SB
SCase1	S17	CS1SB
SCase2	S13	CS2SB
SCase3	S6	CS4SBFS
SCase4	S23	CS4SBFSGZ

(b) Sub-surface Fertilizer (Comparison Set)

Econ #	Scenario #	Abbrev.
DBase	S7	CS4DB
DCase1	S19	CS1DB
DCase2	S15	CS2DB
DCase3	S8	CS4DBFS
DCase4	S24	CS4DBFSGZ

(c) VFS (Simulate Grazing Effect)

Econ #	Scenario #	Abbrev.
BBLS	S31	BBLS
SWCH	S32	SWCH
FESC	S33	FESC
	S34	FSGZ0
	S35	FSGZ1
	S36	FSGZ2
	S37	FSGZ3
	S38	FSGZ4

Table A-19 Scenario Number and Abbreviation for In-Stream Delivery Effect Analysis

Econ #	Scenario #	Abbrev.
	S1	CS5SB
	S2	CS5SBFS
	S3	CS5DB
	S4	CS5DBFS
SBase	S5	CS4SB
SCase3	S6	CS4SBFS
DBase	S7	CS4DB
DCase3	S8	CS4DBFS
	S9	CS3SB
	S10	CS3SBFS
	S11	CS3DB
	S12	CS3DBFS
SCase2	S13	CS2SB
	S14	CS2SBFS
DCase2	S15	CS2DB
	S16	CS2DBFS
SCase1	S17	CS1SB
	S18	CS1SBFS
DCase1	S19	CS1DB
	S20	CS1DBFS

Econ #	Scenario #	Abbrev.
	S21	CS5SBFSGZ
	S22	CS5DBFSGZ
SCase4	S23	CS4SBFSGZ
DCase4	S24	CS4DBFSGZ
	S25	CS3SBFSGZ
	S26	CS3DBFSGZ
	S27	CS2SBFSGZ
	S28	CS2DBFSGZ
	S29	CS1SBFSGZ
	S30	CS1DBFSGZ
	S31	BBLS
	S32	SWCH
	S33	FESC
	S34	FSGZ0
	S35	FSGZ1
	S36	FSGZ2
	S37	FSGZ3
	S38	FSGZ4

Table A-20 Scenario Number and Abbreviation for In-Field Uncertainty Analysis

Scenario #	Abbrev.	Scenario #	Abbrev.	Scenario #	Abbrev.	Scenario #	Abbrev.
S1	CS5SB	S21	C5SB	S41	S5SB	S61	G5SB
S2	CS5SBFS	S22	C5SBFS	S42	S5SBFS	S62	G5SBFS
S3	CS5DB	S23	C5DB	S43	S5DB	S63	G5DB
S4	CS5DBFS	S24	C5DBFS	S44	S5DBFS	S64	G5DBFS
S5	CS4SB	S25	C4SB	S45	S4SB	S65	G4SB
S6	CS4SBFS	S26	C4SBFS	S46	S4SBFS	S66	G4SBFS
S7	CS4DB	S27	C4DB	S47	S4DB	S67	G4DB
S8	CS4DBFS	S28	C4DBFS	S48	S4DBFS	S68	G4DBFS
S9	CS3SB	S29	C3SB	S49	S3SB	S69	G3SB
S10	CS3SBFS	S30	C3SBFS	S50	S3SBFS	S70	G3SBFS
S11	CS3DB	S31	C3DB	S51	S3DB	S71	G3DB
S12	CS3DBFS	S32	C3DBFS	S52	S3DBFS	S72	G3DBFS
S13	CS2SB	S33	C2SB	S53	S2SB	S73	G2SB
S14	CS2SBFS	S34	C2SBFS	S54	S2SBFS	S74	G2SBFS
S15	CS2DB	S35	C2DB	S55	S2DB	S75	G2DB
S16	CS2DBFS	S36	C2DBFS	S56	S2DBFS	S76	G2DBFS
S17	CS1SB	S37	C1SB	S57	S1SB	S77	G1SB
S18	CS1SBFS	S38	C1SBFS	S58	S1SBFS	S78	G1SBFS
S19	CS1DB	S39	C1DB	S59	S1DB	S79	G1DB
S20	CS1DBFS	S40	C1DBFS	S60	S1DBFS	S80	G1DBFS
Scenario #	Abbrev.	Scenario #	Abbrev.	Scenario #	Abbrev.	Scenario #	Abbrev.
S81	W5SB	S101	WS5SB	S121	GS5SB	S141	WF5SB
S82	W5SBFS	S102	WS5SBFS	S122	GS5SBFS	S142	WF5SBFS
S83	W5DB	S103	WS5DB	S123	GS5DB	S143	WF5DB
S84	W5DBFS	S104	WS5DBFS	S124	GS5DBFS	S144	WF5DBFS
S85	W4SB	S105	WS4SB	S125	GS4SB	S145	WF4SB
S86	W4SBFS	S106	WS4SBFS	S126	GS4SBFS	S146	WF4SBFS
S87	W4DB	S107	WS4DB	S127	GS4DB	S147	WF4DB
S88	W4DBFS	S108	WS4DBFS	S128	GS4DBFS	S148	WF4DBFS
S89	W3SB	S109	WS3SB	S129	GS3SB	S149	WF3SB
S90	W3SBFS	S110	WS3SBFS	S130	GS3SBFS	S150	WF3SBFS
S91	W3DB	S111	WS3DB	S131	GS3DB	S151	WF3DB
S92	W3DBFS	S112	WS3DBFS	S132	GS3DBFS	S152	WF3DBFS
S93	W2SB	S113	WS2SB	S133	GS2SB	S153	WF2SB
S94	W2SBFS	S114	WS2SBFS	S134	GS2SBFS	S154	WF2SBFS
S95	W2DB	S115	WS2DB	S135	GS2DB	S155	WF2DB
S96	W2DBFS	S116	WS2DBFS	S136	GS2DBFS	S156	WF2DBFS
S97	W1SB	S117	WS1SB	S137	GS1SB	S157	WF1SB
S98	W1SBFS	S118	WS1SBFS	S138	GS1SBFS	S158	WF1SBFS
S99	W1DB	S119	WS1DB	S139	GS1DB	S159	WF1DB
S100	W1DBFS	S120	WS1DBFS	S140	GS1DBFS	S160	WF1DBFS

Scenario #	Abbrev.
S161	WC5SB
S162	WC5SBFS
S163	WC5DB
S164	WC5DBFS
S165	WC4SB
S166	WC4SBFS
S167	WC4DB
S168	WC4DBFS
S169	WC3SB
S170	WC3SBFS
S171	WC3DB
S172	WC3DBFS
S173	WC2SB
S174	WC2SBFS
S175	WC2DB
S176	WC2DBFS
S177	WC1SB
S178	WC1SBFS
S179	WC1DB
S180	WC1DBFS

Scenario #	Abbrev.
S181	WG5SB
S182	WG5SBFS
S183	WG5DB
S184	WG5DBFS
S185	WG4SB
S186	WG4SBFS
S187	WG4DB
S188	WG4DBFS
S189	WG3SB
S190	WG3SBFS
S191	WG3DB
S192	WG3DBFS
S193	WG2SB
S194	WG2SBFS
S195	WG2DB
S196	WG2DBFS
S197	WG1SB
S198	WG1SBFS
S199	WG1DB
S200	WG1DBFS

Scenario #	Abbrev.
S201	WGS5SB
S202	WGS5SBFS
S203	WGS5DB
S204	WGS5DBFS
S205	WGS4SB
S206	WGS4SBFS
S207	WGS4DB
S208	WGS4DBFS
S209	WGS3SB
S210	WGS3SBFS
S211	WGS3DB
S212	WGS3DBFS
S213	WGS2SB
S214	WGS2SBFS
S215	WGS2DB
S216	WGS2DBFS
S217	WGS1SB
S218	WGS1SBFS
S219	WGS1DB
S220	WGS1DBFS

Scenario #	Abbrev.
S221	BBLS
S222	SWCH
S223	FESC
S224	FSGZ0
S225	FSGZ1

Table A-21 Scenario Number and Abbreviation for Temporal Effect Analysis

Scenario #	Abbrev.
S1	CS5SB
S2	CS5SBFS
S3	CS5DB
S4	CS5DBFS
S5	CS4SB
S6	CS4SBFS
S7	CS4DB
S8	CS4DBFS
S9	CS3SB
S10	CS3SBFS
S11	CS3DB
S12	CS3DBFS
S13	CS2SB
S14	CS2SBFS
S15	CS2DB
S16	CS2DBFS
S17	CS1SB
S18	CS1SBFS
S19	CS1DB
S20	CS1DBFS

Scenario #	Abbrev.
S21	C5SB
S22	C5SBFS
S23	C5DB
S24	C5DBFS
S25	C4SB
S26	C4SBFS
S27	C4DB
S28	C4DBFS
S29	C3SB
S30	C3SBFS
S31	C3DB
S32	C3DBFS
S33	C2SB
S34	C2SBFS
S35	C2DB
S36	C2DBFS
S37	C1SB
S38	C1SBFS
S39	C1DB
S40	C1DBFS

Scenario #	Abbrev.
S41	S5SB
S42	S5SBFS
S43	S5DB
S44	S5DBFS
S45	S4SB
S46	S4SBFS
S47	S4DB
S48	S4DBFS
S49	S3SB
S50	S3SBFS
S51	S3DB
S52	S3DBFS
S53	S2SB
S54	S2SBFS
S55	S2DB
S56	S2DBFS
S57	S1SB
S58	S1SBFS
S59	S1DB
S60	S1DBFS

Scenario #	Abbrev.
S61	BBLS
S62	SWCH
S63	FESC
S64	FSGZ0
S65	FSGZ1

Table A-22 Denomination and Abbreviation for Alternative Scenario Design

Cropping: Single-Year

Native Prairie
BBLS
SWCH

FESC
FESC1
FESC2
FESC3
FESC3X2
FESC3X3
FESC3X4

Tillage	Fertilizer	CORN (1-yr)		GRSG (1-yr)		WWHT (1-yr)		SOYB (1-yr)		WWHT-SOYB (1-yr)	
		w/o	w/ VFS	w/o	w/ VFS	w/o	w/ VFS	w/o	w/ VFS	w/o	w/ VFS
NT	SB	C1SB	C1SBFS	G1SB	G1SBFS	W1SB	W1SBFS	S1SB	S1SBFS	WS1SB	WS1SBFS
	DB	C1DB	C1DBFS	G1DB	G1DBFS	W1DB	W1DBFS	S1DB	S1DBFS	WS1DB	WS1DBFS
OT	SB	C2SB	C2SBFS	G2SB	G2SBFS	W2SB	W2SBFS	S2SB	S2SBFS	WS2SB	WS2SBFS
	DB	C2DB	C2DBFS	G2DB	G2DBFS	W2DB	W2DBFS	S2DB	S2DBFS	WS2DB	WS2DBFS
RT	SB	C3SB	C3SBFS	G3SB	G3SBFS	W3SB	W3SBFS	S3SB	S3SBFS	WS3SB	WS3SBFS
	DB	C3DB	C3DBFS	G3DB	G3DBFS	W3DB	W3DBFS	S3DB	S3DBFS	WS3DB	WS3DBFS
MT	SB	C4SB	C4SBFS	G4SB	G4SBFS	W4SB	W4SBFS	S4SB	S4SBFS	WS4SB	WS4SBFS
	DB	C4DB	C4DBFS	G4DB	G4DBFS	W4DB	W4DBFS	S4DB	S4DBFS	WS4DB	WS4DBFS
CT	SB	C5SB	C5SBFS	G5SB	G5SBFS	W5SB	W5SBFS	S5SB	S5SBFS	WS5SB	WS5SBFS
	DB	C5DB	C5DBFS	G5DB	G5DBFS	W5DB	W5DBFS	S5DB	S5DBFS	WS5DB	WS5DBFS

Cropping: Multiple Years

Tillage	Fert. Method	CORN-SOYB (2-yr)			GRGS-SOYB (2-yr)		WWHT-FALW (2-yr)		WWHT-CORN (3-yr)		WWHT-GRSG (3-yr)		WWHT-GRSG-SOYB	
		w/o	w/ VFS	w/ VFS-GZ	w/o	w/ VFS	w/o	w/ VFS	w/o	w/ VFS	w/o	w/ VFS	w/o	w/ VFS
NT	SB	CS1SB	CS1SBFS	CS1SBFSGZ	GS1SB	GS1SBFS	WF1SB	WF1SBFS	WC1SB	WC1SBFS	WG1SB	WG1SBFS	WGS1SB	WGS1SBFS
	DB	CS1DB	CS1DBFS	CS1DBFSGZ	GS1DB	GS1DBFS	WF1DB	WF1DBFS	WC1DB	WC1DBFS	WG1DB	WG1DBFS	WGS1DB	WGS1DBFS
OT	SB	CS2SB	CS2SBFS	CS2SBFSGZ	GS2SB	GS2SBFS	WF2SB	WF2SBFS	WC2SB	WC2SBFS	WG2SB	WG2SBFS	WGS2SB	WGS2SBFS
	DB	CS2DB	CS2DBFS	CS2DBFSGZ	GS2DB	GS2DBFS	WF2DB	WF2DBFS	WC2DB	WC2DBFS	WG2DB	WG2DBFS	WGS2DB	WGS2DBFS
RT	SB	CS3SB	CS3SBFS	CS3SBFSGZ	GS3SB	GS3SBFS	WF3SB	WF3SBFS	WC3SB	WC3SBFS	WG3SB	WG3SBFS	WGS3SB	WGS3SBFS
	DB	CS3DB	CS3DBFS	CS3DBFSGZ	GS3DB	GS3DBFS	WF3DB	WF3DBFS	WC3DB	WC3DBFS	WG3DB	WG3DBFS	WGS3DB	WGS3DBFS
MT	SB	CS4SB	CS4SBFS	CS4SBFSGZ	GS4SB	GS4SBFS	WF4SB	WF4SBFS	WC4SB	WC4SBFS	WG4SB	WG4SBFS	WGS4SB	WGS4SBFS
	DB	CS4DB	CS4DBFS	CS4DBFSGZ	GS4DB	GS4DBFS	WF4DB	WF4DBFS	WC4DB	WC4DBFS	WG4DB	WG4DBFS	WGS4DB	WGS4DBFS
CT	SB	CS5SB	CS5SBFS	CS5SBFSGZ	GS5SB	GS5SBFS	WF5SB	WF5SBFS	WC5SB	WC5SBFS	WG5SB	WG5SBFS	WGS5SB	WGS5SBFS
	DB	CS5DB	CS5DBFS	CS5DBFSGZ	GS5DB	GS5DBFS	WF5DB	WF5DBFS	WC5DB	WC5DBFS	WG5DB	WG5DBFS	WGS5DB	WGS5DBFS

Crop Rotation Definition

BBLS	BBLS	Native Prairie (use Big Bluestem parameters)
SWCH	SWCH	Alternative Energy - Bio-fuel (use Alamo Switchgrass)
FESC	FESC	Kansas cool season grass for vegetative filter strip
C	CORN	Continuous Corn
G	GRSG	Continuous Grain Sorghum
S	SOYB	Continuous Soybean
W	WWHT	Continuous Winter Wheat
WS	WWHT-SOYB	Winter Wheat-Soybean 1 year double crop
CS	CORN-SOYB	Corn-Soybean rotation
GS	GRGS-SOYB	Grain Sorghum-Soybean rotation
WC	WWHT-CORN	Winter Wheat-Corn rotation
WG	WWHT-GRSG	Winter Wheat-Grain Sorghum rotation
WGS	WWHT-GRSG-SOYB	Winter Wheat-Grain Sorghum -Soybean rotation

Tillage Method

1	NT	No till
2	OT	Rotational No-till
3	RT	Reduced Tillage
4	MT	Minimum Tillage
5	CT	Conventional Tillage

Fertilizer Application Method			Edge-of-Field BMPs
Surface Broadcast	SB	without any BMP	without BMP
	SBFS	with VFS (20m)	with VFS
	SBFSGZ	with VFS & grazing	with VFS/GZ
Sub-surface Deep Band	DB	without any BMP	without BMP
	DBFS	with VFS (20m)	with VFS
	DBFSGZ	with VFS & grazing	with VFS/GZ

Table A-23 Minimum Fertilizer Requirements for Each Crop Rotation

Crop	Est. Yield	Req. N	Req. P	Fertilizer Application	Tillage	Pre-Plant (15%) w/ field cultivator					Plant (85 to 75%) w/ planter					After Plant (10%) w/ side dress			
	Bu./acre	kg/ha	kg/ha			FRT_S	CHM	Fert. (kg/ha)	Eq. N	Eq. P	FRT_S	CHM	Fert. (kg/ha)	Eq. N	Eq. P	FRT_S	CHM	Fert. (kg/ha)	Eq. N
CORN [Cont. CORN]	100	140	36.986	SB	CT/MT/RT	0.70	DAP	12.061	2.171	5.548	0.80	DAP	68.343	12.302	31.438	0.85	UAN	43.750	14.000
							UAN	58.841	18.829			UAN	289.681	92.698					
					NT						0.90	DAP	80.404	14.473	36.986	0.95	UAN	65.625	21.000
												UAN	326.647	104.527					
				DB	CT/MT/RT	0.10	DAP	12.061	2.171	5.548	0.10	DAP	68.343	12.302	31.438	0.10	AHY	17.073	14.000
							AHY	22.962	18.829			AHY	113.046	92.698					
					NT						0.10	DAP	80.404	14.473	36.986				
												AHY	153.082	125.527					
Cont. GRSG	80	76.22	35.866	SB	CT/MT/RT	0.70	DAP	11.695	2.105	5.380	0.80	DAP	66.274	11.929	30.486	0.85	UAN	23.819	7.622
							UAN	29.150	9.328			UAN	141.363	45.236					
					NT						0.90	DAP	77.969	14.034	35.866	0.95	UAN	35.728	11.433
												UAN	158.603	50.753					
				DB	CT/MT/RT	0.10	DAP	11.695	2.105	5.380	0.10	DAP	66.274	11.929	30.486	0.10	AHY	9.295	7.622
							AHY	11.376	9.328			AHY	55.166	45.236					
					NT						0.10	DAP	77.969	14.034	35.866				
												AHY	75.837	62.186					
Cont. SOYB	40	n/a	35.866	SB	CT/MT/RT	0.70	DAP	11.695	2.105	5.380	0.80	DAP	66.274	11.929	30.486				
					NT						0.90	DAP	77.970	14.035	35.866				
				DB	CT/MT/RT	0.20	DAP	11.695	2.105	5.380	0.20	DAP	66.274	11.929	30.486				
					NT						0.20	DAP	77.970	14.035	35.866				
WWHT [Rotate/Cont.]	40	57.16	22.416	SB	CT/MT/RT	0.70	DAP	7.310	1.316	3.363	0.80	DAP	41.422	7.456	19.054	0.85	UAN	128.531	41.130
							UAN	22.681	7.258										
					NT						0.90	DAP	48.730	8.771	22.416	0.95	UAN	128.531	41.130
												UAN	22.684	7.259					
				DB	CT/MT/RT	0.10	DAP	7.310	1.316	3.363	0.10	DAP	41.422	7.456	19.054	0.10	AHY	34.854	28.580
							AHY	8.851	7.258			AHY	15.305	12.550					
					NT						0.10	DAP	48.730	8.771	22.416	0.10	AHY	34.854	28.580
												AHY	24.157	19.809					
WWHT [Double Crop]	40	90.784	22.416	SB	CT/MT/RT	0.70	DAP	7.310	1.316	3.363	0.80	DAP	41.422	7.456	19.054	0.85	UAN	212.775	68.088
							UAN	38.444	12.302			UAN	5.069	1.622					
					NT						0.90	DAP	48.730	8.771	22.416	0.95	UAN	212.775	68.088
												UAN	43.516	13.925					
				DB	CT/MT/RT	0.10	DAP	7.310	1.316	3.363	0.10	DAP	41.422	7.456	19.054	0.10	AHY	55.356	45.392
							AHY	15.002	12.302			AHY	29.656	24.318					
					NT						0.10	DAP	48.730	8.771	22.416	0.10	AHY	55.356	45.392
												AHY	44.660	36.621					

Note:

1. Chemical: Anhydrous Ammonia (82-0-0), DAP-Ammonium Phosphates ($(NH_4)_2HPO_4$) (18-46-0), Urea (46-0-0), Ammonium Nitrate (NH_4NO_3) (34-0-0), Urea ammonium nitrate (UAN) (32-0-0)

2. Price: Anhydrous Ammonia ($500 /ton), DAP-Ammonium Phosphates $(NH_4)_2HPO_4$) ($240 /ton), Urea ($445 /ton), Ammonium Nitrate (NH_4NO_3) ($361 /ton), Urea ammonium nitrate (UAN) ($314 /ton) (NRCS, 2008a). Source: Energy Consumption Awareness Tool: Nitrogen. USDA NRCS. Available at: nfat.sc.egov.usda.gov.

3. For winter wheat: only a small amount of total nitrogen should be applied in fall. The rest of nitrogen should be applied as spring top-dress to minimize nitrogen loss through leaching or volatilization.

4. Revenues for application methods: point injection ($966/ac), broadcasting ($899/ac), knife N ($872/ac) (Jones and Jacobsen, 2003)

Type of Fertilizer and Chemical Components

Agricultural Chemical (SWAT Fertilizer Definition)		N %	P_2O_5 %	($/ton)
AHY:	Anhydrous Ammonia (82-0-0)	0.82	0.00	731
DAP:	Ammonium Phosphates $(NH_4)_2HPO_4$ (18-46-0)	0.18	0.46	240
ELN:	Elemental N (100-0-0)	1.00	0.00	
ELP:	Elemental P (0-100-0)	0.00	1.00	
	Ammonium Nitrate (NH_4NO_3) (34-0-0)	0.34	0.00	465
	Urea (46-0-0)	0.46	0.00	537
UAN:	Urea ammonium nitrate (UAN) (32-0-0)	0.32	0.00	375

Top-10mm Fertilizer Available Percentage for Each Cultivation

Tillage System		Field Cultivator	No-till	Row Cultivator	Blade
		Lt15ft	Mixing	Lt15ft	10 ft
EFTMIX		0.30	0.05	0.25	0.25
DEPTIL(mm)		100.00	25.00	25.00	25.00
Top 10mm	SB	0.730	0.970	0.850	0.850
	DB	0.030	0.020	0.100	0.100
FRT_S	SB	**0.70**	**0.90**	**0.85**	**0.85**
	DB	**0.10**	**0.10**	**0.10**	**0.10**

Table A-24 Cultivating Operation Dates for Native Prairie Grasses

Native Prairie Grass					Tandem	Chisel	Moldboard	Tandem	Field	Fertilizer	No-till	Planting	Fertilizer	Blade	Row	Fertilizer	Harvest
Crop	Case #	Till	S-Mgmt Crop	TL	Disk Reg Ge 19ft	Plow Gt15ft	Plow Reg Ge7b	Disk Reg 14-18ft	Cultivator Lt15ft	with Cultivator	Mixing		with Planter	10 Ft	Cultivator Lt15ft	with Side-Dress	
BBLS	BBLS	n/a	BBLS									03/15/01					12/01/01
SWCH	SWCH	n/a	SWCH									03/15/01					12/01/01
FESC	FESC	n/a	FESC									03/01/01					12/01/01

Table A-25 Cultivating Operation Dates for 1-Yr Crop Rotation

One-Year Rotation					Tandem	Chisel	Moldboard	Tandem	Field	Fertilizer	No-till	Planting	Fertilizer	Blade	Row	Fertilizer	Harvest
Crop	Case #	Till	S-Mgmt Crop	TL	Disk Reg Ge 19ft	Plow Gt15ft	Plow Reg Ge7b	Disk Reg 14-18ft	Cultivator Lt15ft	with Cultivator	Mixing		with Planter	10 Ft	Cultivator Lt15ft	with Side-Dress	
Continuous CORN	C1 SB/DB	NT	COR2								05/01/01	05/01/01	05/01/01			06/01/01	09/15/01
	C2 SB/DB	OT	COR2	NT							05/01/02	05/01/02	05/01/02			06/01/02	09/15/02
			COR1	MT		11/05/02		04/10/01	04/25/01	04/25/01		05/01/01	05/01/01		06/01/01	06/01/01	09/15/01
	C3 SB/DB	RT	COR1						04/25/01	04/25/01		05/01/01	05/01/01		06/01/01	06/01/01	09/15/01
	C4 SB/DB	MT	COR1			11/05/01		04/10/01	04/25/01	04/25/01		05/01/01	05/01/01		06/01/01	06/01/01	09/15/01
	C5 SB/DB	CT	COR1		10/25/01	11/05/01	03/20/01	04/10/01	04/25/01	04/25/01		05/01/01	05/01/01		06/01/01	06/01/01	09/15/01
Continuous GRSG	G1 SB/DB	NT	GRS2								06/01/01	06/01/01	06/01/01			07/01/01	10/15/01
	G2 SB/DB	OT	GRS2	NT							06/01/02	06/01/02	06/01/02			07/01/02	10/15/02
			GRS1	MT		11/05/02		04/25/01	05/25/01	05/25/01		06/01/01	06/01/01		07/01/01	07/01/01	10/15/01
	G3 SB/DB	RT	GRS1						05/25/01	05/25/01		06/01/01	06/01/01		07/01/01	07/01/01	10/15/01
	G4 SB/DB	MT	GRS1			11/05/01		04/25/01	05/25/01	05/25/01		06/01/01	06/01/01		07/01/01	07/01/01	10/15/01
	G5 SB/DB	CT	GRS1		10/25/01	11/05/01	04/01/01	04/25/01	05/25/01	05/25/01		06/01/01	06/01/01		07/01/01	07/01/01	10/15/01
Continuous SOYB	S1 SB/DB	NT	SOY2								05/15/01	05/15/01	05/15/01				10/07/01
	S2 SB/DB	OT	SOY2	NT							05/15/02	05/15/02	05/15/02				10/07/02
			SOY1	MT		11/05/02		04/15/01	05/10/01	05/10/01		05/15/01	05/15/01				10/07/01
	S3 SB/DB	RT	SOY1						05/10/01	05/10/01		05/15/01	05/15/01				10/07/01
	S4 SB/DB	MT	SOY1			11/05/01		04/15/01	05/10/01	05/10/01		05/15/01	05/15/01				10/07/01
	S5 SB/DB	CT	SOY1		10/25/01	11/05/01	03/20/01	04/15/01	05/10/01	05/10/01		05/15/01	05/15/01				10/07/01
Continuous WWHT	W1 SB/DB	NT	WWHT								09/15/01	09/15/01	09/15/01	03/15/01		03/15/01	06/15/01
	W2 SB/DB	OT	WWHT	NT							09/15/02	09/15/01	09/15/02	03/15/02		03/15/02	06/15/01
			WWHT	MT			07/15/01	08/15/01	09/01/01	09/01/01		09/15/02	09/15/01	03/1, 3/10, 3/15		03/15/01	06/15/02
	W3 SB/DB	RT	WWHT						09/01/01	09/01/01		09/15/01	09/15/01	03/1, 3/15		03/15/01	06/15/01
	W4 SB/DB	MT	WWHT				07/15/01	08/15/01	09/01/01	09/01/01		09/15/01	09/15/01	03/1, 3/10, 3/15		03/15/01	06/15/01
	W5 SB/DB	CT	WWHT		07/01/01		08/01/01	08/20/01	09/01/01	09/01/01		09/15/01	09/15/01	03/1, 3/10, 3/15		03/15/01	06/15/01
WWHT-SOYB (Double Crop)	WS1 SB/DB	NT	WWHT								10/01/01	10/01/01	10/01/01	03/10/01		03/10/01	05/22/01
			SOY2								06/01/01	06/01/01	06/01/01				09/15/01
	WS2 SB/DB	OT	WWHT	NT							10/01/01	10/01/01	10/01/01	03/10/01		03/10/01	05/22/01
			SOY1	MT				05/25/01	05/27/01	05/27/01		06/01/01	06/01/01				09/15/01
	WS3 SB/DB	RT	WWHT						09/25/01	09/25/01		10/01/01	10/01/01	3/10, 3/15/01		03/10/01	05/22/01
			SOY1						05/25/01	05/25/01		06/01/01	06/01/01			`	09/15/01
	WS4 SB/DB	MT	WWHT					09/20/01	09/25/01	09/25/01		10/01/01	10/01/01	3/10, 3/15/01		03/10/01	05/22/01
			SOY1					05/25/01	05/27/01	05/27/01		06/01/01	06/01/01				09/15/01
	WS5 SB/DB	CT	WWHT				09/16/01	09/20/01	09/25/01	09/25/01		10/01/01	10/01/01	3/10, 3/15/01		03/10/01	05/22/01
			SOY1				05/23/01	05/25/01	05/27/01	05/27/01		06/01/01	06/01/01				09/15/01

Table A-26 Cultivating Operation Dates for 2-Yr Crop Rotation

Two-Year Rotation Crop	Case #	Till	S-Mgmt Crop	TL	Tandem Disk Reg Ge 19ft	Chisel Plow Gt15ft	Moldboard Plow Reg Ge7b	Tandem Disk Reg 14-18ft	Field Cultivator Lt15ft	Fertilizer with Cultivator	No-till Mixing	Planting	Fertilizer with Planter	Blade 10 Ft	Row Cultivator Lt15ft	Fertilizer with Side-Dress	Harvest
CORN-SOYB	CS1 SB/DB	NT	COR2								05/01/01	05/01/01	05/01/01			06/01/01	09/15/01
			SOY2								05/15/02	05/15/02	05/15/02				10/07/02
	CS2 SB/DB	OT	COR2	NT							05/01/01	05/01/01	05/01/01			06/01/01	09/15/01
			SOY1	MT		11/05/01		04/15/02	05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
	CS3 SB/DB	RT	COR1						04/25/01	04/25/01		05/01/01	05/01/01		06/01/01	06/01/01	09/15/01
			SOY1						05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
	CS4 SB/DB	MT	COR1			11/05/02		04/10/01	04/25/01	04/25/01		05/01/01	05/01/01		06/01/01	06/01/01	09/15/01
			SOY1			11/05/01		04/15/02	05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
	CS5 SB/DB	CT	COR1		10/25/02	11/05/02	03/20/01	04/10/01	04/25/01	04/25/01		05/01/01	05/01/01		06/01/01	06/01/01	09/15/01
			SOY1		10/25/01	11/05/01	03/20/02	04/15/02	05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
GRGS-SOYB	GS1 SB/DB	NT	GRS2								06/01/01	06/01/01	06/01/01			07/01/01	10/15/01
			SOY2								05/15/02	05/15/02	05/15/02				10/07/02
	GS2 SB/DB	OT	GRS2	NT							06/01/01	06/01/01	06/01/01			07/01/01	10/15/01
			SOY1	MT		11/05/01		04/15/02	05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
	GS3 SB/DB	RT	GRS1						05/25/01	05/25/01		06/01/01	06/01/01		07/01/01	07/01/01	10/15/01
			SOY1						05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
	GS4 SB/DB	MT	GRS1			11/05/02		04/25/01	05/25/01	05/25/01		06/01/01	06/01/01		07/01/01	07/01/01	10/15/01
			SOY1			11/05/01		04/15/02	05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
	GS5 SB/DB	CT	GRS1		10/25/02	11/05/02	04/01/01	04/25/01	05/25/01	05/25/01		06/01/01	06/01/01		07/01/01	07/01/01	10/15/01
			SOY1		10/25/01	11/05/01	03/20/02	04/15/02	05/10/02	05/10/02		05/15/02	05/15/02				10/07/02
WWHT-FALW	WF1 SB/DB	NT	WWHT								09/15/01	09/15/01	09/15/01	03/15/02		03/15/02	06/15/02
			FALW														
	WF2 SB/DB	OT	WWHT	NT							09/15/01	09/15/01	09/15/01	03/15/02		03/15/02	06/15/02
			FALW														
			WWHT	MT			07/15/03	08/15/03	09/01/03	09/01/03		09/15/03	09/15/03	03/1, 3/10, 3/15/04		03/15/04	06/15/04
			FALW														
	WF3 SB/DB	RT	WWHT						09/01/01	09/01/01		09/15/01	09/15/01	03/1, 3/15/02		03/15/02	06/15/02
			FALW														
	WF4 SB/DB	MT	WWHT				07/15/01	08/15/01	09/01/01	09/01/01		09/15/01	09/15/01	03/1, 3/10, 3/15/02		03/15/02	06/15/02
			FALW														
	WF5 SB/DB	CT	WWHT		07/01/01		08/01/01	08/20/01	09/01/01	09/01/01		09/15/01	09/15/01	03/1, 3/10, 3/15/02		03/15/02	06/15/02
			FALW														

Table A-27 Cultivating Operation Dates for Three-Year Crop Rotation

Three-Year Rotation					Tandem Disk	Chisel Plow	Moldboard Plow	Tandem Disk	Field Cultivator	Fertilizer with Cultivator	No-till Mixing	Planting	Fertilizer with Planter	Blade	Row Cultivator	Fertilizer with Side-Dress	Harvest
Crop	Case #	Till	S-Mgmt Crop	TL	Reg Ge 19ft	Gt15ft	Reg Ge7b	Reg 14-18ft	Lt15ft					10 Ft	Lt15ft		
WWHT-CORN	WC1 SB/DB	NT	WWHT								09/15/03	09/15/03	09/15/03	03/15/01		03/15/01	06/15/01
			COR2								05/01/02	05/01/02	05/01/02			06/01/02	09/15/02
	WC2 SB/DB	OT	WWHT	NT							09/15/03	09/15/03	09/15/03	03/15/01		03/15/01	06/15/01
			COR1	MT		11/01/01		04/10/02	04/25/02	04/25/02		05/01/02	05/01/02		06/01/02	06/01/02	09/15/02
	WC3 SB/DB	RT	WWHT						09/01/03	09/01/03		09/15/03	09/15/03	03/1, 3/15/01		03/15/01	06/15/01
			COR1						04/25/02	04/25/02		05/01/02	05/01/02		06/01/02	06/01/02	09/15/02
	WC4 SB/DB	MT	WWHT				07/15/03	08/15/03	09/01/03	09/01/03		09/15/03	09/15/03	03/1, 3/10, 3/15/01		03/15/01	06/15/01
			COR1			11/01/01		04/10/02	04/25/02	04/25/02		05/01/02	05/01/02		06/01/02	06/01/02	09/15/02
	WC5 SB/DB	CT	WWHT		07/01/03		08/01/03	08/20/03	09/01/03	09/01/03		09/15/03	09/15/03	03/1, 3/10, 3/15/01		03/15/01	06/15/01
			COR1		10/15/01	11/01/01	03/20/02	04/10/02	04/25/02	04/25/02		05/01/02	05/01/02		06/01/02	06/01/02	09/15/02
WWHT-GRSG	WG1 SB/DB	NT	WWHT								09/15/03	09/15/03	09/15/03	03/15/01		03/15/01	06/15/01
			GRS2								06/01/02	06/01/02	06/01/02			07/01/02	10/15/02
	WG2 SB/DB	OT	WWHT	NT							09/15/03	09/15/03	09/15/03	03/15/01		03/15/01	06/15/01
			GRS1	MT		11/01/01		04/25/02	05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
	WG3 SB/DB	RT	WWHT						09/01/03	09/01/03		09/15/03	09/15/03	03/1, 3/15/01		03/15/01	06/15/01
			GRS1						05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
	WG4 SB/DB	MT	WWHT				07/15/03	08/15/03	09/01/03	09/01/03		09/15/03	09/15/03	03/1, 3/10, 3/15/01		03/15/01	06/15/01
			GRS1			11/01/01		04/25/02	05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
	WG5 SB/DB	CT	WWHT		07/01/03		08/01/03	08/20/03	09/01/03	09/01/03		09/15/03	09/15/03	03/1, 3/10, 3/15/01		03/15/01	06/15/01
			GRS1		10/15/01	11/01/01	04/01/02	04/25/02	05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
WWHT-GRSG-SOYB	WGS1 SB/DB	NT	WWHT								10/01/03	10/01/03	10/01/03	03/15/01		03/15/01	06/15/01
			GRS2								06/01/02	06/01/02	06/01/02			07/01/02	10/15/02
			SOY2								05/15/03	05/15/03	05/15/03				09/15/03
	WGS2 SB/DB	OT	WWHT	NT							10/01/03	10/01/03	10/01/03	03/15/01		03/15/01	06/15/01
			GRS1	MT		11/01/01		04/25/02	05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
			SOY1	MT		11/01/02		04/15/03	05/10/03	05/10/03		05/15/03	05/15/03				09/15/03
	WGS3 SB/DB	RT	WWHT						09/25/03	09/25/03		10/01/03	10/01/03	03/1, 3/15/01		03/15/01	06/15/01
			GRS1						05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
			SOY1						05/10/03	05/10/03		05/15/03	05/15/03				09/15/03
	WGS4 SB/DB	MT	WWHT					09/20/03	09/25/03	09/25/03		10/01/03	10/01/03	03/1, 3/10, 3/15/01		03/15/01	06/15/01
			GRS1			11/01/01		04/25/02	05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
			SOY1			11/01/02		04/15/03	05/10/03	05/10/03		05/15/03	05/15/03				09/15/03
	WGS5 SB/DB	CT	WWHT				09/16/03	09/20/03	09/25/03	09/25/03		10/01/03	10/01/03	03/1, 3/10, 3/15/01		03/15/01	06/15/01
			GRS1		10/15/01	11/01/01	04/01/02	04/25/02	05/25/02	05/25/02		06/01/02	06/01/02		07/01/02	07/01/02	10/15/02
			SOY1		10/25/02	11/01/02	03/20/03	04/15/03	05/10/03	05/10/03		05/15/03	05/15/03				09/15/03

Table A-28 Fertilizer Application Dates for Native Prairie Grasses

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
BBLS	BBLS	n/a	BBLS								03/15/01											12/01/01
SWCH	SWCH	n/a	SWCH								03/15/01											12/01/01
FESC	FESC	n/a	FESC								03/01/01											12/01/01

Table A-29 Fertilizer Application Dates for Continuous Corn

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
Continuous CORN [1 yr] Rotation	C1SB	NT	COR2								05/01/01	05/01/01	0.90	DAP	80.404	UAN	326.647	06/01/01	0.95	UAN	65.625	09/15/01
	C2SB	OT	COR2	NT							05/01/02	05/01/02	0.90	DAP	80.404	UAN	326.647	06/01/02	0.95	UAN	65.625	09/15/02
			COR1	MT	04/25/01	0.70	DAP	12.061	UAN	58.841	05/01/01	05/01/01	0.80	DAP	68..343	UAN	289.681	06/01/01	0.85	UAN	43.750	09/15/01
	C3SB	RT	COR1		04/25/01	0.70	DAP	12.061	UAN	58.841	05/01/01	05/01/01	0.80	DAP	68.343	UAN	289.681	06/01/01	0.85	UAN	43.750	09/15/01
	C4SB	MT	COR1		04/25/01	0.70	DAP	12.061	UAN	58.841	05/01/01	05/01/01	0.80	DAP	68.343	UAN	289.681	06/01/01	0.85	UAN	43.750	09/15/01
	C5SB	CT	COR1		04/25/01	0.70	DAP	12.061	UAN	58.841	05/01/01	05/01/01	0.80	DAP	68.343	UAN	289.681	06/01/01	0.85	UAN	43.750	09/15/01
	C1DB	NT	COR2								05/01/01	05/01/01	0.10	DAP	80.404	AHY	153.082					09/15/01
	C2DB	OT	COR2	NT							05/01/02	05/01/02	0.10	DAP	80.404	AHY	153.082					09/15/02
			COR1	MT	04/25/01	0.10	DAP	12.061	AHY	22.962	05/01/01	05/01/01	0.10	DAP	68.343	AHY	113.046	06/01/01	0.10	AHY	17.073	09/15/01
	C3DB	RT	COR1		04/25/01	0.10	DAP	12.061	AHY	22.962	05/01/01	05/01/01	0.10	DAP	68.343	AHY	113.046	06/01/01	0.10	AHY	17.073	09/15/01
	C4DB	MT	COR1		04/25/01	0.10	DAP	12.061	AHY	22.962	05/01/01	05/01/01	0.10	DAP	68.343	AHY	113.046	06/01/01	0.10	AHY	17.073	09/15/01
	C5DB	CT	COR1		04/25/01	0.10	DAP	12.061	AHY	22.962	05/01/01	05/01/01	0.10	DAP	68.343	AHY	113.046	06/01/01	0.10	AHY	17.073	09/15/01

Table A-30 Fertilizer Application Dates for Continuous Grain Sorghum

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
Continuous GRSG [1 yr] Rotation	G1SB	NT	GRS2								06/01/01	06/01/01	0.90	DAP	77.969	UAN	158.603	07/01/01	0.95	UAN	35.728	10/15/01
	G2SB	OT	GRS2	NT							06/01/02	06/01/02	0.90	DAP	77.969	UAN	158.603	07/01/02	0.95	UAN	35.728	10/15/02
			GRS1	MT	05/25/01	0.70	DAP	11.695	UAN	29.150	06/01/01	06/01/01	0.80	DAP	66.274	UAN	141.363	07/01/01	0.85	UAN	23.819	10/15/01
	G3SB	RT	GRS1		05/25/01	0.70	DAP	11.695	UAN	29.150	06/01/01	06/01/01	0.80	DAP	66.274	UAN	141.363	07/01/01	0.85	UAN	23.819	10/15/01
	G4SB	MT	GRS1		05/25/01	0.70	DAP	11.695	UAN	29.150	06/01/01	06/01/01	0.80	DAP	66.274	UAN	141.363	07/01/01	0.85	UAN	23.819	10/15/01
	G5SB	CT	GRS1		05/25/01	0.70	DAP	11.695	UAN	29.150	06/01/01	06/01/01	0.80	DAP	66.274	UAN	141.363	07/01/01	0.85	UAN	23.819	10/15/01
	G1DB	NT	GRS2								06/01/01	06/01/01	0.10	DAP	77.969	AHY	75.837					10/15/01
	G2DB	OT	GRS2	NT							06/01/02	06/01/02	0.10	DAP	77.969	AHY	75.837					10/15/02
			GRS1	MT	05/25/01	0.10	DAP	11.695	AHY	11.376	06/01/01	06/01/01	0.10	DAP	66.274	AHY	55.166	07/01/01	0.10	AHY	9.295	10/15/01
	G3DB	RT	GRS1		05/25/01	0.10	DAP	11.695	AHY	11.376	06/01/01	06/01/01	0.10	DAP	66.274	AHY	55.166	07/01/01	0.10	AHY	9.295	10/15/01
	G4DB	MT	GRS1		05/25/01	0.10	DAP	11.695	AHY	11.376	06/01/01	06/01/01	0.10	DAP	66.274	AHY	55.166	07/01/01	0.10	AHY	9.295	10/15/01
	G5DB	CT	GRS1		05/25/01	0.10	DAP	11.695	AHY	11.376	06/01/01	06/01/01	0.10	DAP	66.274	AHY	55.166	07/01/01	0.10	AHY	9.295	10/15/01

Table A-31 Fertilizer Application Dates for Continuous Soybean

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
Continuous SOYB [1 yr] Rotation	S1SB	NT	SOY2								05/15/01	05/15/01	0.90	DAP	77.970							10/07/01
	S2SB	OT	SOY2	NT							05/15/02	05/15/02	0.90	DAP	77.970							10/07/02
			SOY1	MT	05/10/01	0.70	DAP	11.695			05/15/01	05/15/01	0.80	DAP	66.274							10/07/01
	S3SB	RT	SOY1		05/10/01	0.70	DAP	11.695			05/15/01	05/15/01	0.80	DAP	66.274							10/07/01
	S4SB	MT	SOY1		05/10/01	0.70	DAP	11.695			05/15/01	05/15/01	0.80	DAP	66.274							10/07/01
	S5SB	CT	SOY1		05/10/01	0.70	DAP	11.695			05/15/01	05/15/01	0.80	DAP	66.274							10/07/01
	S1DB	NT	SOY2								05/15/01	05/15/01	0.20	DAP	77.970							10/07/01
	S2DB	OT	SOY2	NT							05/15/02	05/15/02	0.20	DAP	77.970							10/07/02
			SOY1	MT	05/10/01	0.20	DAP	11.695			05/15/01	05/15/01	0.20	DAP	66.274							10/07/01
	S3DB	RT	SOY1		05/10/01	0.20	DAP	11.695			05/15/01	05/15/01	0.20	DAP	66.274							10/07/01
	S4DB	MT	SOY1		05/10/01	0.20	DAP	11.695			05/15/01	05/15/01	0.20	DAP	66.274							10/07/01
	S5DB	CT	SOY1		05/10/01	0.20	DAP	11.695			05/15/01	05/15/01	0.20	DAP	66.274							10/07/01

Table A-32 Fertilizer Application Dates for Continuous Winter Wheat

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
Continuous WWHT [1 yr] Rotation	W1SB	NT	WWHT								09/15/01	09/15/01	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
	W2SB	OT	WWHT	NT							09/15/02	09/15/02	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
			WWHT	MT	09/01/01	0.70	DAP	7.310	UAN	22.681	09/15/01	09/15/01	0.80	DAP	41.422			03/15/02	0.85	UAN	128.531	06/15/02
	W3SB	RT	WWHT		09/01/01	0.70	DAP	7.310	UAN	22.681	09/15/01	09/15/01	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
	W4SB	MT	WWHT		09/01/01	0.70	DAP	7.310	UAN	22.681	09/15/01	09/15/01	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
	W5SB	CT	WWHT		09/01/01	0.70	DAP	7.310	UAN	22.681	09/15/01	09/15/01	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
	W1DB	NT	WWHT								09/15/01	09/15/01	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
	W2DB	OT	WWHT	NT							09/15/02	09/15/02	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
			WWHT	MT	09/01/01	0.10	DAP	7.310	AHY	8.851	09/15/01	09/15/01	0.10	DAP	41.422	AHY	15.305	03/15/02	0.10	AHY	34.854	06/15/02
	W3DB	RT	WWHT		09/01/01	0.10	DAP	7.310	AHY	8.851	09/15/01	09/15/01	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
	W4DB	MT	WWHT		09/01/01	0.10	DAP	7.310	AHY	8.851	09/15/01	09/15/01	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
	W5DB	CT	WWHT		09/01/01	0.10	DAP	7.310	AHY	8.851	09/15/01	09/15/01	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01

Table A-33 Fertilizer Application Dates for Winter Wheat-Soybean Double Crop

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
WWHT-SOYB Double Crop [1 yr] Rotation	WS1SB	NT	WWHT								10/01/01	10/01/01	0.90	DAP	48.730	UAN	43.516	03/10/01	0.95	UAN	212.775	05/22/01
			SOY2								06/01/01	06/01/01	0.90	DAP	77.970							09/15/01
	WS2SB	OT	WWHT	NT							10/01/01	10/01/01	0.90	DAP	48.730	UAN	43.516	03/10/01	0.95	UAN	212.775	05/22/01
			SOY1	MT	05/27/01	0.70	DAP	11.695			06/01/01	06/01/01	0.80	DAP	66.274							09/15/01
	WS3SB	RT	WWHT		09/25/01	0.70	DAP	7.310	UAN	38.440	10/01/01	10/01/01	0.80	DAP	41.422	UAN	5.069	03/10/01	0.85	UAN	212.775	05/22/01
			SOY1		05/25/01	0.70	DAP	11.695			06/01/01	06/01/01	0.80	DAP	66.274			`				09/15/01
	WS4SB	MT	WWHT		09/25/01	0.70	DAP	7.310	UAN	38.440	10/01/01	10/01/01	0.80	DAP	41.422	UAN	5.069	03/10/01	0.85	UAN	212.775	05/22/01
			SOY1		05/27/01	0.70	DAP	11.695			06/01/01	06/01/01	0.80	DAP	66.274							09/15/01
	WS5SB	CT	WWHT		09/25/01	0.70	DAP	7.310	UAN	38.440	10/01/01	10/01/01	0.80	DAP	41.422	UAN	5.069	03/10/01	0.85	UAN	212.775	05/22/01
			SOY1		05/27/01	0.70	DAP	11.695			06/01/01	06/01/01	0.80	DAP	66.274							09/15/01
	WS1DB	NT	WWHT								10/01/01	10/01/01	0.10	DAP	48.730	AHY	44.660	03/10/01	0.10	AHY	55.356	05/22/01
			SOY2								06/01/01	06/01/01	0.20	DAP	77.970							09/15/01
	WS2DB	OT	WWHT	NT							10/01/01	10/01/01	0.10	DAP	48.730	AHY	44.660	03/10/01	0.10	AHY	55.356	05/22/01
			SOY1	MT	05/27/01	0.20	DAP	11.695			06/01/01	06/01/01	0.20	DAP	66.274							09/15/01
	WS3DB	RT	WWHT		09/25/01	0.10	DAP	7.310	AHY	15.002	10/01/01	10/01/01	0.10	DAP	41.422	AHY	29.656	03/10/01	0.10	AHY	55.356	05/22/01
			SOY1		05/25/01	0.20	DAP	11.695			06/01/01	06/01/01	0.20	DAP	66.274			`				09/15/01
	WS4DB	MT	WWHT		09/25/01	0.10	DAP	7.310	AHY	15.002	10/01/01	10/01/01	0.10	DAP	41.422	AHY	29.656	03/10/01	0.10	AHY	55.356	05/22/01
			SOY1		05/27/01	0.20	DAP	11.695			06/01/01	06/01/01	0.20	DAP	66.274							09/15/01
	WS5DB	CT	WWHT		09/25/01	0.10	DAP	7.310	AHY	15.002	10/01/01	10/01/01	0.10	DAP	41.422	AHY	29.656	03/10/01	0.10	AHY	55.356	05/22/01
			SOY1		05/27/01	0.20	DAP	11.695			06/01/01	06/01/01	0.20	DAP	66.274							09/15/01

Table A-34 Fertilizer Application Dates for Corn-Soybean Rotation

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
CORN-SOYB [2 yr] Rotation	CS1SB	NT	COR2								05/01/01	05/01/01	0.90	DAP	80.404	UAN	326.647	06/01/01	0.95	UAN	65.625	09/15/01
			SOY2								05/15/02	05/15/02	0.90	DAP	77.970							10/07/02
	CS2SB	OT	COR2	NT							05/01/01	05/01/01	0.90	DAP	80.404	UAN	326.647	06/01/01	0.95	UAN	65.625	09/15/01
			SOY1	MT	05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02
	CS3SB	RT	COR1		04/25/01	0.70	DAP	12.061	UAN	58.841	05/01/01	05/01/01	0.80	DAP	68.343	UAN	289.681	06/01/01	0.85	UAN	43.750	09/15/01
			SOY1		05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02
	CS4SB	MT	COR1		04/25/01	0.70	DAP	12.061	UAN	58.841	05/01/01	05/01/01	0.80	DAP	68.343	UAN	289.681	06/01/01	0.85	UAN	43.750	09/15/01
			SOY1		05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02
	CS5SB	CT	COR1		04/25/01	0.70	DAP	12.061	UAN	58.841	05/01/01	05/01/01	0.80	DAP	68.343	UAN	289.681	06/01/01	0.85	UAN	43.750	09/15/01
			SOY1		05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02

Crop	Case #	Till	S-Mgmt Crop	TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
	CS1DB	NT	COR2								05/01/01	05/01/01	0.10	DAP	80.404	AHY	153.082					09/15/01
			SOY2								05/15/02	05/15/02	0.20	DAP	77.970							10/07/02
	CS2DB	OT	COR2	NT							05/01/01	05/01/01	0.10	DAP	80.404	AHY	153.082					09/15/01
			SOY1	MT	05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02
	CS3DB	RT	COR1		04/25/01	0.10	DAP	12.061	AHY	22.962	05/01/01	05/01/01	0.10	DAP	68.343	AHY	113.046	06/01/01	0.10	AHY	17.073	09/15/01
			SOY1		05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02
	CS4DB	MT	COR1		04/25/01	0.10	DAP	12.061	AHY	22.962	05/01/01	05/01/01	0.10	DAP	68.343	AHY	113.046	06/01/01	0.10	AHY	17.073	09/15/01
			SOY1		05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02
	CS5DB	CT	COR1		04/25/01	0.10	DAP	12.061	AHY	22.962	05/01/01	05/01/01	0.10	DAP	68.343	AHY	113.046	06/01/01	0.10	AHY	17.073	09/15/01
			SOY1		05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02

Table A-35 Fertilizer Application Dates for Grain Sorghum-Soybean Rotation

Crop	Case #	Till	S-Mgmt Crop	TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
GRGS-SOYB [2 yr] Rotation	GS1SB	NT	GRS2								06/01/01	06/01/01	0.90	DAP	77.969	UAN	158.603	07/01/01	0.95	UAN	35.728	10/15/01
			SOY2								05/15/02	05/15/02	0.90	DAP	77.970							10/07/02
	GS2SB	OT	GRS2	NT							06/01/01	06/01/01	0.90	DAP	77.969	UAN	158.603	07/01/01	0.95	UAN	35.728	10/15/01
			SOY1	MT	05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02
	GS3SB	RT	GRS1		05/25/01	0.70	DAP	11.695	UAN	29.150	06/01/01	06/01/01	0.80	DAP	66.274	UAN	141.363	07/01/01	0.85	UAN	23.819	10/15/01
			SOY1		05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02
	GS4SB	MT	GRS1		05/25/01	0.70	DAP	11.695	UAN	29.150	06/01/01	06/01/01	0.80	DAP	66.274	UAN	141.363	07/01/01	0.85	UAN	23.819	10/15/01
			SOY1		05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02
	GS5SB	CT	GRS1		05/25/01	0.70	DAP	11.695	UAN	29.150	06/01/01	06/01/01	0.80	DAP	66.274	UAN	141.363	07/01/01	0.85	UAN	23.819	10/15/01
			SOY1		05/10/02	0.70	DAP	11.695			05/15/02	05/15/02	0.80	DAP	66.274							10/07/02
	GS1DB	NT	GRS2								06/01/01	06/01/01	0.10	DAP	77.969	AHY	75.837					10/15/01
			SOY2								05/15/02	05/15/02	0.20	DAP	77.970							10/07/02
	GS2DB	OT	GRS2	NT							06/01/01	06/01/01	0.10	DAP	77.969	AHY	75.837					10/15/01
			SOY1	MT	05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02
	GS3DB	RT	GRS1		05/25/01	0.10	DAP	11.695	AHY	11.376	06/01/01	06/01/01	0.10	DAP	66.274	AHY	55.166	07/01/01	0.10	AHY	9.295	10/15/01
			SOY1		05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02
	GS4DB	MT	GRS1		05/25/01	0.10	DAP	11.695	AHY	11.376	06/01/01	06/01/01	0.10	DAP	66.274	AHY	55.166	07/01/01	0.10	AHY	9.295	10/15/01
			SOY1		05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02
	GS5DB	CT	GRS1		05/25/01	0.10	DAP	11.695	AHY	11.376	06/01/01	06/01/01	0.10	DAP	66.274	AHY	55.166	07/01/01	0.10	AHY	9.295	10/15/01
			SOY1		05/10/02	0.20	DAP	11.695			05/15/02	05/15/02	0.20	DAP	66.274							10/07/02

Table A-36 Fertilizer Application Dates for Winter Wheat-Fallow Rotation

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
WWHT-FALW [2 yr] Rotation	WF1SB	NT	WWHT								09/15/01	09/15/01	0.90	DAP	48.730	UAN	22.684	03/15/02	0.95	UAN	128.531	06/15/02
			FALW																			
	WF2SB	OT	WWHT	NT							09/15/01	09/15/01	0.90	DAP	48.730	UAN	22.684	03/15/02	0.95	UAN	128.531	06/15/02
			FALW																			
			WWHT	MT	09/01/03	0.70	DAP	7.310	UAN	22.681	09/15/03	09/15/03	0.80	DAP	41.422			03/15/04	0.85	UAN	128.531	06/15/04
			FALW																			
	WF3SB	RT	WWHT		09/01/01	0.70	DAP	7.310	UAN	22.681	09/15/01	09/15/01	0.80	DAP	41.422			03/15/02	0.85	UAN	128.531	06/15/02
			FALW																			
	WF4SB	MT	WWHT		09/01/01	0.70	DAP	7.310	UAN	22.681	09/15/01	09/15/01	0.80	DAP	41.422			03/15/02	0.85	UAN	128.531	06/15/02
			FALW																			
	WF5SB	CT	WWHT		09/01/01	0.70	DAP	7.310	UAN	22.681	09/15/01	09/15/01	0.80	DAP	41.422			03/15/02	0.85	UAN	128.531	06/15/02
			FALW																			
	WF1DB	NT	WWHT								09/15/01	09/15/01	0.10	DAP	48.730	AHY	24.157	03/15/02	0.10	AHY	34.854	06/15/02
			FALW																			
	WF2DB	OT	WWHT	NT							09/15/01	09/15/01	0.10	DAP	48.730	AHY	24.157	03/15/02	0.10	AHY	34.854	06/15/02
			FALW																			
			WWHT	MT	09/01/03	0.10	DAP	7.310	AHY	8.851	09/15/03	09/15/03	0.10	DAP	41.422	AHY	15.305	03/15/04	0.10	AHY	34.854	06/15/04
			FALW																			
	WF3DB	RT	WWHT		09/01/01	0.10	DAP	7.310	AHY	8.851	09/15/01	09/15/01	0.10	DAP	41.422	AHY	15.305	03/15/02	0.10	AHY	34.854	06/15/02
			FALW																			
	WF4DB	MT	WWHT		09/01/01	0.10	DAP	7.310	AHY	8.851	09/15/01	09/15/01	0.10	DAP	41.422	AHY	15.305	03/15/02	0.10	AHY	34.854	06/15/02
			FALW																			
	WF5DB	CT	WWHT		09/01/01	0.10	DAP	7.310	AHY	8.851	09/15/01	09/15/01	0.10	DAP	41.422	AHY	15.305	03/15/02	0.10	AHT	34.854	06/15/02
			FALW																			

Table A-37 Fertilizer Application Dates for Winter Wheat-Corn Rotation

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
WWHT-CORN [3 yr] Rotation	WC1SB	NT	WWHT								09/15/03	09/15/03	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
			COR2								05/01/02	05/01/02	0.90	DAP	80.404	UAN	252.272	06/01/02	0.95	UAN	52.500	09/15/02
	WC2SB	OT	WWHT	NT							09/15/03	09/15/03	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
			COR1	MT	04/25/02	0.70	DAP	12.061	UAN	45.716	05/01/02	05/01/02	0.80	DAP	68.343	UAN	224.056	06/01/02	0.85	UAN	35.000	09/15/02
	WC3SB	RT	WWHT		09/01/03	0.70	DAP	7.310	UAN	22.681	09/15/03	09/15/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			COR1		04/25/02	0.70	DAP	12.061	UAN	45.716	05/01/02	05/01/02	0.80	DAP	68.343	UAN	224.056	06/01/02	0.85	UAN	35.000	09/15/02
	WC4SB	MT	WWHT		09/01/03	0.70	DAP	7.310	UAN	22.681	09/15/03	09/15/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			COR1		04/25/02	0.70	DAP	12.061	UAN	45.716	05/01/02	05/01/02	0.80	DAP	68.343	UAN	224.056	06/01/02	0.85	UAN	35.000	09/15/02
	WC5SB	CT	WWHT		09/01/03	0.70	DAP	7.310	UAN	22.681	09/15/03	09/15/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			COR1		04/25/02	0.70	DAP	12.061	UAN	45.716	05/01/02	05/01/02	0.80	DAP	68.343	UAN	224.056	06/01/02	0.85	UAN	35.000	09/15/02
	WC1DB	NT	WWHT								09/15/03	09/15/03	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
			COR2								05/01/02	05/01/02	0.10	DAP	80.404	AHY	118.935					09/15/02
	WC2DB	OT	WWHT	NT							09/15/03	09/15/03	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
			COR1	MT	04/25/02	0.10	DAP	12.061	AHY	17.840	05/01/02	05/01/02	0.10	DAP	68.343	AHY	87.437	06/01/02	0.10	AHY	17.073	09/15/02
	WC3DB	RT	WWHT		09/01/03	0.10	DAP	7.310	AHY	8.851	09/15/03	09/15/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			COR1		04/25/02	0.10	DAP	12.061	AHY	17.840	05/01/02	05/01/02	0.10	DAP	68.343	AHY	87.437	06/01/02	0.10	AHY	17.073	09/15/02
	WC4DB	MT	WWHT		09/01/03	0.10	DAP	7.310	AHY	8.851	09/15/03	09/15/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			COR1		04/25/02	0.10	DAP	12.061	AHY	17.840	05/01/02	05/01/02	0.10	DAP	68.343	AHY	87.437	06/01/02	0.10	AHY	17.073	09/15/02
	WC5DB	CT	WWHT		09/01/03	0.10	DAP	7.310	AHY	8.851	09/15/03	09/15/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			COR1		04/25/02	0.10	DAP	12.061	AHY	17.840	05/01/02	05/01/02	0.10	DAP	68.343	AHY	87.437	06/01/02	0.10	AHY	17.073	09/15/02

Table A-38 Fertilizer Application Dates for Winter Wheat-Grain Sorghum Rotation

Crop	Case #	Till	S-Mgmt Crop	S-Mgmt TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
WWHT-GRSG [3 yr] Rotation	WG1SB	NT	WWHT								09/15/03	09/15/03	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
			GRS2								06/01/02	06/01/02	0.90	DAP	77.969	UAN	158.603	07/01/02	0.95	UAN	35.728	10/15/02
	WG2SB	OT	WWHT	NT							09/15/03	09/15/03	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
			GRS1	MT	05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
	WG3SB	RT	WWHT		09/01/03	0.70	DAP	7.310	UAN	22.681	09/15/03	09/15/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			GRS1		05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
	WG4SB	MT	WWHT		09/01/03	0.70	DAP	7.310	UAN	22.681	09/15/03	09/15/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			GRS1		05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
	WG5SB	CT	WWHT		09/01/03	0.70	DAP	7.310	UAN	22.681	09/15/03	09/15/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			GRS1		05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
	WG1DB	NT	WWHT								09/15/03	09/15/03	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
			GRS2								06/01/02	06/01/02	0.10	DAP	77.969	AHY	75.837					10/15/02
	WG2DB	OT	WWHT	NT							09/15/03	09/15/03	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1	MT	05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02
	WG3DB	RT	WWHT		09/01/03	0.10	DAP	7.310	AHY	8.851	09/15/03	09/15/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1		05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02
	WG4DB	MT	WWHT		09/01/03	0.10	DAP	7.310	AHY	8.851	09/15/03	09/15/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1		05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02
	WG5DB	CT	WWHT		09/01/03	0.10	DAP	7.310	AHY	8.851	09/15/03	09/15/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1		05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02

Table A-39 Fertilizer Application Dates for Winter Wheat-Grain Sorghum-Corn Rotation

Crop	Case #	Till	S-Mgmt Crop	TL	Fertilizer Pre-	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fert (kg/ha)		Planting	Fertilizer Planting	FRT_S	1st. Fertilizer (kg/ha)		2nd. Fertilizer (kg/ha)		Fertilizer After-	FRT_S	1st. Fertilizer (kg/ha)		Harvest
WWHT-GRSG-SOYB [3 yr] Rotation	WGS1SB	NT	WWHT								10/01/03	10/01/03	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
			GRS2								06/01/02	06/01/02	0.90	DAP	77.969	UAN	158.603	07/01/02	0.95	UAN	35.728	10/15/02
			SOY2								05/15/03	05/15/03	0.90	DAP	77.970							09/15/03
	WGS2SB	OT	WWHT	NT							10/01/03	10/01/03	0.90	DAP	48.730	UAN	22.684	03/15/01	0.95	UAN	128.531	06/15/01
			GRS1	MT	05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
			SOY1	MT	05/10/03	0.70	DAP	11.695			05/15/03	05/15/03	0.80	DAP	66.274							09/15/03
	WGS3SB	RT	WWHT		09/25/03	0.70	DAP	7.310	UAN	22.681	10/01/03	10/01/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			GRS1		05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
			SOY1		05/10/03	0.70	DAP	11.695			05/15/03	05/15/03	0.80	DAP	66.274							09/15/03
	WGS4SB	MT	WWHT		09/25/03	0.70	DAP	7.310	UAN	22.681	10/01/03	10/01/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			GRS1		05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
			SOY1		05/10/03	0.70	DAP	11.695			05/15/03	05/15/03	0.80	DAP	66.274							09/15/03
	WGS5SB	CT	WWHT		09/25/03	0.70	DAP	7.310	UAN	22.681	10/01/03	10/01/03	0.80	DAP	41.422			03/15/01	0.85	UAN	128.531	06/15/01
			GRS1		05/25/02	0.70	DAP	11.695	UAN	29.150	06/01/02	06/01/02	0.80	DAP	66.274	UAN	141.363	07/01/02	0.85	UAN	23.819	10/15/02
			SOY1		05/10/03	0.70	DAP	11.695			05/15/03	05/15/03	0.80	DAP	66.274							09/15/03
	WGS1DB	NT	WWHT								10/01/03	10/01/03	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
			GRS2								06/01/02	06/01/02	0.10	DAP	77.969	AHY	75.837					10/15/02
			SOY2								05/15/03	05/15/03	0.20	DAP	77.970							09/15/03
	WGS2DB	OT	WWHT	NT							10/01/03	10/01/03	0.10	DAP	48.730	AHY	24.157	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1	MT	05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02
			SOY1	MT	05/10/03	0.20	DAP	11.695			05/15/03	05/15/03	0.20	DAP	66.274							09/15/03
	WGS3DB	RT	WWHT		09/25/03	0.10	DAP	7.310	AHY	8.851	10/01/03	10/01/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1		05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02
			SOY1		05/10/03	0.20	DAP	11.695			05/15/03	05/15/03	0.20	DAP	66.274							09/15/03
	WGS4DB	MT	WWHT		09/25/03	0.10	DAP	7.310	AHY	8.851	10/01/03	10/01/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1		05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02
			SOY1		05/10/03	0.20	DAP	11.695			05/15/03	05/15/03	0.20	DAP	66.274							09/15/03
	WGS5DB	CT	WWHT		09/25/03	0.10	DAP	7.310	AHY	8.851	10/01/03	10/01/03	0.10	DAP	41.422	AHY	15.305	03/15/01	0.10	AHY	34.854	06/15/01
			GRS1		05/25/02	0.10	DAP	11.695	AHY	11.376	06/01/02	06/01/02	0.10	DAP	66.274	AHY	55.166	07/01/02	0.10	AHY	9.295	10/15/02
			SOY1		05/10/03	0.20	DAP	11.695			05/15/03	05/15/03	0.20	DAP	66.274							09/15/03

A.5 References

ASAE Standard. 2003. D384.1: Manure production and characteristics. St. Joseph, MI: Am. Soc. Agric. Eng. (ASAE).

ASAE Standard. 2005. D384.2: Manure production and characteristics. St. Joseph, MI: Am. Soc. Agric. Eng. (ASAE).

Babcock, B. A., P. W. Gassman, M. Jha, and C. L. Kling. 2007. Adoption Subsidies and Environmental Impacts of Alternative Energy Crops. Briefing Paper 07-BP 50. Ames, IA: Center for Agricultural and Rural Development, Iowa State University.

Barnes, P. L. 2006. Personal communication. Manhattan, KS.

Bosch, D. D., J. G. Arnold, M. Volk. 2007. SWAT Revisions for Simulating Landscape Components and Buffer Systems. ASABE Paper No. 072175. St. Joseph, Mich.: ASABE.

Boyer, W. R. 2006. Interview by author. E-mail communication. Manhattan, KS.

Chandler, Scott R. 1998. Utilization of Corn Residue Grazing as a Major Feed Source for Beef Cattle in North Carolina. Extension Animal Husbandry, Department of Animal Science, North Carolina accessed: Dec. 31, 2008.

Devlin, D. L., D. A. Whitney, R. E. Lamond. 1996. *Best Management Practices for Nitrogen*. MF-2202, Manhattan, KS: Kansas State University, Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L. 1998. *Grain Sorghum Production Handbook*. C-687 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., D. Peterson, D. A. Whitney, 1997. *Soybean Production Handbook*. C-449. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Fjell, D. L., R. L. Vanderlip, K. L. Roozeboom, 2007. *Corn Production Handbook*. C-560 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Harner, J. P., J. P. Murphy, D. L. Devlin, W. H. Fick, and G. L. Kilgore. 2000. *Vegetative Filter Strip System for Animal Feeding Operations.* MF-2454. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Honeyman, M., J. Russell, D. Morrical, D. Maxwell, D. Busby and J. Sellers. 2006. Beef cattle on grass supplemented with self-fed by-products. In annual progress reports-2005. Armstrong Research and Demonstration Farm. ISRF05-12. Ames, IA: Iowa State University. Available at: www.ag.iastate.edu/farms/reports.html. Accessed April 30, 2009.

Jones, C., and J. Jacobsen. 2003. Fertilizer Placement and Timing, Nutrient Management Module No. 11. 4449-11. Bozeman, MT: Montana State University Extension Service, Montana State University-Bozeman.

Kilgore, G. L. and F. K. Brazle. 1994. *Tall Fescue Production and Utilization*. C-729. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

KSU. 2006. Common Kansas Crop Rotations. Unpublished technical note. Manhattan, KS: Extension Agronomy, Kansas State University (KSU).

Leeds, R., L. C. Brown, M. R. Sulc, L. VanLieshout. 1994. Vegetative Filter Strips: Application, Installation and Maintenance. AEX-467-94. Columbus, OH: Ohio State University Extension.

Maddux, L. D. 2006. Interview by author. E-mail communication. Manhattan, KS. February 23.

Maddux, Larry D., 2008. Macronutrient Fertility on Irrigated Corn and Soybean in a Corn/Soybean Rotation. Kansas River Valley and East Central Kansas Experiment Fields, Field Research 2008. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Maski, D., K. R. Mankin, K. A. Janssen, and P. Tuppad. 2007. Sensitivity analysis of SWAT nutrient modeling under different management practices. 2007 ASABE Annual Meeting Paper No. 072060. St. Joseph, MI: ASABE.

Maski, D., K.R. Mankin, K.A. Janssen, P. Tuppad, and G.M. Pierzynski. 2008. Modeling runoff and sediment yields from combined in-field crop practices using SWAT. *J. Soil and Water Conserv.* 63(4): 193-203.

Moore, J. A., J. D. Smyth, E. S. Baker, and J. R. Miner. 1988. Evaluating coliform concentrations in runoff from various animal waste management systems. Special Report 817. Corvallis, OR: Oregon State University, Agricultural Experiment Stations.

Moore, K. J., M. H. Wiedenhoeft, E. C. Brummer, J. R. Russell, R. Hintz, J. Secor, and D. Maxwell. 2001. Sequential grazing systems for beef cattle production. In annual progress reports-2000. Armstrong Research and Demonstration Farm. ISRF00-35. Ames, IA: Iowa State University. Available at: www.agaware.iastate.edu/farms/2000reports/mcnay/. Accessed April 30, 2009.

NASS, 2008. Acreage. Washington, D.C.: USDA, National Agricultural Statistics Service (NASS), Agricultural Statistics Board.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and J. R. Williams. 2004. *Soil and Water Assessment Tool Input / Output File Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS.

Nelson, N. and A. Keeler. 2005. Water Quality Trading in Georgia: Addressing Two Potential Impediments to Success. In *Proc. 2005 Georgia Water Resources Conference*. Kathryn J. Ed. Athens, Georgia: Institute Ecology, University of Georgia. Available at: www.uga.edu/water/GWRC/Papers/NelsonN-GWRCpaper%20April13.pdf. Accessed April 30, 2009.

NJDEP. 2004. Structural Stormwater Management Measures. Chapter 9 in *New Jersey Storm water Best Management Practices Manual*. Trenton, NJ: New Jersey Department of Environmental Protection (NJDEP), Division of Watershed Management.

NRCS, 2008a. Energy Consumption Awareness Tool: Nitrogen. USDA-NRCS. Available at: nfat.sc.egov.usda.gov. Accessed 31 December, 2008

NRCS, 2008b. Kansas Natural Resources Conservation Service Administrative Area 3. USDA-NRCS. Available at: www.ks.nrcs.usda.gov/about/profiles/nrcs_area3.html. Accessed 31 December, 2008

NRCS. 2004. Hydrologic Soil-Cover Complexes. Chapter 9 in: *National Engineering Handbook, Part 630 Hydrology*. Washington, D.C.: USDA-NRCS

NRCS-Kansas. 2003. Conservation Practice Standard, Filter Strip (acre.) Code: 393. Salina, KS: USDA-NRCS, Kansas Division.

Parajuli, P. B. 2007. SWAT bacteria sub-model evaluation and application. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

Peterson, J. M., J. A. Fox, J. C. Leatherman, and C. M. Smith. 2007. Choice Experiments to Assess Farmers' Willingness to Participate in a Water Quality Trading Market. In *Proc: 2007 Annual Meeting,* July 29-August 1, 2007, Portland, OR: AAEA.

Regehr, D. L., D. L. Davlin, and P. L. Barnes. 1996. *Using Vegetative Filter Strips in Crop Fields*. MF-2224. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

SCS, 1972. *National Engineering Handbook: Section 4 - Hydrology*. Washington, D.C: USDA, Soil Conservation Service (SCS, now Natural Resources Conservation Service, NRCS), Engineering Division.

SCS, 1986. *Urban Hydrology for Small Watersheds - Technical Release 55 (TR-55)* 2nd ed. Washington, D.C: USDA, Soil Conservation Service (SCS, now Natural Resources Conservation Service, NRCS), Engineering Division.

Shroyer, J. P., C. Thompson, R. Brown, P. D. Ohlenbush, D. L. Fjell, S. Staggenborg, S. Duncan, G. L. Kilgore. 1996. *Kansas Crop Planting Guide*. L-818. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Shroyer, J. P., D. L. Fjell, K. C Dhuyvetter, L. N. Langemeier, G. L. Kuhl, J. O. Fritz. 1993. *Wheat Pasture in Kansas*. C-713 Revised. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Shroyer, J. P., D. Whitney, and D. Peterson. 1997. *Wheat Production Handbook*. C-529. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Smith, C. M., J. M. Peterson, and J. C. Leatherman. 2007. Attitudes of Great Plains Producers about Best Management Practices, Conservation Programs, and Water Quality. *J. Soil and Water Conserv.* 62: 97A-103A.

Staggenborg, S. A., J. P. Shroyer, D. Leikam, D. Fjell. 2004. *Managing No-till Wheat Following a Summer Crop in Eastern Kansas*. MF-2641. Manhattan, KS: Kansas State University, Department of Agricultural Economics.

Wanielista, M. P., R. Kersten, and R. Ealgin, 1997. *Hydrology: Water Quantity and Quality Control*. New York, NY: John Wiley & Sons.

Whitney, D. A., D. L. Devlin, and D. J. Jardine. 1999. *Kansas No-Till Handbook*. S-126. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Whitney, D. A., L. R. Stone, K. A. Janssen, and J. H. Long. 1991. *The Effects of Nitrogen Fertilizer on Soil*. C-625. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Whitney, David A., 1988. *Phosphorus Facts*. C-665. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Williams, J. R., and H. D. Berndt. 1977. Sediment yield prediction based on watershed hydrology. *Trans. ASAE* 20 (6), 1100-1104.

Wischmeier, W. H. and D. D. Smith. 1965. *Predicting Rainfall Erosion Losses from Cropland East of the Rocky Mountains*. Agriculture Handbook: No. 282. USDA. Washington, D.C.: U.S. Government Printing Office.

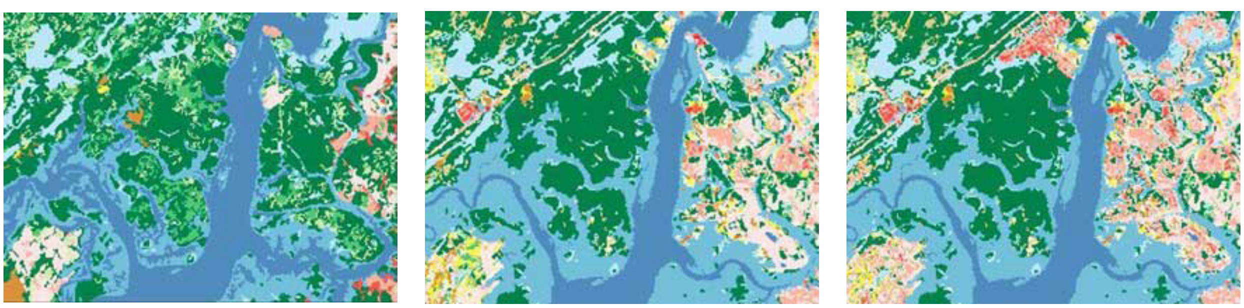
Wischmeier, W. H. and D. D. Smith. 1978. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning*. Agriculture Handbook: No. 537. USDA. Washington, D.C.: U.S. Government Printing Office.

Appendix B SWAT Inputs Preparation

Introduction

Fields rarely are comprised of a single soil/landuse map unit with uniform topography and weather condition. Thus, a method is needed to evaluate the field to choose the “dominant property” or “significant parameters” of the field for watershed (environmental) model estimation. Topography, soil, landuse, and climate data are the four major categories of georeferenced inputs for watershed delineation as well as model simulating.

SWAT has interface to help scientist to delineate watershed. The interface included a set of dialogs to help user to input model parameters as well as GIS function for preparing the watershed scale georeferenced inputs such as precipitation, soil information from existing GIS dataset. However, some interfaces are out-of-date that the built-in functions could not help users to get and maintain the up-to-date information. For example, the landuse /land cover dataset: National Land Cover Database (NLCD) provided by Multi-Resolution Land Characteristics Consortium program (MRLC, 2008a), have at least 1992, 2001 and 2006 three versions (Figure B-1, USEPA, 2007). There are some slight differences among these version, and user need to prepare their own lookup tables for SWAT to extract the correct landuse information.



NLCD 1992 **NLCD 2001** **NLCD 2006**

Figure B-1 Differences between 1992, 2001, and 2006 NLCD (USEPA, 2007)

Another issue related to SWAT inputs is the data continuity and integrity. For example, the NOAA daily precipitations and temperatures have been examined by professionals, but some gage stations still have missing data gaps on their records. SWAT model will automatically interpolate the missing data with present dataset. However, if the missing data gaps are too long or too frequently, the modeling results would lose its accuracy. Therefore, we developed series methods to prepare the SWAT inputs in this study.

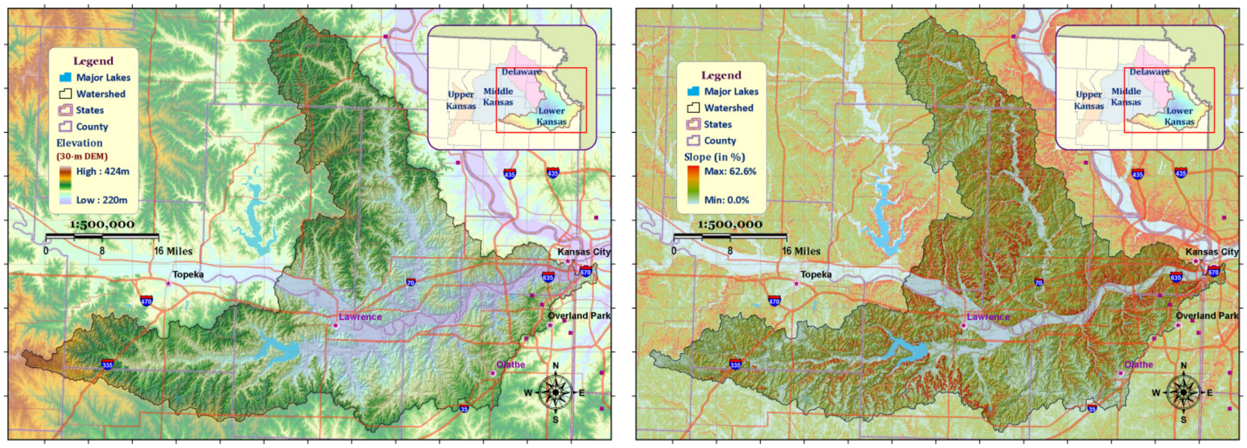
In order to keep all the geo-referenced data with a consistence coordinate system and also to simplify the geo-processing processes, a Universal Transverse Mercator (UTM) coordinate system (NAD, 1983; UTM Zone 15N [spheroid = GRS80, NAD 1983]) was chosen as the default projection. For most data and model output units in this study are in metric system, in terms of meter, kilometer or kilogram, except some common usage were provided in both metric and English units.

B.1 Study Area

As described in Section: 1.1.4, the total nitrogen (TN) and total phosphorus (TP) are the nutrient issues of Kansas surface water resources. According to Figure 1-3, northeastern Kansas is suitable for TN trade and southeastern Kansas for TP. Due to the location of major wastewater treatment plants in relation to major streams and reservoirs, the trading type for TN could be point source to point source (PS-PS) trade or point source to nonpoint source (PS-NPS) trade in northeastern Kansas. Similarly, the trading type of TP would be point source to nonpoint source (PS-NPS) trade in the southeast (Leatherman et al., 2005).

Following WQT program site-selection criteria, and potential trading partners availability, Lower Kansas watershed (USGS HUC8: 10270104) was selected as this study area. It located on Kansas and Delaware River Basin (USGS HUC6: 102701) in northeastern Kansas. It encompasses a large proportion of the Kansas population within its 429,000 ha (1,060,000 ac) drainage basin, which also includes a large number and diverse range of PS and NPS sources. The watershed has 99.6% of its area in Atchison, Douglas, Jefferson, Johnson, Leavenworth, Osage, Shawnee, Wabaunsee, Wyandotte, and Wyandotte Counties of northeastern Kansas and 0.4% in Jackson County, Missouri. Grassland and woodland cover approximately 46% of this area as well as 18% in crop land, 17% in forest and 2% in water classes.

Figure B-2 (a) illustrates terrain elevation of study watershed. The elevation ranges from 424 m to 220 m, with an average around 301 m. Figure B-2 (b) renders a map of surface slope in percentage. The reddish blocks in Figure B-2 (b) represent a steep slope area and imply more potential for soil erosion from these areas. To simplify the trading problem for this case study, only NPS-PS trades will be allowed for this WQT market in the watershed. The stream path with its natural flow direction was used for network analysis and estimate delivery effects. A downstream trade is only allowed for an upstream farmer (NPS) to trade its load reduction to a downstream WWTP (PS). Upstream or bi-direction trade was not feasible for this pre-run study.



(a) Terrain Elevation (b) Surface Slope in Percentage

Figure B-2 Study Area: Lower Kansas Watershed, Kansas (USGS HUC: 10270104)

B.2 Elevation

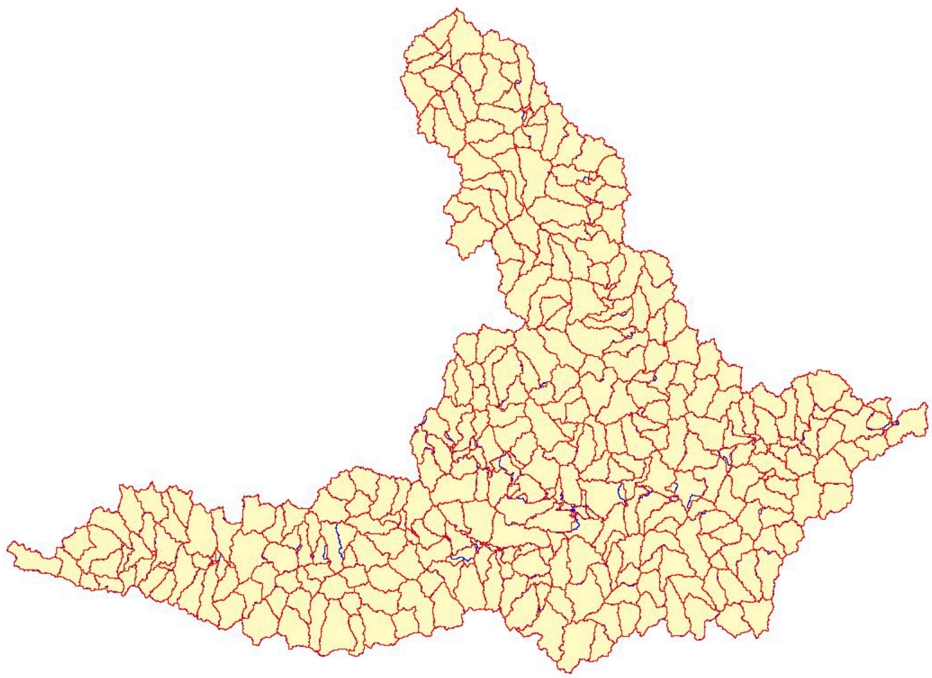
Most soil erosion, hydrology and hydraulic equations are relative to the surface elevation and its side slope. SWAT model simply assumed the elevation and side slope for a sub-watershed are constants (Neitsch et al., 2005). In other words, SWAT uses a set of average of height and slope for model simulation within a subbasin (Neitsch et al., 2005). For the specific area with a distinct topography, such as large lake or reservoir, it needs to be split as an individual subbasin to avoid the potential bias on simulation. Therefore, managing the burn-in streams, defining minimum stream threshold, and delineating multiple hydrologic response units (HRUs) with suitable landuse/soil would be critical.

A digital elevation model (DEM) is a representation of ground surface topography. It is also widely known as a digital terrain model (DTM). A DEM can be stored as the rectangle grids in raster format or in a triangular irregular network (TIN). In this study, we used the square grid DEM under the orthogonal coordinate system, which is in a Universal Transverse Mercator (UTM) coordinate system (NAD, 1983; UTM Zone 15N [spheroid = GRS80, NAD 1983]).

USGS National Elevation Dataset (NED) provided a seamless digital elevation model (DEM) for the entire study watershed at both 10-m and 30-m resolutions (USGS, 2006). Both 10-m and 30-m DEM showed a similar watershed delineating ability while applied the delineation stream thresholds in 810 hectares (2000 acres). Figure B-3 show the subbasin boundary differences between 10-m and 30-m DEM delineation: blue subbasin boundary represents the 30-m DEM and red one represents 10-m DEM. The statistics of subbasin area for both DEM resolutions were listed in Table B-1. Due to both DEM data provide nearly identical subbasin delineation in study area, the 30-m DEM was then chose as the basic topographic reference in this study.

Table B-1 Subbasin Area Statistics for 10-m and 30-m DEM Resolution

30m DEM (ha)		10m DEM (ha)	
Mean	1178.76	Mean	1173.76
Median	1167.80	Median	1170.17
Standard Deviation	655.62	Standard Deviation	654.84
Count	364.00	Count	365.00
Largest(10)	2591.28	Largest(10)	2593.65
Smallest(10)	30.06	Smallest(10)	18.23
Confidence Level (95.0%)	67.58	Confidence Level (95.0%)	67.40



Note: Delineated subbasin boundary with 10-m DEM (red) and 30-m DEM (blue).

Figure B-3 Subbasin Boundary Difference between 10-m and 30-m DEM

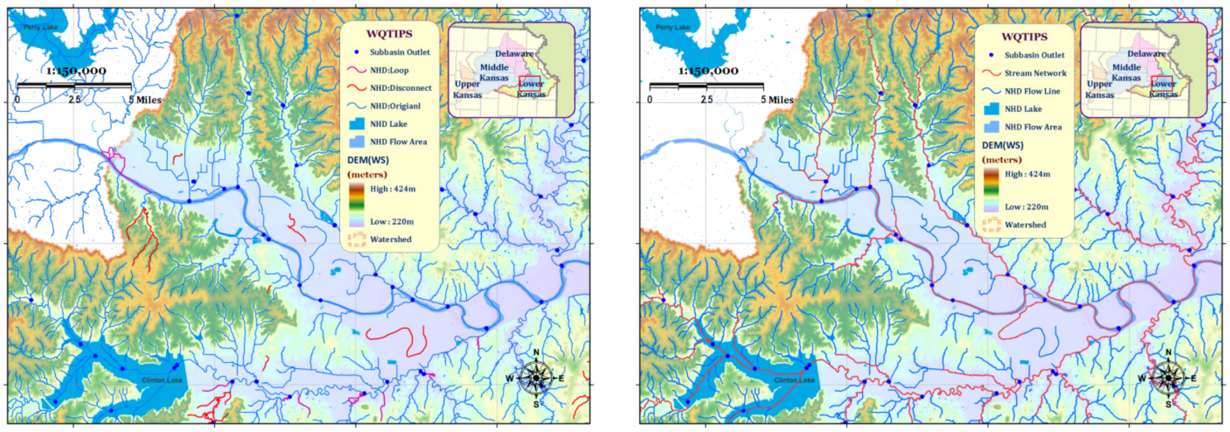
B.3 Hydrography

B.3.1 Stream Network

The National Hydrography Dataset (NHD), which hosted by USGS, provides a good source for surface hydrology features to meet the SWAT model preprocessing requirement. NHD provide the hydrography dataset which incorporated USGS Digital Line Graph (DLG) and EPA Reach File Version 3 (RF3) together (USGS, 2008). However, in study watershed, NHD has some issues in duplicate stream lines, crossing topology and missing network connectivity. It would cause network hierarchy errors and redundant stream line features in study area.

Figure B-4 (a) illustrates the original high resolution NHD flow line in study watershed. The couple crossing lines, loops or isolated (disconnected) stream in red lines can be easily spotted in Figure B-4 (a).

Following the characteristic of stream networks, the stream network should the single direction with two parent links topology (Maidment, 2002; ESRI, 2009). Therefore, the Utility Network Analyst Tool in ArcGIS Map was used to fix these issues. Figure B-4 (b) shows the revised NHD flow lines. Based on this revised stream network, we can delineate more reasonable subbasins and river routes without trivial features in SWAT.



(a) Before Revised **(b) After Revised**

Figure B-4 Sample of Revised High Resolution NHD Flow line

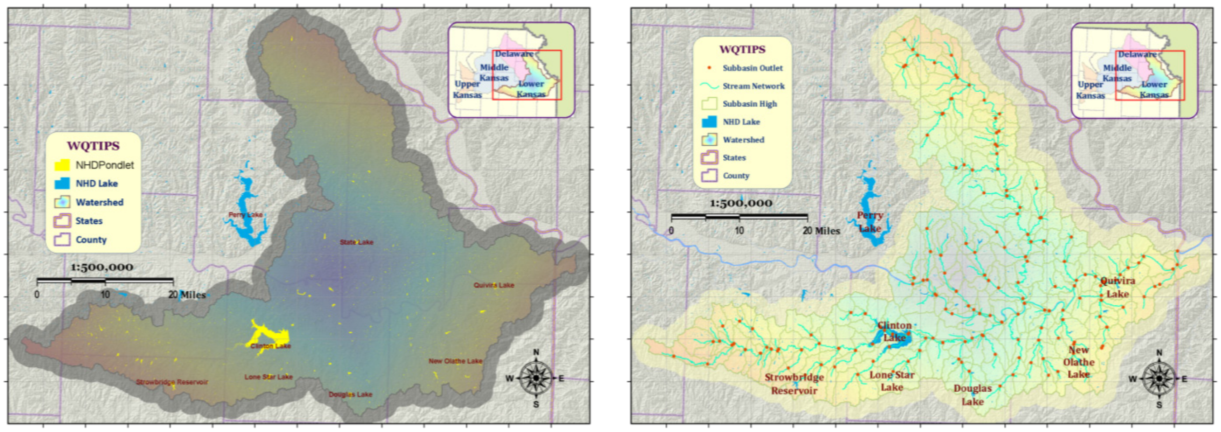
B.3.2 Lake and Reservoir

The high resolution NHD waterbody layer also contains a huge number of reservoirs, lakes, ponds and other un-named water bodies in study area. Figure B-5 (a) illustrates the all 10761 waterbodies in high resolution NHD waterbody layer of study watershed. It would be very difficult to simulate all the waterbodies in one SWAT modeling project. In fact, only 7 of 10761 waterbodies' area are larger than 50 ha, and only one lake/reservoir, the Clinton Lake, is larger than 100 ha (1 km^2). The others are small farm ponds and even their basic hydrologic properties are unknown. Table B-2 lists the major waterbodies and their area in the watershed and Figure B-5 (b) shows the major waterbodies in Lower Kansas watershed. Therefore, only Clinton Lake is large enough to have significant effects in modeling results and have highly influence on stream network delivery.

Although the other waterbodies were neglected in this study, it didn't mean they are least important. On the contrary, these small ponds would have significantly effects on subbasin level in-field model simulations due to their hydrological properties to detain/retain/store the surface runoff, to intercept the sheet flow, and to change the flow length. Therefore, including small farm ponds in modeling processes, the surface runoff velocity would decrease and deposition phenomena might become more significant than ever.

Table B-2 Major Waterbody (Lake/Reservoir) Attributes in Study Watershed

Fdate	Resolution	Gnis_id	Gnis_name	Area(km^2)	Ftype
20040316	High	479837	Clinton Lake	30.235	Lake/Pond
20020225	High	479459	Strowbridge Reservoir	0.984	Lake/Pond
20040316	High	479477	Lone Star Lake	0.719	Lake/Pond
20020225	High	480947	Douglas Lake	0.719	Lake/Pond
20020225	High	478882	Quivira Lake	0.653	Lake/Pond
20040316	High	479193	New Olathe Lake	0.543	Lake/Pond
20040316	High	478531	State Lake	0.519	Lake/Pond



(a) All Waterbodies **(b) Major Lakes/Reservoirs**

Figure B-5 High Resolution NHD Waterbody and Lake in Study Watershed

B.4 Landuse

There are several exist landuse dataset can be incorporated into SWAT model in study watershed area. Parajuli (2007) used the Gap Analysis Program (GAP) as the landuse source of SWAT to model the Clinton Lake, Kansas. Tuppad (2006) used SWAT and self-prepared landuse, which were analyzed from satellite remote sensing images, to model the Kannapolis watershed, Kansas. However, the GAP landuse mainly focused on the information for identifying priority areas for conservation. It provided regional assessments of the conservation status of native vertebrate species and natural land cover types (GAP, 2008). GAP dataset was generated using a two-stage hybrid classification of multi-temporal Landsat Thematic Mapper (TM) imagery, and the state-level GAP landuse was based on the same satellite imagery as 1992 NLCD used. In other words, the GAP landuse is more focusing on the current land cover status instead of landuse survey. Furthermore, the self-prepared landuse, which was used by Tuppad (2006), presented a flexible definition on landuse type and classification. The precision and accuracy of this landuse data may not be suitable for a large watershed modeling works. Moreover, no sufficient quality check and quality assurance processes were applied on the self-prepared landuse; it might results a biased result on model simulations.

B.4.1 Difference between NLCD 1992 and 2001

To standardized data collection processes and also maintain a sufficient data quality, we first used NLCD 1992 (1992 National Land Cover Data) and then the newly NLCD 2001 (2001 National Land Cover Data) dataset in this study. The landuse classifications have been changed from NLCD 1992 to NLCD 2001 (USGS, 1999; MRLC, 2008a; MRLC, 2008c).

Moreover, the classification of cultivated land has been changed between from NLCD1992 to NLCD 2001. In NLCD 2001, cultivated land was classified as general cropland and pasture. The original AGRR and AGRC landuse classes in NLCD 1992 were merged into a single AGRR class. This change simplified data pre-processing and also reduce the work loads. Table B-3 lists the changes between NLCD 1992 and 2001 and the landuse classification in SWAT model. The detail changes between NLCD 2001 and NLCD 1992 can be found in EPA MRLC website (MRLC, 2008b).

Table B-3 Cultivated Class Changes between NLCD 1992 and 2001

SWAT	Descriptions	NLCD 1992 Cultivated Classes
PAST	Pasture	81 Pasture/Hay
AGRR	Agricultural Land-Row Crops	82 Row Crops
AGRC	Agricultural Land-Close grown	83 Small Grains
----	----	84 Fallow
URLD	Residential-Low Density	85 Urban/Recreational Grasses
SWAT	Descriptions	NLCD 2001 Cultivated Classes
WPAS	Winter Pasture (Fescue)	81. Pasture/Hay
AGRR	Agricultural Land-Row Crops	82. Cultivated Crops

B.4.2 SWAT Landuse Lookup Table

To use NLCD as SWAT landuse dataset, a lookup table was prepared for definition translation. Due to the changes of landuse classification between NLCD 1992 and NLCD 2001, this lookup table also has been updated to fit the new classification (Homer et al., 2004; Neitsch et al., 2004; Neitsch et al., 2005; USGS, 1999; MRLC, 2008a; MRLC, 2008c). Table B-4 shows the classifications and descriptions for both SWAT and NLCD 2001. The gray out rows in Table B-4 indicates those landuse type/classification are not applied in SWAT in this study.

Table B-4 Landuse Classification for SWAT and NLCD 2001

Code	SWAT Landuse Description	Land Cover Class	NLCD Classification / Description
WATR	Water	Water	11. Open Water
			12. Perennial Ice/Snow
URLD	Residential-Low Density	Developed	21. Developed, Open Space
URMD	Residential-Medium Density		22. Developed, Low Intensity
URHD	Residential-High Density		23. Developed, Medium Intensity
UIDU	Industrial		24. Developed, High Intensity
UINS	Institutional	Barren	31. Barren Land (Rock/Sand/Clay)
WETN	Wetlands-Non-Forested		32. Unconsolidated Shore*
FRSD	Forest-Deciduous	Forested Upland	41. Deciduous Forest
FRSE	Forest-Evergreen		42. Evergreen Forest
FRST	Forest-Mixed		43. Mixed Forest
		Scrubland	51. Dwarf Scrub[@]
RNGB	Range-Brush		52. Shrub/Scrub
ORCD	Orchard	Non-Natural Woody	None
RNGE	Range-Grasses	Herbaceous Upland Natural/Semi-natural Vegetation	71. Grassland/Herbaceous
			72. Sedge/Herbaceous[@]
			73. Lichens[@]
			74. Moss[@]
WPAS	Winter Pasture (Fescue)	Herbaceous Planted/Cultivated	81. Pasture/Hay
AGRR	Agricultural Land-Row Crops		82. Cultivated Crops
WETF	Wetlands-Forested	Wetlands	90. Woody Wetlands
			91. Palustrine Forested Wetland*
			92. Palustrine Scrub/Shrub Wetland*
			93. Estuarine Forested Wetland*
			94. Estuarine Scrub/Shrub Wetland*
WETL	Wetlands-Mixed		95. Emergent Herbaceous Wetlands
			96. Palustrine Emergent Wetland (Persistent)*
			97. Estuarine Emergent Wetland*
			98. Palustrine Aquatic Bed*
			99. Estuarine Aquatic Bed*

Note: the superscript ([@]) after the NLCD Classification indicated the Alaska only landuse as well as the superscript (*) indicated the Coastal only classification.

B.5 Soil

The most widely used soil survey databases available in study watershed are the 1:250,000 State Soil Geographic Database (STATSGO), the 1:24,000 Soil Survey Geographic Database (SSURGO), and the newly STATSGO2: U.S. General Soil Map (GSM) (NRCS, 1997; NRCS, 2008b; NRCS, 2008d). STATSGO is the default dataset of AVSWAT-X for preparing the basic soil information for the SWAT model (Di Luzio et al., 2002). As described in Section: 3.3.3, STATSGO is a spatially explicit database consisting of a broadly based inventory of soils and non-soil areas that occur in landscape (NRCS, 1995). It was created by generalizing the detailed SSURGO (NRCS, 2008d). Thus, STATSGO is the generalized version of detailed soil survey maps, whereas SSURGO used field mapping based on national standards as the source for detailed soil information (NRCS, 2007). SSURGO is the most detailed level of soil mapping done by the NRCS (2007).

Later in 2006, the STATSGO spatial and tabular data were revised and updated based on detailed SSURGO maps in 1- by 2-degree topographic quadrangle units and its attributes were determined by expanding the data statistics of whole map unit (NRCS, 2008d). It also has been renamed to STATSGO2 or GSM (NRCS, 2008d). The GSM attribute formats are similar to the SSURGO version 2.0 (NRCS, 2007; NRCS, 2008c; NRCS, 2008d). In other words, the attribute table structures are different between STATSGO and. Due to both STATSGO and GSM (STATSGO2) are the generalized version of detail soil survey maps, the SSURGO constructed with field mapping methods using national standards became the source for detail soil information (NRCS, 2007). SSURGO is the most detailed level of soil mapping done by the USDA, Natural Resources Conservation Service (NRCS, 2007).

B.5.1 Difference among Soil Databases

With more details in soil maps, several researches claimed that using SSURGO with watershed models would conduct more precise soil erosions or pollutant loads than STATSGO (Anderson et al., 2006; Peschel et al., 2006; Wang and Melesse, 2006; Williamson and Odom, 2007). However, the other researches indicated the difference between STATSGO and SSURGO might not be significant or even STATSGO is superior to SSURGO in nutrient loads (Grove et al., 2001; Peschel et al., 2003; Di Luzio et al., 2004; Gowda and Mulla, 2005; Heathman and Larose, 2006; Geza and McCray, 2007; Ghidey et al., 2007). In design, STATSGO generalized the detail soil survey data with using the U.S. Geological Survey's 1:250,000 scale quadrangle map series as base maps. While the detail soil survey data are unavailable, soil scientists combine data on geology, topography, vegetation, and climate with Land Remote Sensing Satellite (LANDSAT) images and study soils of similar areas to determine the probable classification and extent of the soils (NRCS, 1995). They determine map unit composition by transecting or sampling areas on the more detailed maps and expanding the data statistically to characterize the whole map unit (NRCS, 1995). In contrast, soil scientists use 1:24,000 aerial photographs as base maps to finish SSURGO with detail soil survey (NRCS, 2008d). Therefore, SSURGO is primarily good for smaller scale study such as a township or county application. Conversely, STATSGO is not detailed enough to make interpretations at a local or county scale; it may be better for use in broad-scale resource management. Furthermore, the surveyor observes soils along delineation boundary use field traverses and transects to determine map unit composition (NRCS, 2007). Each polygon in Figure B-6 represents a soil map unit which named for its dominant soils and contains several components which represent the separate soils with distinct properties (Mednick et al., 2008). SSURGO (grey polygons) could contain no more than three components, and may be comprised of only a single component (NRCS, 2007; Mednick et al., 2008). On the other hand, the aggregated STATSGO (red polygons) might contain up to twenty-one different component soils (NRCS, 1995; Mednick et al., 2008). Apparently in Figure B-6, SSURGO provided very detail soil information and STATSGO just briefly described the soil property and status on the same area.

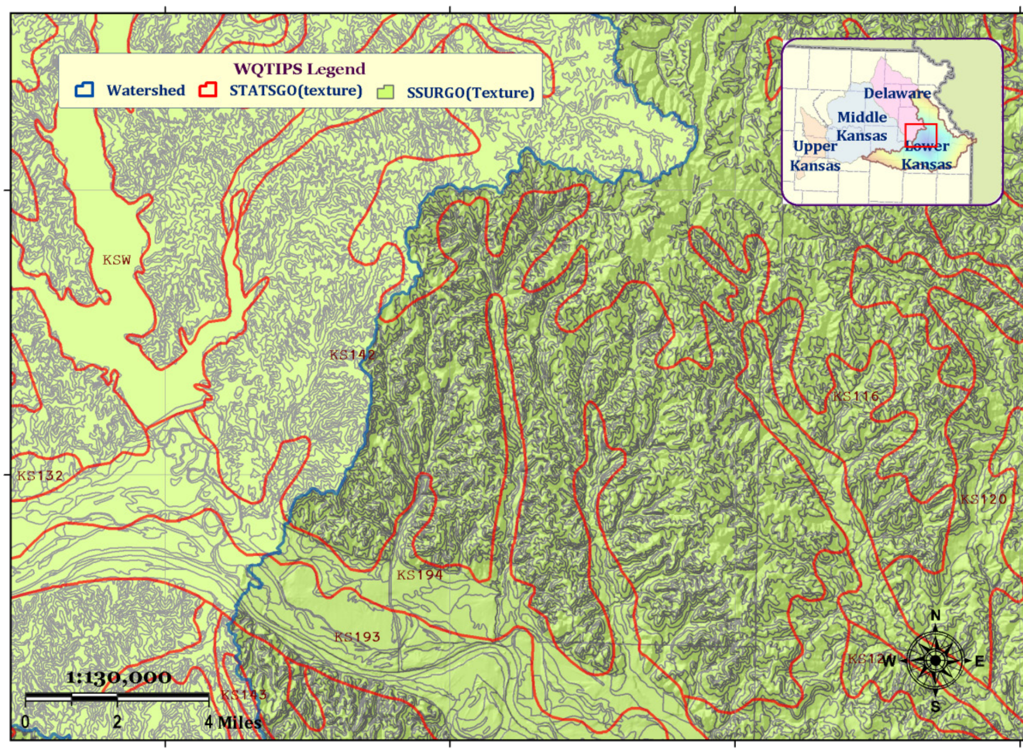
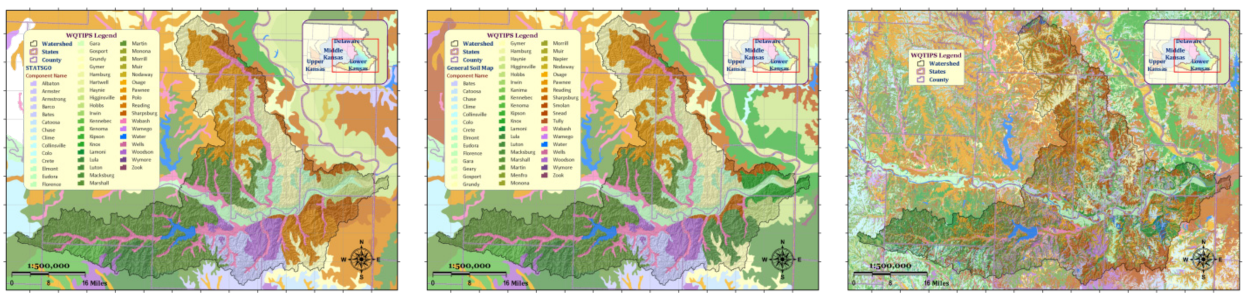


Figure B-6 STATSGO versus SSURGO Map Unit Boundary Comparison

In this study, we first used STATSGO and than SSURGO with SWAT to simulate the potential nutrient loads within each subbasin. SSURGO seems to provide more accuracy estimations, but it will generate more HRUs in a subbasin that will dramatically drag the model processing. However, there are no solid evidences to prove these hypotheses. Below figures presents the differences among STATSGO, SSURGO and SSURGO2 in soil components, soil texture, hydrologic soil group, the USLE K parameter, and the soil saturated conductivity (K_{SAT}).

B.5.1.1 *Soil Component*

Figure B-7 illustrates the soil component patterns for three soil datasets. SSURGO shows very detail classification in component name (Figure B-7 (c)); STATSGO and GSM have relative smaller number of soil component than SSURGO. Both STATSGO and GSM shared the same soil map unit boundary and the components are similar but not identical.

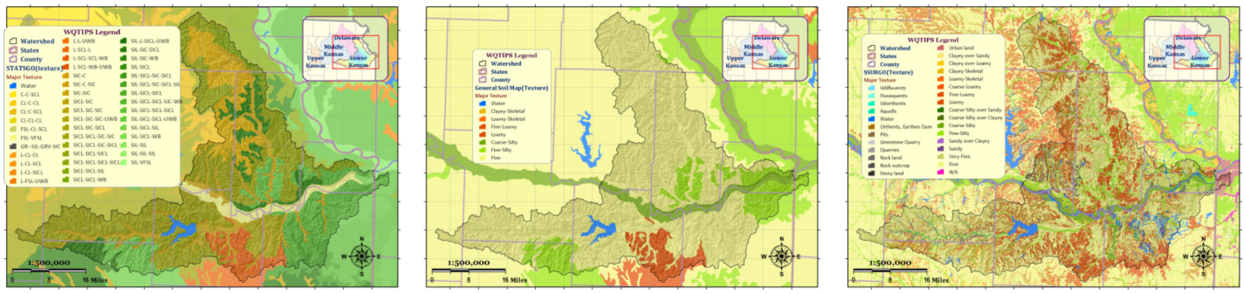


(a) STATSGO **(b) GSM (STATSGO2)** **(c) SSURGO**

Figure B-7 Soil Component Map Comparison

B.5.1.2 *Soil Major Texture*

Soil textures such as the soil particle size, the Clay-Silt-Sand-Rock percentage, or organic carbon content percentage might dramatically affect the SWAT to calculate soil erosion while using USLE equation (Chapter 22, Neitsch et al., 2004). Figure B-8 illustrates the major soil texture of three soil database. The GSM only classified whole watershed into eight classes includes water. It mainly focused on the classification of soil particle (texture) size (Figure B-8 (b)). In contrast, STATSGO were classified more than forty classes. The names of major texture of STATSGO are obscure which combined several texture abbreviations with hyphen (Figure B-8 (a)). The terminology of major texture used in SSURGO is clearer than STATSGO; but SSURGO mixed out two denomination rules for the soil texture. One denomination used soil elements or particle size, such as Clay-Silt-Sand or fine-very fine, another one directly applied the soil taxonomy suborder name, such as Aquolls or Fluvaquents (Figure B-8 (c)). For users who are not familiar with soil taxonomy, they might be confused with these denominations. However, soil texture's name is only a tag; it would not be processed in SWAT modeling processes.

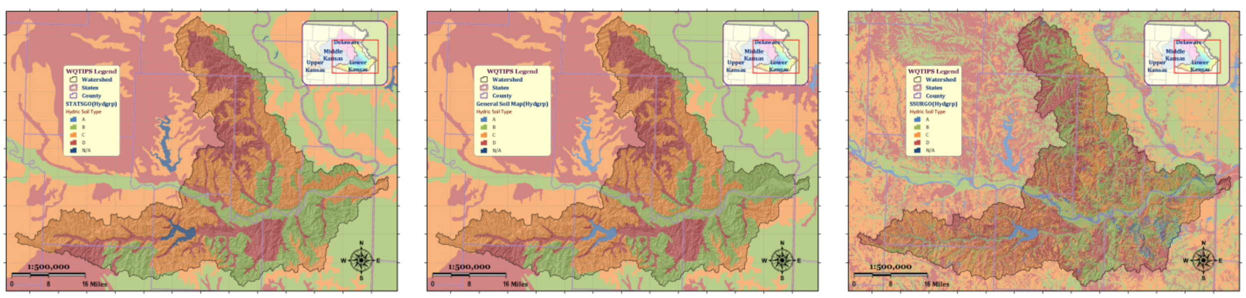


(a) STATSGO **(b) GSM (STATSGO2)** **(c) SSURGO**

Figure B-8 Soil Major Texture Map Comparison

B.5.1.3 *Hydrologic Soil Group*

The USDA NRCS classified soils into four hydrologic groups based on the theory that the minimum permeability occurs within the uppermost 50 cm and infiltration characteristics of the soils (NRCS, 2004; NRCS, 2009). NRCS (1996) defined the hydrologic soil group as a set of soils having similar runoff potential under similar storm and land cover conditions. It categorized soils from A to D to represent the high infiltration (low runoff potential) to slow infiltration rate (NRCS, 2009). Figure B-9 shows the pattern of soil hydrology groups in study watershed. GSM and STATSGO have a very similar pattern, but SSURGO has some slight difference on upland area.

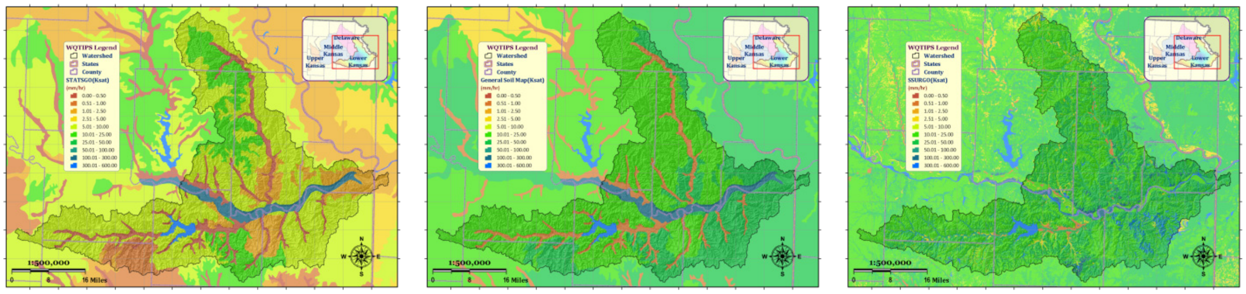


(a) STATSGO **(b) GSM (STATSGO2)** **(c) SSURGO**

Figure B-9 Hydrologic Soil Group Map Comparison

B.5.1.4 *Saturated Hydraulic Conductivity*

Hydraulic conductivity (K) relates soil water flow rate (flux density) to the hydraulic gradient that describes the ease of water movement through pore spaces or fractures of soil. It depends on the intrinsic permeability of soil layer and on the degree of saturation. The saturated hydraulic conductivity (K_{SAT}) is a quantitative measure of a saturated soil's ability to transmit water when subjected to a hydraulic gradient. Figure B-10 displays the K_{SAT} maps for each soil dataset. The K_{SAT} patterns of GSM and SSURGO are similar, but different to STATSGO (Figure B-10 (a)). However, both GSM and STATSGO have a very small K_{SAT} (less than 0.5 mm/hr) distributed along the main tributary of stream network in watershed, but not in the SSURGO. The most K_{SAT} value of GSM and SSURGO ranges from 10 to 100 mm/hr but from 1 to 50 mm/hr for STATSGO. The potential explanations for this difference might be the field survey techniques have been improved since STATSGO database created. The K_{SAT} value collected in SSURGO and GSM is updated. However, this difference in K_{SAT} would cause some significant trends on surface runoff and soil erosion estimation.

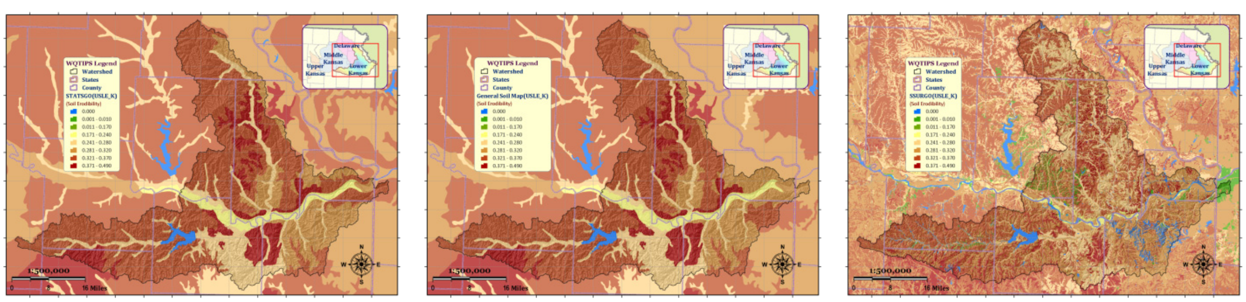


(a) STATSGO (b) GSM (STATSGO2) (c) SSURGO

Figure B-10 Saturated Hydraulic Conductivity Map Comparison

B.5.1.5 *USLE Soil Erodibility (K) Factor*

Wischmeier and Smith (1978) define the USLE soil erodibility (USLE-K) factor as an average soil loss rate per erosion index unit for a particular soil in cultivated, continuous fallow with an arbitrarily selected and measured on a unit plot which is 22.13 m (72.6-ft) long with a uniform length-wise slope of 9%. USLE-K is a measure of the susceptibility for soil particles detached and transported by precipitation and surface runoff. The general value of USLE-K ranged from 0.01 to 0.46 depends on soil texture, structure, permeability, and organic matter content (Neitsch et al., 2005). The USLE-K factor patterns of GSM and STATSGO are similar (Figure B-11 (a) and (b)). The USLE-K value ranges from 0.17 to 0.49 in both datasets. In contrast, the USLE-K of SSURGO ranges from 0.01 to 0.49. However, if we consider the difference in the size of map unit between SSURGO and the other STATSGOs, the USLE-K pattern of three datasets are similar.



(a) STATSGO (b) GSM (STATSGO2) (c) SSURGO

Figure B-11 USLE Soil Erodibility (K) Map Comparison

B.5.1.6 *Conclusion and Selection*

Based on the comparisons of three major soil datasets, STATSGO, GSM (STATSGO2), and SSURGO, the SSURGO was used as the soil database for SWAT in this study. The STATSGO incorporates the soil attributes published in 1994 but SSURGO and GSM are with 2001 updates. GSM (STATSGO2) soil database seems to be superior to the original STATSGO in updated attributes or to SSURGO in model processing efficiency. However, GSM database was not finished at the time of preparing SWAT inputs for this study. Therefore, the advantages for using SSURGO are obvious. However, incorporated SSURGO with SWAT will limit the ability to generate the multiple HRUs and also dramatically increasing model processing time. For the future study, GSM might be an alternative.

B.5.2 Prepared Soil Data for SWAT

B.5.2.1 *Import SSURGO*

Several optional extensions in AVSWAT-X interface could import and prepare SSURGO as the soil data source for SWAT (Peschel et al., 2003; Di Luzio et al., 2004). Most of these SWAT-SSURGO extensions include two stages: they first convert and aggregate the original SSURGO attribute files (in plain ASCII format) to SWAT default soil database format (in dBase IV format). And second, a dialog is used to define the user soil dataset parameters. However, the first stage of extensions might be failed due to the updates in survey area and/or classifications of SSURGO in study watershed. Incompatible SSURGO will cause some warning and error messages while import soil data with SWAT-SSURGO extension.

After reviewed SSURGO metadata documents and its attribute tables, the changes in survey map unit ID and boundary will causes an error message and stop the extension on first stage. Moreover, the missing or blank attributes of some specific soil or non-soil type in SSURGO will issue the warning messages. The warning messages will not stop the import processes on the first stage. However, each warning message represents a potential error in the imported soil dataset. Without fixing these potential errors, the second stage of SWAT-SSURGO extension still can be executed, but the final SWAT soil dataset would be flawed; the modeling simulations would be nonsense.

Manually to inspect and fix each potential issue is a tedious thing and it could become almost impossible for a large watershed area. In this study, we developed a set of VBA scripts (see Figure B-12) to automatically inspect and revise the SSURGO attributes to avoid these issues. We also update the default soil survey map in SWAT-SSURGO extension with the Soil Data Availability Status Map which acquired from USDA NRCS Soil Data Mart (NRCS, 2008a).

In order to inspect SSURGO attributes and avoid the missing or blank values in specific soil types, several conditional assumptions were made in the automatic process. Table B-5 lists the major conditional assumptions for the interesting fields of SWAT soil dataset. For those fields listed in Table B-5, the adequate values were assumed according to SWAT documents (Neitsch et al., 2005), SSURGO metadata documents (NRCS, 2007; NRCS, 2008c) and soil survey literatures (NRCS, 1996; NRCS, 1999; Buol, 2003). For those special soils, which component name equals to: "Water", "Aquents", "Arents", "Psamments", "Fluvents", "Orthents", "Pits", "Dumps", "Quarry", "Aquolls", "Rock outcrop", "Urban land", and "Limestone quarry" were fine-tuned its attributes with the criteria listed in Table B-6.

Table B-5 Default Assigned Values under SWAT-SSURGO Data Import Processes

Field	Assigned Value and/or Conditional Assumption
MUID	Field (”areasymb”)
SEQN	Accumulated read-in record counts
SNAM	Field ("areasymb") + field("musym") + "-" + value of “SEQN”
S5ID	Assign “” (blank)
CMPPCT	Field ("comppct_r"); for missing data, assign “0” to represent 0.00%
NLAYERS	Accumulated read-in layer counts; for larger than ten layers, assign “10” (SWAT limits).
HYDGRP	Field ("hydgrp"); for missing data, assign “D” (such as Quarries, pit); for multiple hydrologic group symbol of a soil (A/D, B/D, C/D), use the later one (assume soil un-fractured).
ANION_EXCL	Assign “0.5” (SWAT default assumption)
SOL_CRK	Assign “0.5” (SWAT default assumption)
TEXTURE	Field ("taxpartsz"); for missing data, use field ("compname") or blank.
SOL_Z	Field ("hzdepb_r") x 10 in mm; for missing data, assign “25.4” and only one layer (Water, Quarries, Pits)
SOL_ZMX	The value of “SOL_Z” in the lowest layer of the same “SNAM”
SOL_BD	Field ("db3bar_r") in g/cm^3; for missing data assign “1.1” except Water in “1.0” (1.1 ~ 1.9 Mg/m^3)
SOL_AWC	Field ("awc_r") in cm/cm or mm/mm; for missing data assign ”0.01”.
SOL_K	Field ("ksat_r") x 3.6 to convert unit from um/sec into mm/hr; for missing data, assign “3.6”.
SOL_CBN	Field ("om_r") / 1.72 to convert Organic Matter into Organic Carbon for SWAT; for missing data, assign “0.01”
CLAY	Field ("claytot_r"); for missing data, use 100 subtracted by other non-zero components and average.
SILT	Field ("silttot_r"); for missing data, use 100 subtracted by other non-zero components and average.
SAND	Field ("sandtot_r"); for missing data, use 100 subtracted by other non-zero components and average.
ROCK	Field ("rock"); for missing data, assign “0.00” to represent 0.00%.
SOL_ALB	Field ("albedody_r"); for missing data, assign “0.23” to represent 23%
USLE_K	Field ("kffact"); for missing data, assign "0.01"
SOL_EC	Field ("ec_r") in mmhos/cm (= dS/m); for missing data, assign “0.00” due to current version of SWAT did not be used.
SSURGOVER	Assign "2"
MUKEY	Field ("mukey")
COKEY	Field ("mucokey")
COMPNAME	Field ("compname"); for those non-regular soil whose COMPNAME = "Water", "Aquents", "Arents", "Arents, earthen dam", "Psamments", "Fluvents", "Orthents", "Pits", "Dumps", "Quarry", "Aquolls", "Rock outcrop", "Urban land", and "Limestone quarry", it need to revise and fine-tune its value in fields.

Table B-6 Soil Attribute Adjustments for Specific Soil Types in SSURGO

Component Name	Water	Aquents, Arents, Psamments, Fluvents, Orthents	Pits, Dumps, Aquolls, Urban land,	Quarry, Rock outcrop, Limestone quarry
Field				
HYDGRP	A	D	D	D
SOL_Z	25.4	600	1524	25.4
SOL_BD	1.0	1.5	1.3	1.9
SOL_AWC	0.7	0.01	0.01	0.01
SOL_K	600	3.6	0.03	0.03
CLAY			5	5
SILT			10	10
SAND			50	20
ROCK			35	65
SOL_ALB	0.12	0.23	0.25	0.35
USLE_K	0.01	0.01	0.01	0.01

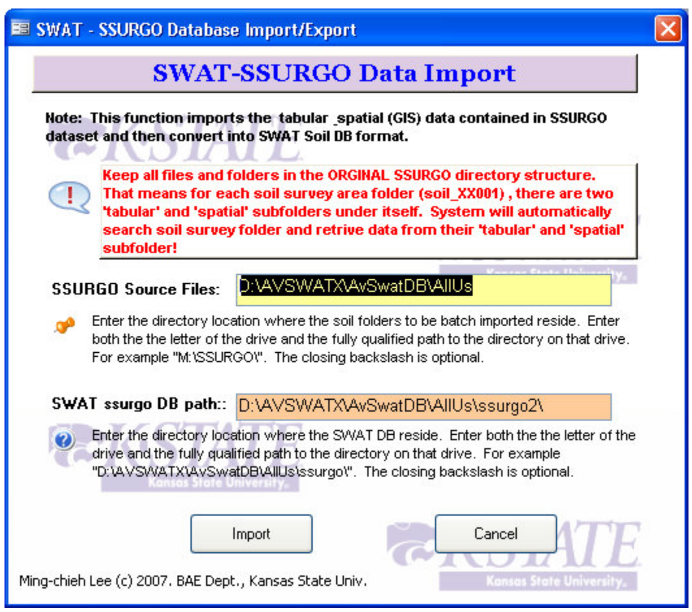


Figure B-12 Screen Snapshot of Developed SWAT-SSURGO Data Import Tool

B.6 Climate

The National Environmental Satellite, Data and Information Service (NESDIS) of National Oceanic and Atmospheric Administration (NOAA) and National Climatic Data Center (NCDC) of US Department of Commerce provide the meteorological information including daily surface precipitation, maximum and minimum temperature, and other indicators for more than 10,000 stations across the United States. It is a quality climate data source for watershed modeling and can be acquired directly online. These climate data can be acquired from NCDC Daily Surface Data website (NCDC, 2009).

There are five basic weather data can be defined in the SWAT: precipitation, temperature, solar radiation, wind speed, and relative humidity (Neitsch et al., 2005). For the default method of SWAT modeling surface hydrology, only daily precipitation and temperature are required, the others are optional. Table B-7 (a) and (b) describe the input format requirement for precipitation and maximum/minimum temperature. For the missing observations, SWAT required a negative 99.0 (-99.0), which will trigger SWAT to estimate the precipitation or temperature for that day (Neitsch et al., 2004). SWAT estimated the absent climate elements based on the 30-year averages of weather simulation data (Neitsch et al., 2005). For long periods of missing data, it would better to substitute data from the adjacent gauges.

Table B-7 Climate Input Data Field and Format Definitions in AVSWAT-X

(a) Precipitation Input Format

Field Name	Description
Date	The observation date in MM/DD/YYYY format
PCP	Amount of precipitation falling in the time period (mm)

(b) Temperature Input Format

Field Name	Description
Date	The observation date in MM/DD/YYYY format
MAX	Daily maximum temperature (ºC)
MIN	Daily maximum temperature (ºC)

The data format of downloaded climate from NCDC CDO, Daily Surface Data is different to SWAT required in Table B-7. Another issue is the missing observations. Although NCDC has done a good data quality control for every weather station, but the missing data issues are still common across the study watershed. The daily precipitation and temperature dataset need to be filtered any significant long missing period and placed the missing marks for SWAT. Therefore, a set of VBA scripts were developed to automatic these processes in this study (Figure B-13).

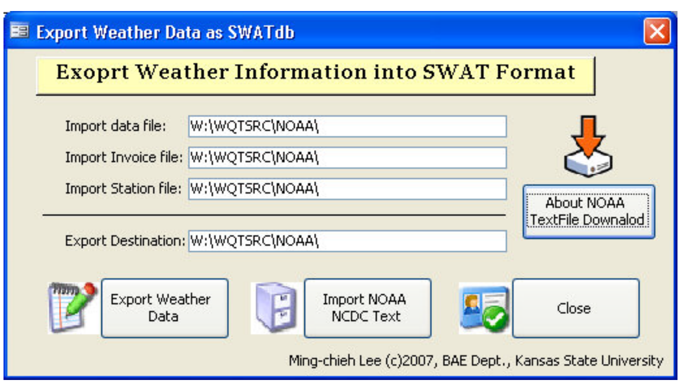


Figure B-13 Screen Snapshot of Developed SWAT-NOAA Data Management Tool

AVSWAT-X does not use any interpolating method such as Thiessen's polygon to estimate a surface of precipitation or temperature. Instead of that, AVSWAT-X assigns the nearest weather station for each subbasin (Neitsch et al., 2005). AVSWAT-X will automatically search the nearest station for each subbasin based on the distance between the stations and the subbasin centroid (Neitsch et al., 2005). That means several subbasins will share a set of identical weather data from the same station.

According to NOAA NCDC information, there are total 82 precipitation, 43 temperature gage stations, and 7 weather simulation data sites within the 20 miles buffer of Lower Kansas watershed. Only 41 precipitation and 20 temperature gages have more than 15-year continuous data. However, SWAT calibration notes suggest that one temperature gage for a watershed is usually adequate, but include as many precipitation gauges as possible can drives the hydrologic cycle of model much well (Neitsch, 2003). SWAT default only uses maximum 18 weather stations for each climate category in a simulation. The total 18 precipitation, 13 temperature gages, and one weather simulation data site were really used in modeling processes. Figure B-14 illustrates the selection of precipitation and temperature stations in this study.

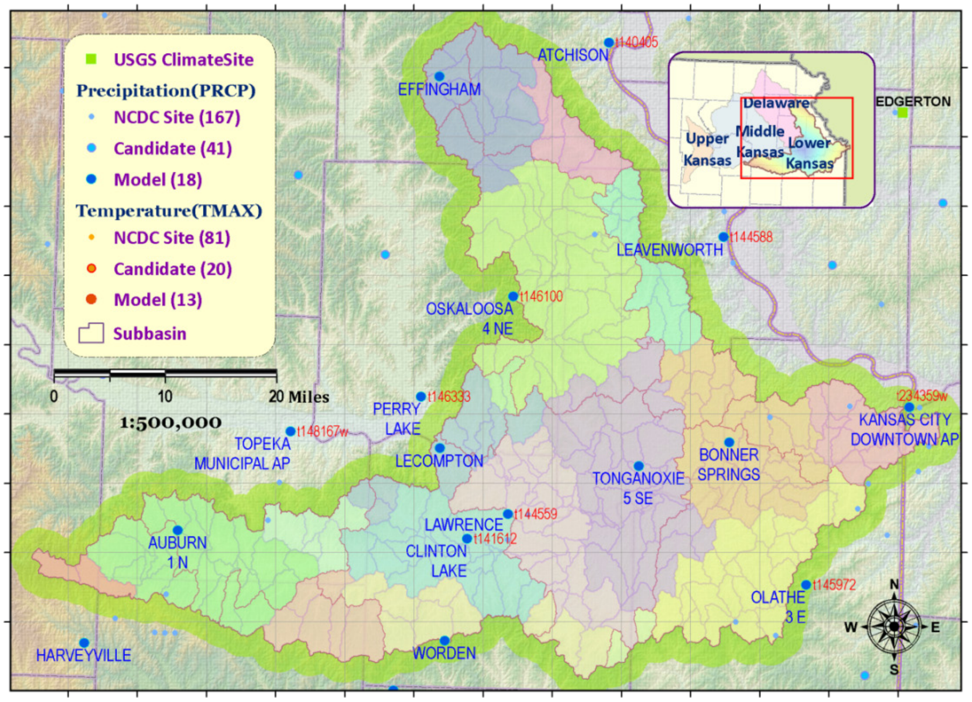


Figure B-14 Precipitation and Temperature Stations around Lower Kansas Watershed

B.7 Watershed Delineation

B.7.1 Subbasin Definition

The Federal Geographic Data Committee (FGDC) release the Federal Standard for Delineation of Hydrologic Unit Boundaries in October 2004 to delineate hydrologic unit boundaries consistently, modify existing hydrologic units, and establish a national watershed boundary dataset (WBD). This guideline provides the criteria and methods for hydrologic unit selection and boundary delineation to develop standardized hydrologic units (FGDC, 2004). Based on this guideline and previous watershed data pretest, we chose the 30-m DEM from NED and revised high resolution stream network from NHD for subbasin delineation.

In order to delineate each subbasin to maintain a hydrology-reasonable shape, the stream definition thresholds were set as 990 ha (2450 ac) in SWAT. Manually adjustments for the subbasin shapes and sizes were applied: each subbasin area is less than 4000 ha and reach length is no more than 8000 m. There are 286 subbasins and outlets were delineated.

According to Kansas 2002 Census of Agriculture report from USDA NASS, the average farm size in Kansas is around 296.6 ha (733 ac); the weighted average is 130 ha (322 ac) and median is 52 ha (129 ac) for the study watershed (NASS, 2004). Table B-8 lists the farm size statistics for each county in study area. The weighted watershed average farm size is the summation of every county average size of farm multiply by its portion of total area. This number is lower than State average but similar to the median.

Table B-8 Average Farm Size Statistics in Study Watershed (NASS, 2004)

County	Total Farm	Total Area (ac)	Average size of farm		Median Size of Farm		% in Study Area
Atchison	537	155,598	366 ac.	148.1 ha	178 ac.	72.0 ha	5.95%
Douglas	764	128,638	230 ac.	93.1 ha	86 ac.	34.8 ha	8.31%
Jefferson	872	169,201	269 ac.	108.9 ha	130 ac.	52.6 ha	21.67%
Johnson	542	88,043	226 ac.	91.5 ha	71 ac.	28.7 ha	11.80%
Leavenworth	947	119,727	180 ac.	72.8 ha	85 ac.	34.4 ha	14.60%
Osage	813	216,256	397 ac.	160.7 ha	160 ac.	64.7 ha	21.64%
Shawnee	779	135,766	240 ac.	97.1 ha	96 ac.	38.8 ha	5.79%
Wabaunsee	527	139,658	736 ac.	297.8 ha	235 ac.	95.1 ha	9.49%
Wyandotte	129	9,842	86 ac.	34.8 ha	35 ac.	14.2 ha	0.76%
Watershed	56,703	29,542,022	733 ac.	296.6 ha	290 ac.	117.4 ha	100.00%

Figure B-15 exhibits the area statistics of all 286 subbasins. The subbasin areas range from 250 to 4000 ha, as well as the mean is around 1500 ha which is about five times for the state average farm size or eleven and half for the watershed average farm size. That imply a suitable HRU size might be the one-twelfths of the mean area that equal to a single farm size at this area.

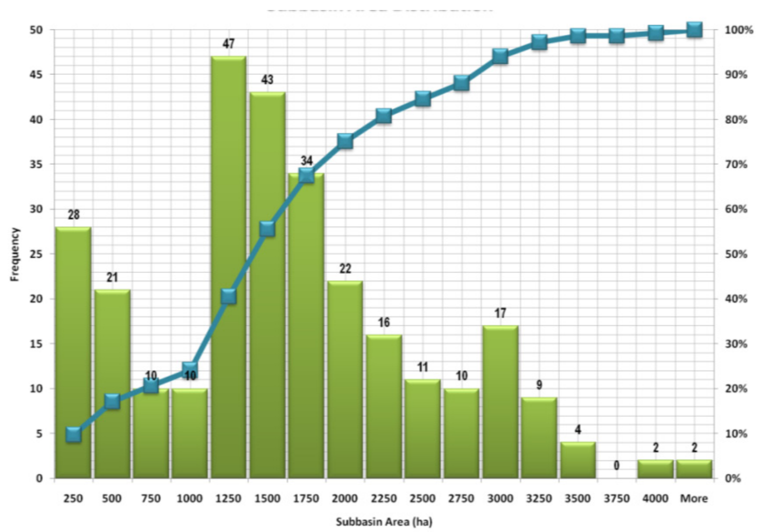


Figure B-15 Subbasin Area Distribution (Stream Threshold=990 ha)

B.7.2 Multiple HRUs Generalization

SWAT defined each subbasin with one or more sub-units to estimate the individual soil erosion of each subunit with MUSLE equation (Neitsch et al., 2005). Each sub-unit is a basic hydrologic calculation unit, or hydrologic response unit (HRU). AVSWAT-X provides a tool for help user to define the multiple HRUs based on the two important criteria: landuse and soil properties within the subbasin. It is critical to generalize both landuse and soil to produce an adequate number of HRUs that still can represent the major characteristics of the subbasin and also keep acceptable modeling performance.

To create a set of multiple HRUs, it first defines the landuse over subbasin area percentage. That means the percentage of a landuse class less than the defined number will be neglected; only the remainder will be taken in account. And then it defined what percentage of soil over a landuse classes in the subbasin could be a HRU. Figure B-16 displays how the landuse and soil generalization can be set for the multiple HRU. Following these criteria, the multiple HRUs for every delineated subbasin will be generated.

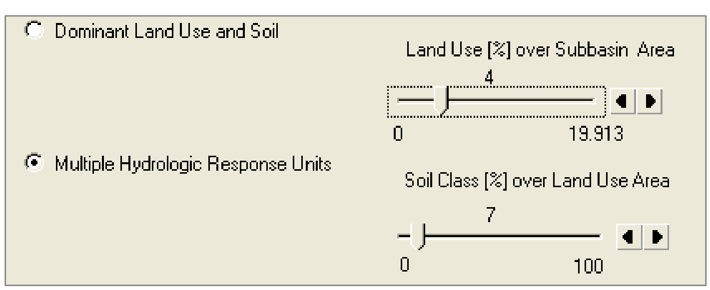


Figure B-16 Landuse/Soil Definition of HRU Generalization in AVSWAT-X

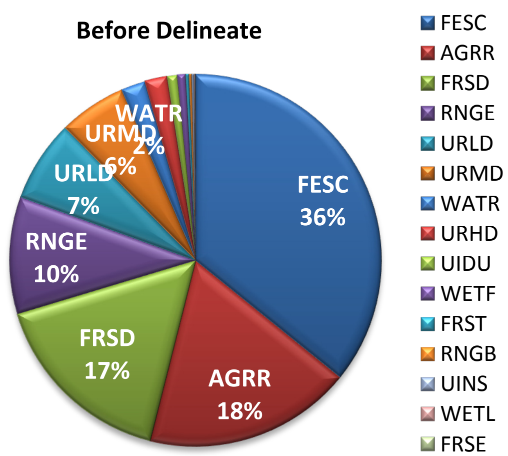
To design a well defined Hydrological Response Unit (HRU) which include the most significant physical properties of ground truth as well as keep a reasonable number of HRU for modeling processes is a tedious thing. The straight forward way to design HRU is included every landuse/soil classes combination. That applied the area of landuse larger than 0% over subbasin area as well as soil classes' area larger than 0% over chosen landuse (0%/0%) for multiple HRUs definition. That will not drop or neglect any landuse/soil classes. However, in practices, with the chosen landuse and soil dataset in this study, there are more than 10000 HRUs would be generate in the watershed. Not only the troubles in post analyzing 10000 x 10000 combinations of modeling data, it also will reach the ArcView as well as AVSWAT-X limitation which might cause serious system crash.

Another way to define HRU is using the dominant landuse/soil in subbasin to classify. There will be one and only one HRU for each subbasin. It might be an acceptable method for the areas have homogenous landuse and soil, but not for the variant landuse and soil. For example in Table B-9, we applied the dominant landuse/soil method in 4%/7% to subbasin #11, the FESO of landuse and KS0057586 of soil are dominant. However, FESO only occupied 50% of total area of landuse as well as KS0057586 only in 38.18% of the FESO area. That will results the 19% total subbasin area is in FESO-KS0057586 combination. Applied this method in the study watershed might cause some biases on modeling results

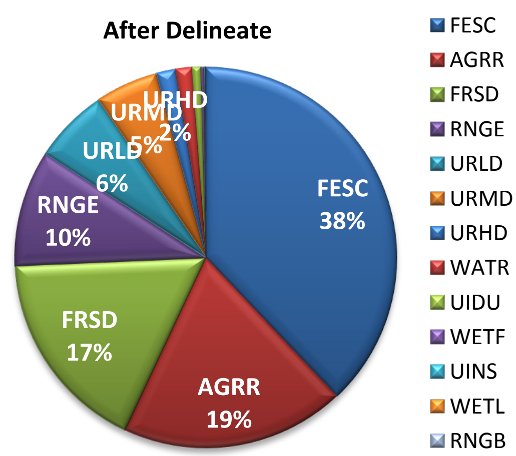
Table B-9 Landuse versus Soil Classes for Subbasin #11

Landuse	WATR	URLD	URMD	URHD	UINS	FRSD		RNGB	RNGE	FESC		AGRR	
KS0057594	1800	12600	0	0	0	106200	7.24%	0	0	333900	3.54%	54000	0.82%
KS0057502	0	134100	5400	0	0	200700	13.69%	900	21600	1841400	19.53%	1208700	18.45%
KS0057541	0	163800	0	0	0	16200	1.10%	2700	78300	1179900	12.51%	1353600	20.66%
KS0057052	0	30600	0	0	0	456300	31.12%	7200	24300	529200	5.61%	411300	6.28%
KS0057051	3600	18000	1800	0	0	272700	18.60%	2700	44100	290700	3.08%	54000	0.82%
KS0057585	0	49500	2700	0	0	48600	3.31%	2700	39600	832500	8.83%	309600	4.72%
KS0057851	2700	7200	0	0	0	13500	0.92%	0	15300	115200	1.22%	135000	2.06%
KS0057586	58500	136800	2700	0	0	346500	23.63%	10800	109800	3600000	38.18%	1403100	21.41%
KS0057253	7200	72000	76500	8100	12600	2700	0.18%	0	0	567900	6.02%	1075500	16.41%
KS0057252	0	45900	37800	0	8100	0	0.00%	0	0	90000	0.95%	350100	5.34%
KS0054350	0	0	0	0	0	0	0.00%	0	0	0	0.00%	10800	0.16%
KS0057540	0	1800	0	0	0	1800	0.12%	0	0	42300	0.45%	87300	1.33%
KS0057090	0	0	0	0	0	900	0.06%	0	0	5400	0.06%	99900	1.52%
SUM	73800	672300	126900	8100	20700	1466100	100%	27000	333000	9428400	100%	6552900	100%
Percentage	0.39%	3.59%	0.68%	0.04%	0.11%	7.84%		0.14%	1.78%	50.39%		35.03%	

After testing modeling performance and modeling results, to generate the reasonable number of Hydrological Response Unit (HRU) for modeling and aggregate the most ground truth within the study watershed, only the landuse (NLCD2001) over subbasin area is larger than 4% and soil (SSURGO) classes over landuse area is larger than 7% were considered as a HRU for this study. Figure B-17 characterized the percentages of landuse classes before and after multiple HRU delineation. The landuse classes in Forest-Mixed (FRST), Range-Brush (RNGB), and Forest-Evergreen (FRSE) were neglected. The major landuse classes in Tall Fescue (FESC), Agricultural Land-Row Crops (AGRR), and Forest-Deciduous (FRSD) were slightly increased around 1% compared to other classes were slightly decreased less than 1% of total adjusted area.



(a) Before Multiple HRU Delineation



(b) After Multiple HRU Delineation

Figure B-17 Landuse Classes and Percentages of Study Watershed in SWAT

Based on the hydrologic unit boundary delineation guideline, which published by Federal Geographic Data Committee (FGDC, 2004), the total 286 subbasins and 5395 HRUs were delineated in study watershed with landuse-soil ratios in 4%/ 7% of selected NLCD 2001 and SSURGO datasets. Within these 5395 HRUs, only 1043 HRUs were categorized as cropland HRU (landuse type = AGRR) which distributed in 255 of 286 subbasin. The subbasins without cropland HRU, the purple blocks in Figure B-18, are mostly in urban landuse and distributed around Kansas City Metropolitan.

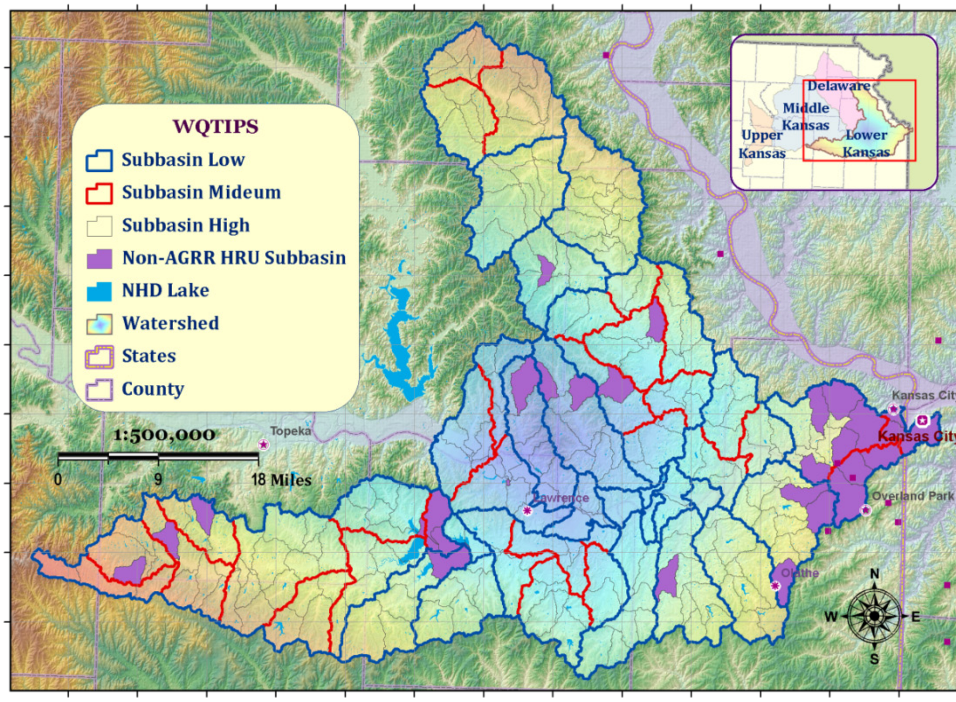
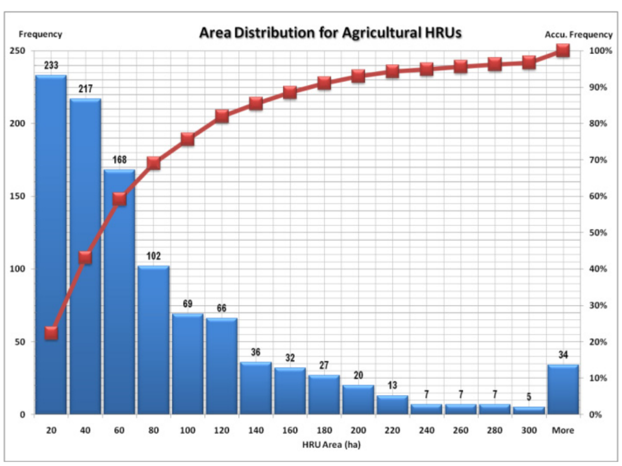
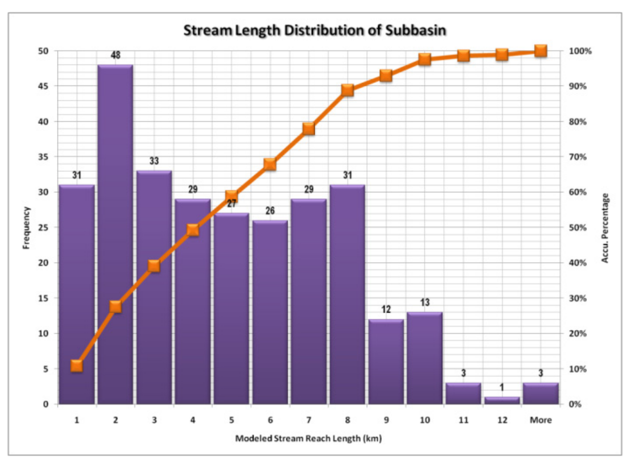


Figure B-18 Subbasin without Any Agricultural Cropland HRU

Figure B-19 (a) shows the area statistics and Figure B-19 (b) shows the stream length of all the delineated subbasins. Most HRU areas range from 20 to 120 ha which is roughly matched the median of watershed farm size (130.5 ha) in Table B-8. That means an individual HRU can represent a common farm in size in study watershed. Moreover, as illustrated in Figure B-19 (b), more than 90% delineated stream length in watershed is less than 8000 meters. These statistics also match the criteria for delineating a subbasin with as suitable shape in study watershed.



(a) Area Distribution



(b) Stream Length Distribution

Figure B-19 Area and Stream Length Statistics of Delineated Subbasins

B.7.3 Mismatched Boundary

Reviewed all the geo-referenced inputs in this study, some slight boundary mismatching issues occurred especially around a large waterbody, such as lakes or reservoirs. Figure B-20 shows the waterbody boundary in NHD, landuse of NLCD 2001, soil of SSURGO and STATSGO around Clinton Lake. In Figure B-20, STATSGO has the largest waterbody area among these inputs; NHD, NLCD 2001 and SSURGO share a common boundary but there are still some slight differences in detail. These inconsistencies are due to the raw data sources of each dataset. The inconsistence in waterbody boundary may cause some issues on modeling a small watershed. To minimize these issues, we suggest delineating a single subbasin to include the whole waterbody.

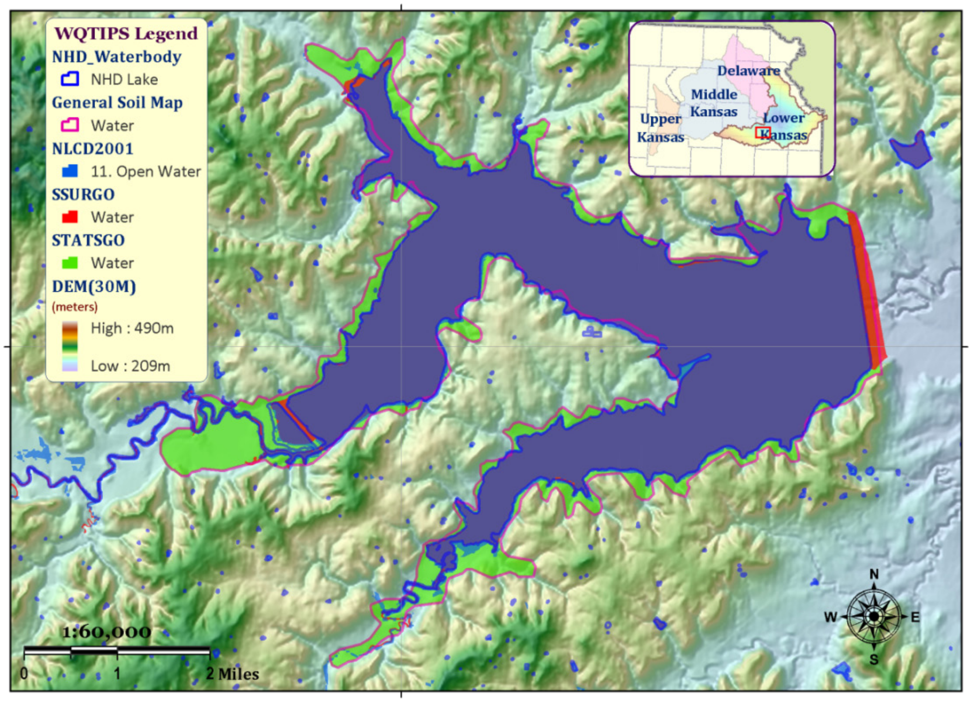


Figure B-20 Boundary of Major Geospatial Inputs around Clinton Lake Area

B.8 References

Anderson, R. M., V. I. Koren and S. M. Reed. 2006. Using SSURGO Data to Improve Sacramento Model A Priori Parameter Estimates. *J. Hydrology* 320:103-116.

Buol, S. W. 2003. *Soil Genesis and Classification*. Ames, IA: Iowa State Press.

Di Luzio, M., J. G. Arnold, and R. Srinivasan. 2004. Integration of SSURGO maps and soil parameters within a geographic information system and nonpoint source pollution model system. *J. Soil and Water Conserv.* 59(4):123-133.

Di Luzio, M., R. Srinivasan, J. G. Arnold, and S. L. Neitsch. 2002. ArcView Interface for SWAT2000: User's Guide. Report TR-193. College Station, TX: Texas Water Resources Institute.

ESRI. 2009. Hydro Data Model. Redlands, CA: Environmental Systems Research Institute (ESRI), Inc. Available at: support.esri.com/index.cfm?fa=downloads.datamodels.filteredgateway&dmid=15. Accessed April 30, 2009.

FGDC. 2004. *Federal Standards for Delineation of Hydrologic Unit Boundaries Version 2.0*. Washington, D.C.: Federal Geographic Data Committee (FGDC). Available at: www.ncgc.nrcs.usda.gov/products/datasets/watershed/. Accessed April 30, 2009.

Geza, M. and J. E. McCray. 2007. Effects of soil data resolution on SWAT model stream flow and water quality predictions. *J. Environ. Management* 88(3):393-406.

Ghidey, F., E. J. Sadler, R. N. Lerch, and C. Baffaut. 2007. Scaling up the SWAT model from Goodwater Creek Experimental Watershed to the Long Branch Watershed. ASABE Paper No. 072403. St. Joseph, Mich.: ASABE.

Gowda, P. H. and D. J. Mulla. 2005. Scale Effects of STATSGO vs. SSURGO Soil Databases on Water Quality Predictions. In *Proc. 3rd Watershed Management to Meet Water Quality Standards and Emerging TMDL Conference.* 579-587. P. Gassmann, ed. ASABE Paper No.701P0105. St. Joseph, Mich.: ASABE.

Grove, M., J. Harbor, B.A. Engel, and S. Muthukrishnan. 2001. Impacts of urbanization on surface hydrology, Little Eagle Creek, Indiana, and analysis of L-THIA model sensitivity to data resolution. Physical Geography 22(2):135-153.

Heathman, G.C. and M. Larose. 2006. Modeling streamflow using SWAT with different soil and land cover geospatial datasets. In H.Q. Tian (ed.). Proceedings of the Second IASTED International Conference on Environmental Modeling and Simulation. St. Thomas, U.S. Virgin Islands.

Homer C, Huang C, Yang L, Wylie, B. and Coan M. 2004. Development of a 2001 National Land-cover Database for the United States. *Photogrammetric Engineering and Remote Sensing* 70:829-840.

Leatherman, J., J. M. Peterson, and K. R. Mankin. 2005. Is water quality trading a policy option for Kansas? In *Proc. 22nd Annual Water and the Future of Kansas Conference*. Topeka, KS: Kansas State University.

Maidment, D. R. 2002. *Arc Hydro: GIS for water resources*. Redlands, CA: ESRI Press.

Mednick, A. C., J. Sullivan, and D. J. Watermolen. 2008. Comparing the Use of STATSGO and SSURGO Soils Data in Water Quality Modeling-A Literature Review: Resources, Research/Management Findings. SS-760 2008. Madison, WI: Bureau of Science Services, Wisconsin Department of Natural Resources (WDNR). Available at: www.dnr.state.wi.us/org/es/science/publications/PUB_SS_760_2008.pdf. Accessed April 30, 2009.

MRLC, 2008a. National Land Cover Database. Multi-Resolution Land Characteristics Consortium. Available at: www.mrlc.gov. Accessed April 30, 2009.

MRLC, 2008b. NLCD 1992-2001 Retrofit Change Product. Multi-Resolution Land Characteristics Consortium. Available at: www.mrlc.gov/changeproduct.php. Accessed April 30, 2009.

MRLC. 2008c. National Land Cover Database 2001 (NLCD 2001). Washington, D.C.: Multi-Resolution Land Characteristics Consortium (MRLC). Available at: www.mrlc.gov. Accessed April 30, 2009.

NASS. 2004. Kansas, State and County Data, Volume 1, Geographic Area Series Part 16, 2002 Census of Agriculture. AC-02-A-16. Washington, D.C.: National Agricultural Statistics Service (NASS), Agricultural Statistics Board, USDA.

NCDC. 2009. Daily surface data. Climate Data Online (CDO), National Climatic Data Center (NCDC). NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and U.S. Department of Commerce. Available at: cdo.ncdc.noaa.gov. Accessed March 31, 2009.

Neitsch, S. 2003. Calibration Notes. Unpublished working document. Available at: ftp.brc.tamus.edu/pub/outgoing/nsammons/swat2005doc/usermanual/Calibration%20notes.doc. Accessed Dec. 31, 2008.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, and J. R. Williams. 2005. *Soil and Water Assessment Tool Theoretical Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS & Blackland Research and Extension Center, Texas A&M University.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and J. R. Williams. 2004. *Soil and Water Assessment Tool Input / Output File Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS.

NRCS. 2008a. Soil Data Availability Status Map. USDA-NRCS. Available at: soildatamart.nrcs.usda.gov/StatusMap.aspx. Accessed April 30, 2009.

NRCS. 2008b. Soil Survey Geographic (SSURGO) Database. USDA-NRCS. Available at: soils.usda.gov/survey/geography/ssurgo/. Accessed April 30, 2009.

NRCS. 2008c. SSURGO Metadata Version: 2.2.3. USDA-NRCS. Available at: soildatamart.nrcs.usda.gov/SSURGOMetadata.aspx. Accessed April 30, 2009.

NRCS. 2008d. U.S. General Soil Map (STATSGO2) Database. USDA-NRCS. Available at: soils.usda.gov/survey/geography/statsgo/. Accessed April 30, 2009.

NRCS. 2009. Hydrologic Soil Groups. Chapter 7 in: *National Engineering Handbook, Part 630 Hydrology*. Washington, D.C.: USDA-NRCS

NRCS. 1995. State Soil Geographic Database (STATSGO): Data Use Information. Miscellaneous publication: No. 1492. Washington, D.C.: USDA-NRCS, National Soil Survey Center.

NRCS. 1996. National Soil Survey Handbook. Title 430-VI. USDA-NRCS. Washington, D.C.: U.S. Government Printing Office.

NRCS. 1997. State Soil Geographic (STATSGO) Database. Fort Worth, TX: USDA-NRCS, National Cartography and GIS Center. Available at: www.ncgc.nrcs.usda.gov/products/datasets/statsgo/. Accessed April 30, 2009.

NRCS. 1999. *Soil Taxonomy, a Basic System of Soil Classification for Making and Interpreting Soil Surveys*. 2^{nd} Ed. Agriculture Handbook: No. 436. Washington, D.C.: USDA-NRCS.

NRCS. 2004. Hydrologic Soil-Cover Complexes. Chapter 9 in: *National Engineering Handbook, Part 630 Hydrology*. Washington, D.C.: USDA-NRCS

NRCS. 2007. SSURGO Data Packaging and Use. USDA-NRCS. Available at: soildatamart.nrcs.usda.gov/SSURGOMetadata.aspx. Accessed April 30, 2009.

Parajuli, P. B. 2007. SWAT bacteria sub-model evaluation and application. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

Peschel, J. M., P. K. Haan, and R. E. Lacey. 2006. Influences of soil dataset resolution on hydrologic modeling. *J. Amer. Water Resour. Assoc.* 42(5):1371-1389.

Peschel, J.M., P. K. Haan, and R. E. Lacey. 2003. A SSURGO Pre-Processing Extension for the ArcView Soil and Water Assessment Tool. ASAE Paper No.032123. St. Joseph, Mich.: ASAE.

Tuppad, P. 2006. Hydrologic modeling response to NEXRAD and raingage spatial variability and strategic watershed management. PhD diss. Manhattan, KS: Kansas State University, Department of Biological and Agricultural Engineering.

USEPA. 2007. 2006 National Land Cover Data (NLCD 2006). Washington, D.C.: USEPA. Available at: www.epa.gov/mrlc/nlcd-2006.html. Accessed April 30, 2009

USGS. 1999. National Land Cover Dataset 1992 (NLCD 1992). USGS. Available at: landcover.usgs.gov/mapping_proc.php. Accessed April 30, 2009.

USGS. 2006. National Elevation Dataset (NED). USGS. Available at: ned.usgs.gov. Accessed April 30, 2009.

USGS. 2008. National Hydrography Dataset (NHD). USGS. Available at: nhd.usgs.gov, Accessed April 30, 2009.

Wang, X. and A. M. Melesse. 2006. Effects of STATSGO and SSURGO as inputs on SWAT Model's Snowmelt Simulation. *J. Am. Water Resour. Assoc.* 42:1217-1236.

Williamson, T. and K. R. Odom. 2007. Implications of SSURGO vs. STATSGO data for modeling daily stream flow in Kentucky. In *Proc: ASA-CSSASSSA 2007 International Annual Meetings.* New Orleans, LA.

Wischmeier, W. H. and D. D. Smith. 1978. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning*. Agriculture Handbook: No. 537. USDA. Washington, D.C.: U.S. Government Printing Office.

Appendix C Post Analysis

C.1 Potential Annual Nutrient Load

Figure C-1 illustrates the watershed scale potential annual loads in Table C-1, which are the area weighted average of 286 subbasins (SUB), 1294 HRUs (HRU) and 1206 agricultural cropland HRUs (AGH). For most of scenarios, the nutrient loads of AGH subset are larger than SUB and HRU subsets. With the sorted potential nutrient loads in Table C-1, the top (maximum) and bottom (minimum) 20 scenarios were listed in Table C-2. In Table C-2, the ranking sequences in each data subset are very similar. Figure C-2 illustrates the cumulative probability of all scenarios in Table C-1 for each data subset. The dots of each data subset in Figure C-2 overlap each other in most area. That means any of three data subsets can represent the same trend of all scenarios in potential nutrient load reduction.

Table C-1 Watershed Level Potential Annual Nutrient Load and Cumulative Probability

(Load Units: kg/ha)

SCEN	Abbrev.	RTYR	CROP	TILL	FERT	BMPS	TN:SUB		TN:AGH		TN:HRU		TP:SUB		TP:AGH		TP:HRU	
S1	CS5SB	2-yr	CS	CT	SB	WO	59.648	98.00%	61.511	98.00%	57.328	98.00%	12.033	95.33%	12.416	95.33%	11.572	95.33%
S2	CS5SBFS	2-yr	CS	CT	SB	FS	6.404	48.22%	6.603	48.22%	6.154	48.22%	1.293	45.56%	1.333	45.56%	1.242	45.56%
S3	CS5DB	2-yr	CS	CT	DB	WO	57.926	97.11%	59.755	97.11%	55.691	97.11%	10.233	88.22%	10.559	88.22%	9.841	88.22%
S4	CS5DBFS	2-yr	CS	CT	DB	FS	6.219	47.33%	6.415	47.33%	5.978	47.33%	1.100	38.44%	1.134	38.44%	1.056	38.44%
S5	CS4SB	2-yr	CS	MT	SB	WO	51.551	93.11%	53.101	93.11%	49.490	93.11%	12.062	95.78%	12.431	95.78%	11.586	95.78%
S6	CS4SBFS	2-yr	CS	MT	SB	FS	5.534	43.33%	5.700	43.33%	5.313	43.33%	1.296	46.00%	1.334	46.00%	1.244	46.00%
S7	CS4DB	2-yr	CS	MT	DB	WO	49.938	92.67%	51.458	92.67%	47.959	92.67%	9.774	86.00%	10.079	86.44%	9.393	86.44%
S8	CS4DBFS	2-yr	CS	MT	DB	FS	5.361	42.89%	5.524	42.89%	5.148	42.89%	1.050	36.22%	1.082	36.67%	1.008	36.67%
S9	CS3SB	2-yr	CS	RT	SB	WO	44.358	87.33%	45.613	87.33%	42.511	87.33%	12.588	97.56%	12.943	97.11%	12.063	97.11%
S10	CS3SBFS	2-yr	CS	RT	SB	FS	4.762	37.56%	4.897	37.56%	4.564	37.56%	1.352	47.78%	1.389	47.33%	1.295	47.33%
S11	CS3DB	2-yr	CS	RT	DB	WO	42.652	85.11%	43.872	85.11%	40.888	85.11%	9.775	86.44%	10.063	86.00%	9.379	86.00%
S12	CS3DBFS	2-yr	CS	RT	DB	FS	4.579	35.33%	4.710	35.33%	4.389	35.33%	1.050	36.67%	1.080	36.22%	1.007	36.22%
S13	CS2SB	2-yr	CS	OT	SB	WO	37.370	80.22%	38.389	79.78%	35.778	79.78%	12.280	96.22%	12.615	96.22%	11.757	96.22%
S14	CS2SBFS	2-yr	CS	OT	SB	FS	4.012	30.44%	4.121	30.00%	3.841	30.00%	1.319	46.44%	1.354	46.44%	1.262	46.44%
S15	CS2DB	2-yr	CS	OT	DB	WO	35.221	74.89%	36.194	74.44%	33.732	74.44%	8.956	81.11%	9.215	80.67%	8.588	80.67%
S16	CS2DBFS	2-yr	CS	OT	DB	FS	3.781	25.11%	3.885	24.67%	3.621	24.67%	0.962	31.33%	0.989	30.89%	0.922	30.89%
S17	CS1SB	2-yr	CS	NT	SB	WO	33.016	70.44%	33.897	70.44%	31.592	70.44%	12.318	96.67%	12.652	96.67%	11.791	96.67%
S18	CS1SBFS	2-yr	CS	NT	SB	FS	3.545	20.67%	3.639	20.67%	3.391	20.67%	1.323	46.89%	1.358	46.89%	1.266	46.89%
S19	CS1DB	2-yr	CS	NT	DB	WO	30.569	63.78%	31.399	63.33%	29.264	63.33%	8.435	76.67%	8.675	76.67%	8.085	76.67%
S20	CS1DBFS	2-yr	CS	NT	DB	FS	3.282	14.00%	3.371	13.56%	3.141	13.56%	0.906	26.89%	0.931	26.89%	0.868	26.89%
S21	C5SB	1-yr	C	CT	SB	WO	70.524	99.33%	72.600	99.33%	67.663	99.33%	12.818	98.00%	13.222	98.00%	12.322	98.00%
S22	C5SBFS	1-yr	C	CT	SB	FS	7.571	49.56%	7.794	49.56%	7.264	49.56%	1.377	48.22%	1.419	48.22%	1.323	48.22%
S23	C5DB	1-yr	C	CT	DB	WO	78.889	99.78%	81.267	99.78%	75.740	99.78%	12.550	97.11%	12.944	97.56%	12.064	97.56%
S24	C5DBFS	1-yr	C	CT	DB	FS	8.469	50.00%	8.724	50.00%	8.131	50.00%	1.348	47.33%	1.390	47.78%	1.295	47.78%
S25	C4SB	1-yr	C	MT	SB	WO	64.201	98.89%	66.000	98.89%	61.512	98.89%	12.878	98.44%	13.271	98.44%	12.368	98.44%
S26	C4SBFS	1-yr	C	MT	SB	FS	6.892	49.11%	7.085	49.11%	6.603	49.11%	1.383	48.67%	1.425	48.67%	1.328	48.67%
S27	C4DB	1-yr	C	MT	DB	WO	61.051	98.44%	62.792	98.44%	58.522	98.44%	10.494	90.00%	10.815	90.00%	10.079	90.00%
S28	C4DBFS	1-yr	C	MT	DB	FS	6.554	48.67%	6.741	48.67%	6.282	48.67%	1.128	40.22%	1.161	40.22%	1.082	40.22%
S29	C3SB	1-yr	C	RT	SB	WO	58.538	97.56%	60.075	97.56%	55.990	97.56%	13.626	99.33%	14.021	99.33%	13.067	99.33%
S30	C3SBFS	1-yr	C	RT	SB	FS	6.284	47.78%	6.449	47.78%	6.010	47.78%	1.464	49.56%	1.505	49.56%	1.403	49.56%
S31	C3DB	1-yr	C	RT	DB	WO	55.314	96.22%	56.794	96.22%	52.931	96.22%	10.284	89.11%	10.586	89.11%	9.866	89.11%
S32	C3DBFS	1-yr	C	RT	DB	FS	5.938	46.44%	6.097	46.44%	5.682	46.44%	1.105	39.33%	1.136	39.33%	1.059	39.33%
S33	C2SB	1-yr	C	OT	SB	WO	53.274	94.00%	54.649	94.00%	50.933	94.00%	13.318	98.89%	13.704	98.89%	12.772	98.89%
S34	C2SBFS	1-yr	C	OT	SB	FS	5.719	44.22%	5.867	44.22%	5.468	44.22%	1.431	49.11%	1.471	49.11%	1.371	49.11%

SCEN	Abbrev.	RTYR	CROP	TILL	FERT	BMPS	TN:SUB		TN:AGH		TN:HRU		TP:SUB		TP:AGH		TP:HRU	
S35	C2DB	1-yr	C	OT	DB	WO	49.490	92.22%	50.803	92.22%	47.348	92.22%	9.206	83.33%	9.475	83.33%	8.830	83.33%
S36	C2DBFS	1-yr	C	OT	DB	FS	5.313	42.44%	5.454	42.44%	5.083	42.44%	0.989	33.56%	1.017	33.56%	0.948	33.56%
S37	C1SB	1-yr	C	NT	SB	WO	47.941	91.33%	49.092	91.33%	45.754	91.33%	13.809	99.78%	14.195	99.78%	13.230	99.78%
S38	C1SBFS	1-yr	C	NT	SB	FS	5.147	41.56%	5.270	41.56%	4.912	41.56%	1.483	50.00%	1.524	50.00%	1.420	50.00%
S39	C1DB	1-yr	C	NT	DB	WO	43.569	85.56%	44.646	85.56%	41.610	85.56%	8.374	76.22%	8.605	75.78%	8.020	75.78%
S40	C1DBFS	1-yr	C	NT	DB	FS	4.678	35.78%	4.793	35.78%	4.467	35.78%	0.900	26.44%	0.924	26.00%	0.861	26.00%
S41	S5SB	1-yr	S	CT	SB	WO	55.563	96.67%	57.341	96.67%	53.442	96.67%	11.428	94.44%	11.794	94.44%	10.992	94.44%
S42	S5SBFS	1-yr	S	CT	SB	FS	5.965	46.89%	6.156	46.89%	5.737	46.89%	1.228	44.67%	1.266	44.67%	1.180	44.67%
S43	S5DB	1-yr	S	CT	DB	WO	54.790	95.78%	56.548	95.78%	52.702	95.78%	9.863	86.89%	10.180	86.89%	9.488	86.89%
S44	S5DBFS	1-yr	S	CT	DB	FS	5.882	46.00%	6.070	46.00%	5.658	46.00%	1.060	37.11%	1.093	37.11%	1.018	37.11%
S45	S4SB	1-yr	S	MT	SB	WO	45.904	90.00%	47.334	90.00%	44.115	90.00%	10.722	90.89%	11.052	90.89%	10.301	90.89%
S46	S4SBFS	1-yr	S	MT	SB	FS	4.928	40.22%	5.081	40.22%	4.736	40.22%	1.152	41.11%	1.186	41.11%	1.106	41.11%
S47	S4DB	1-yr	S	MT	DB	WO	45.210	89.11%	46.621	89.11%	43.450	89.11%	9.133	82.44%	9.418	82.44%	8.778	82.44%
S48	S4DBFS	1-yr	S	MT	DB	FS	4.854	39.33%	5.005	39.33%	4.664	39.33%	0.981	32.67%	1.011	32.67%	0.942	32.67%
S49	S3SB	1-yr	S	RT	SB	WO	37.473	81.11%	38.570	81.56%	35.947	81.56%	10.328	89.56%	10.623	89.56%	9.901	89.56%
S50	S3SBFS	1-yr	S	RT	SB	FS	4.023	31.33%	4.140	31.78%	3.859	31.78%	1.110	39.78%	1.140	39.78%	1.063	39.78%
S51	S3DB	1-yr	S	RT	DB	WO	36.658	78.44%	37.728	78.44%	35.162	78.44%	8.726	79.33%	8.980	79.33%	8.370	79.33%
S52	S3DBFS	1-yr	S	RT	DB	FS	3.936	28.67%	4.050	28.67%	3.775	28.67%	0.938	29.56%	0.964	29.56%	0.898	29.56%
S53	S2SB	1-yr	S	OT	SB	WO	32.398	68.67%	33.340	68.67%	31.072	68.67%	9.994	87.33%	10.279	87.33%	9.580	87.33%
S54	S2SBFS	1-yr	S	OT	SB	FS	3.478	18.89%	3.579	18.89%	3.336	18.89%	1.074	37.56%	1.103	37.56%	1.028	37.56%
S55	S2DB	1-yr	S	OT	DB	WO	31.566	66.89%	32.481	66.00%	30.273	66.00%	8.254	75.33%	8.498	75.33%	7.920	75.33%
S56	S2DBFS	1-yr	S	OT	DB	FS	3.389	17.11%	3.487	16.22%	3.250	16.22%	0.887	25.56%	0.912	25.56%	0.850	25.56%
S57	S1SB	1-yr	S	NT	SB	WO	26.901	60.22%	27.647	60.22%	25.767	60.22%	10.104	87.78%	10.386	87.78%	9.680	87.78%
S58	S1SBFS	1-yr	S	NT	SB	FS	2.888	10.44%	2.968	10.44%	2.766	10.44%	1.086	38.00%	1.115	38.00%	1.039	38.00%
S59	S1DB	1-yr	S	NT	DB	WO	26.075	58.89%	26.797	58.89%	24.975	58.89%	8.105	73.56%	8.343	73.56%	7.775	73.56%
S60	S1DBFS	1-yr	S	NT	DB	FS	2.800	9.11%	2.877	9.11%	2.681	9.11%	0.871	23.78%	0.896	23.78%	0.835	23.78%
S61	G5SB	1-yr	G	CT	SB	WO	53.979	94.89%	55.672	94.89%	51.886	94.89%	10.920	91.78%	11.269	91.78%	10.502	91.78%
S62	G5SBFS	1-yr	G	CT	SB	FS	5.795	45.11%	5.976	45.11%	5.570	45.11%	1.173	42.00%	1.210	42.00%	1.127	42.00%
S63	G5DB	1-yr	G	CT	DB	WO	52.543	93.56%	54.218	93.56%	50.531	93.56%	9.626	85.56%	9.929	85.56%	9.254	85.56%
S64	G5DBFS	1-yr	G	CT	DB	FS	5.641	43.78%	5.820	43.78%	5.424	43.78%	1.034	35.78%	1.066	35.78%	0.993	35.78%
S65	G4SB	1-yr	G	MT	SB	WO	45.186	88.67%	46.553	88.67%	43.387	88.67%	10.680	90.44%	11.010	90.44%	10.262	90.44%
S66	G4SBFS	1-yr	G	MT	SB	FS	4.851	38.89%	4.997	38.89%	4.658	38.89%	1.148	40.67%	1.182	40.67%	1.102	40.67%
S67	G4DB	1-yr	G	MT	DB	WO	43.604	86.00%	44.948	86.00%	41.892	86.00%	8.647	78.89%	8.913	78.89%	8.307	78.89%
S68	G4DBFS	1-yr	G	MT	DB	FS	4.681	36.22%	4.825	36.22%	4.497	36.22%	0.929	29.11%	0.957	29.11%	0.892	29.11%
S69	G3SB	1-yr	G	RT	SB	WO	37.456	80.67%	38.521	80.67%	35.902	80.67%	11.077	93.11%	11.402	93.11%	10.627	93.11%
S70	G3SBFS	1-yr	G	RT	SB	FS	4.021	30.89%	4.135	30.89%	3.854	30.89%	1.190	43.33%	1.224	43.33%	1.141	43.33%
S71	G3DB	1-yr	G	RT	DB	WO	35.846	75.78%	36.888	75.33%	34.379	75.33%	8.097	73.11%	8.336	73.11%	7.769	73.11%
S72	G3DBFS	1-yr	G	RT	DB	FS	3.849	26.00%	3.960	25.56%	3.691	25.56%	0.870	23.33%	0.895	23.33%	0.834	23.33%
S73	G2SB	1-yr	G	OT	SB	WO	36.993	79.33%	38.072	79.33%	35.483	79.33%	10.265	88.67%	10.570	88.67%	9.851	88.67%
S74	G2SBFS	1-yr	G	OT	SB	FS	3.972	29.56%	4.087	29.56%	3.809	29.56%	1.103	38.89%	1.135	38.89%	1.058	38.89%
S75	G2DB	1-yr	G	OT	DB	WO	35.067	74.00%	36.120	74.00%	33.664	74.00%	7.483	69.56%	7.707	69.56%	7.183	69.56%
S76	G2DBFS	1-yr	G	OT	DB	FS	3.765	24.22%	3.877	24.22%	3.614	24.22%	0.804	20.22%	0.827	20.22%	0.771	20.22%
S77	G1SB	1-yr	G	NT	SB	WO	24.563	56.67%	25.206	56.22%	23.492	56.22%	11.024	92.67%	11.334	92.67%	10.563	92.67%
S78	G1SBFS	1-yr	G	NT	SB	FS	2.637	6.89%	2.706	6.44%	2.522	6.44%	1.184	42.89%	1.217	42.89%	1.134	42.89%
S79	G1DB	1-yr	G	NT	DB	WO	22.261	53.56%	22.869	53.56%	21.314	53.56%	6.149	59.33%	6.317	59.33%	5.888	59.33%
S80	G1DBFS	1-yr	G	NT	DB	FS	2.390	4.22%	2.455	4.22%	2.288	4.22%	0.661	10.00%	0.678	10.00%	0.632	10.00%
S81	W5SB	1-yr	W	CT	SB	WO	28.843	61.56%	29.760	61.56%	27.736	61.56%	5.475	57.11%	5.646	56.67%	5.262	56.67%
S82	W5SBFS	1-yr	W	CT	SB	FS	3.097	11.78%	3.195	11.78%	2.977	11.78%	0.589	7.78%	0.606	7.33%	0.565	7.33%
S83	W5DB	1-yr	W	CT	DB	WO	27.492	61.11%	28.375	61.11%	26.445	61.11%	4.999	53.56%	5.153	53.56%	4.803	53.56%
S84	W5DBFS	1-yr	W	CT	DB	FS	2.952	11.33%	3.046	11.33%	2.839	11.33%	0.538	3.78%	0.553	3.78%	0.516	3.78%
S85	W4SB	1-yr	W	MT	SB	WO	31.103	64.67%	32.055	64.67%	29.875	64.67%	5.891	58.44%	6.068	58.44%	5.656	58.44%
S86	W4SBFS	1-yr	W	MT	SB	FS	3.339	14.89%	3.441	14.89%	3.207	14.89%	0.634	9.11%	0.651	9.11%	0.607	9.11%
S87	W4DB	1-yr	W	MT	DB	WO	29.720	62.89%	30.638	62.89%	28.554	62.89%	5.420	55.78%	5.581	55.78%	5.201	55.78%
S88	W4DBFS	1-yr	W	MT	DB	FS	3.191	13.11%	3.289	13.11%	3.065	13.11%	0.583	6.00%	0.599	6.00%	0.558	6.00%
S89	W3SB	1-yr	W	RT	SB	WO	12.703	51.78%	13.111	51.78%	12.220	51.78%	2.596	51.78%	2.678	51.78%	2.496	51.78%
S90	W3SBFS	1-yr	W	RT	SB	FS	1.364	1.11%	1.407	1.11%	1.312	1.11%	0.280	1.11%	0.287	1.11%	0.268	1.11%

SCEN	Abbrev.	RTYR	CROP	TILL	FERT	BMPS	TN:SUB		TN:AGH		TN:HRU		TP:SUB		TP:AGH		TP:HRU	
S91	W3DB	1-yr	W	RT	DB	WO	11.793	50.44%	12.181	50.44%	11.353	50.44%	2.257	50.89%	2.330	50.89%	2.171	50.89%
S92	W3DBFS	1-yr	W	RT	DB	FS	1.266	0.22%	1.308	0.22%	1.219	0.22%	0.243	0.22%	0.250	0.22%	0.233	0.22%
S93	W2SB	1-yr	W	OT	SB	WO	21.291	53.11%	21.986	53.11%	20.491	53.11%	4.134	53.11%	4.267	53.11%	3.976	53.11%
S94	W2SBFS	1-yr	W	OT	SB	FS	2.286	3.33%	2.360	3.33%	2.200	3.33%	0.445	3.33%	0.458	3.33%	0.427	3.33%
S95	W2DB	1-yr	W	OT	DB	WO	20.091	52.67%	20.753	52.67%	19.342	52.67%	3.732	52.67%	3.850	52.67%	3.589	52.67%
S96	W2DBFS	1-yr	W	OT	DB	FS	2.157	2.89%	2.228	2.89%	2.076	2.89%	0.402	2.89%	0.413	2.89%	0.385	2.89%
S97	W1SB	1-yr	W	NT	SB	WO	13.153	52.22%	13.587	52.22%	12.663	52.22%	2.981	52.22%	3.079	52.22%	2.870	52.22%
S98	W1SBFS	1-yr	W	NT	SB	FS	1.412	1.56%	1.459	1.56%	1.359	1.56%	0.321	1.56%	0.331	1.56%	0.308	1.56%
S99	W1DB	1-yr	W	NT	DB	WO	12.185	50.89%	12.602	50.89%	11.745	50.89%	2.432	51.33%	2.515	51.33%	2.344	51.33%
S100	W1DBFS	1-yr	W	NT	DB	FS	1.309	0.67%	1.353	0.67%	1.261	0.67%	0.262	0.67%	0.270	0.67%	0.252	0.67%
S101	WS5SB	1-yr	WS	CT	SB	WO	35.948	76.22%	37.120	76.22%	34.595	76.22%	7.302	66.89%	7.533	66.89%	7.021	66.89%
S102	WS5SBFS	1-yr	WS	CT	SB	FS	3.860	26.44%	3.985	26.44%	3.714	26.44%	0.785	17.56%	0.809	17.56%	0.754	17.56%
S103	WS5DB	1-yr	WS	CT	DB	WO	34.591	73.11%	35.740	73.11%	33.310	73.11%	6.258	60.22%	6.457	60.22%	6.018	60.22%
S104	WS5DBFS	1-yr	WS	CT	DB	FS	3.714	23.33%	3.837	23.33%	3.576	23.33%	0.673	10.89%	0.693	10.89%	0.646	10.89%
S105	WS4SB	1-yr	WS	MT	SB	WO	30.790	64.22%	31.740	64.22%	29.582	64.22%	6.429	62.44%	6.628	62.44%	6.177	62.44%
S106	WS4SBFS	1-yr	WS	MT	SB	FS	3.306	14.44%	3.407	14.44%	3.176	14.44%	0.691	13.11%	0.711	13.11%	0.663	13.11%
S107	WS4DB	1-yr	WS	MT	DB	WO	29.663	62.44%	30.595	62.44%	28.514	62.44%	5.215	54.44%	5.379	54.44%	5.013	54.44%
S108	WS4DBFS	1-yr	WS	MT	DB	FS	3.185	12.67%	3.284	12.67%	3.061	12.67%	0.561	4.67%	0.577	4.67%	0.538	4.67%
S109	WS3SB	1-yr	WS	RT	SB	WO	33.325	71.78%	34.318	71.78%	31.984	71.78%	7.394	68.67%	7.618	68.67%	7.100	68.67%
S110	WS3SBFS	1-yr	WS	RT	SB	FS	3.578	22.00%	3.684	22.00%	3.433	22.00%	0.795	19.33%	0.818	19.33%	0.762	19.33%
S111	WS3DB	1-yr	WS	RT	DB	WO	32.070	67.33%	33.039	67.33%	30.792	67.33%	5.718	57.56%	5.894	57.56%	5.493	57.56%
S112	WS3DBFS	1-yr	WS	RT	DB	FS	3.443	17.56%	3.547	17.56%	3.305	17.56%	0.615	8.22%	0.633	8.22%	0.590	8.22%
S113	WS2SB	1-yr	WS	OT	SB	WO	32.465	69.56%	33.457	69.56%	31.182	69.56%	7.648	70.44%	7.888	70.44%	7.351	70.44%
S114	WS2SBFS	1-yr	WS	OT	SB	FS	3.486	19.78%	3.592	19.78%	3.347	19.78%	0.822	21.11%	0.847	21.11%	0.789	21.11%
S115	WS2DB	1-yr	WS	OT	DB	WO	31.235	65.11%	32.205	65.56%	30.015	65.56%	5.776	58.00%	5.959	58.00%	5.553	58.00%
S116	WS2DBFS	1-yr	WS	OT	DB	FS	3.354	15.33%	3.457	15.78%	3.222	15.78%	0.621	8.67%	0.640	8.67%	0.596	8.67%
S117	WS1SB	1-yr	WS	NT	SB	WO	32.872	70.00%	33.842	70.00%	31.540	70.00%	9.382	84.22%	9.678	84.22%	9.020	84.22%
S118	WS1SBFS	1-yr	WS	NT	SB	FS	3.529	20.22%	3.633	20.22%	3.386	20.22%	1.008	34.44%	1.039	34.44%	0.968	34.44%
S119	WS1DB	1-yr	WS	NT	DB	WO	31.256	65.56%	32.192	65.11%	30.002	65.11%	6.291	60.67%	6.488	60.67%	6.047	60.67%
S120	WS1DBFS	1-yr	WS	NT	DB	FS	3.356	15.78%	3.456	15.33%	3.221	15.33%	0.676	11.33%	0.696	11.33%	0.649	11.33%
S121	GS5SB	2-yr	GS	CT	SB	WO	54.772	95.33%	56.518	95.33%	52.675	95.33%	11.260	94.00%	11.619	94.00%	10.829	94.00%
S122	GS5SBFS	2-yr	GS	CT	SB	FS	5.880	45.56%	6.067	45.56%	5.655	45.56%	1.210	44.22%	1.247	44.22%	1.162	44.22%
S123	GS5DB	2-yr	GS	CT	DB	WO	53.832	94.44%	55.563	94.44%	51.784	94.44%	9.596	85.11%	9.903	85.11%	9.229	85.11%
S124	GS5DBFS	2-yr	GS	CT	DB	FS	5.779	44.67%	5.965	44.67%	5.559	44.67%	1.031	35.33%	1.063	35.33%	0.991	35.33%
S125	GS4SB	2-yr	GS	MT	SB	WO	44.069	86.89%	45.438	86.89%	42.348	86.89%	10.816	91.33%	11.149	91.33%	10.390	91.33%
S126	GS4SBFS	2-yr	GS	MT	SB	FS	4.731	37.11%	4.878	37.11%	4.546	37.11%	1.162	41.56%	1.197	41.56%	1.115	41.56%
S127	GS4DB	2-yr	GS	MT	DB	WO	44.422	87.78%	45.809	87.78%	42.694	87.78%	9.047	81.56%	9.331	81.56%	8.696	81.56%
S128	GS4DBFS	2-yr	GS	MT	DB	FS	4.769	38.00%	4.918	38.00%	4.583	38.00%	0.972	31.78%	1.002	31.78%	0.934	31.78%
S129	GS3SB	2-yr	GS	RT	SB	WO	37.478	81.56%	38.570	81.11%	35.947	81.11%	11.524	94.89%	11.850	94.89%	11.044	94.89%
S130	GS3SBFS	2-yr	GS	RT	SB	FS	4.024	31.78%	4.140	31.33%	3.859	31.33%	1.238	45.11%	1.272	45.11%	1.186	45.11%
S131	GS3DB	2-yr	GS	RT	DB	WO	36.317	77.56%	37.385	77.56%	34.843	77.56%	8.933	80.22%	9.198	80.22%	8.573	80.22%
S132	GS3DBFS	2-yr	GS	RT	DB	FS	3.899	27.78%	4.013	27.78%	3.740	27.78%	0.960	30.44%	0.987	30.44%	0.920	30.44%
S133	GS2SB	2-yr	GS	OT	SB	WO	37.710	82.44%	38.816	82.00%	36.176	82.00%	11.004	92.22%	11.326	92.22%	10.556	92.22%
S134	GS2SBFS	2-yr	GS	OT	SB	FS	4.049	32.67%	4.167	32.22%	3.883	32.22%	1.182	42.44%	1.216	42.44%	1.133	42.44%
S135	GS2DB	2-yr	GS	OT	DB	WO	36.297	77.11%	37.375	77.11%	34.833	77.11%	8.456	77.11%	8.714	77.11%	8.121	77.11%
S136	GS2DBFS	2-yr	GS	OT	DB	FS	3.897	27.33%	4.012	27.33%	3.739	27.33%	0.909	27.33%	0.935	27.33%	0.872	27.33%
S137	GS1SB	2-yr	GS	NT	SB	WO	26.262	59.33%	26.987	59.33%	25.151	59.33%	11.226	93.56%	11.531	93.56%	10.747	93.56%
S138	GS1SBFS	2-yr	GS	NT	SB	FS	2.820	9.56%	2.897	9.56%	2.700	9.56%	1.206	43.78%	1.238	43.78%	1.154	43.78%
S139	GS1DB	2-yr	GS	NT	DB	WO	24.643	57.11%	25.333	57.11%	23.610	57.11%	7.613	70.00%	7.828	70.00%	7.295	70.00%
S140	GS1DBFS	2-yr	GS	NT	DB	FS	2.646	7.33%	2.719	7.33%	2.534	7.33%	0.818	20.67%	0.840	20.67%	0.783	20.67%
S141	WF5SB	2-yr	WF	CT	SB	WO	36.338	78.00%	37.564	78.00%	35.009	78.00%	6.846	65.11%	7.079	65.11%	6.598	65.11%
S142	WF5SBFS	2-yr	WF	CT	SB	FS	3.901	28.22%	4.032	28.22%	3.758	28.22%	0.736	15.78%	0.760	15.78%	0.708	15.78%
S143	WF5DB	2-yr	WF	CT	DB	WO	35.836	75.33%	37.056	75.78%	34.536	75.78%	6.700	64.22%	6.928	64.67%	6.457	64.67%
S144	WF5DBFS	2-yr	WF	CT	DB	FS	3.847	25.56%	3.978	26.00%	3.707	26.00%	0.720	14.89%	0.744	15.33%	0.693	15.33%
S145	WF4SB	2-yr	WF	MT	SB	WO	35.072	74.44%	36.238	74.89%	33.774	74.89%	6.650	63.33%	6.874	63.78%	6.406	63.78%
S146	WF4SBFS	2-yr	WF	MT	SB	FS	3.765	24.67%	3.890	25.11%	3.626	25.11%	0.715	14.00%	0.738	14.44%	0.688	14.44%

SCEN	Abbrev.	RTYR	CROP	TILL	FERT	BMPS	TN:SUB		TN:AGH		TN:HRU		TP:SUB		TP:AGH		TP:HRU	
S147	WF4DB	2-yr	WF	MT	DB	WO	34.576	72.67%	35.738	72.67%	33.308	72.67%	6.506	62.89%	6.725	62.89%	6.267	62.89%
S148	WF4DBFS	2-yr	WF	MT	DB	FS	3.712	22.89%	3.836	22.89%	3.576	22.89%	0.699	13.56%	0.722	13.56%	0.673	13.56%
S149	WF3SB	2-yr	WF	RT	SB	WO	26.353	59.78%	27.173	59.78%	25.325	59.78%	5.472	56.67%	5.650	57.11%	5.266	57.11%
S150	WF3SBFS	2-yr	WF	RT	SB	FS	2.829	10.00%	2.917	10.00%	2.719	10.00%	0.588	7.33%	0.607	7.78%	0.565	7.78%
S151	WF3DB	2-yr	WF	RT	DB	WO	25.912	58.00%	26.729	58.44%	24.911	58.44%	5.305	54.89%	5.477	54.89%	5.105	54.89%
S152	WF3DBFS	2-yr	WF	RT	DB	FS	2.782	8.22%	2.869	8.67%	2.674	8.67%	0.571	5.11%	0.588	5.11%	0.548	5.11%
S153	WF2SB	2-yr	WF	OT	SB	WO	31.540	66.00%	32.540	66.44%	30.328	66.44%	6.325	61.56%	6.533	61.56%	6.089	61.56%
S154	WF2SBFS	2-yr	WF	OT	SB	FS	3.386	16.22%	3.493	16.67%	3.256	16.67%	0.680	12.22%	0.701	12.22%	0.654	12.22%
S155	WF2DB	2-yr	WF	OT	DB	WO	31.540	66.44%	32.540	66.89%	30.328	66.89%	6.325	62.00%	6.533	62.00%	6.089	62.00%
S156	WF2DBFS	2-yr	WF	OT	DB	FS	3.386	16.67%	3.493	17.11%	3.256	17.11%	0.680	12.67%	0.701	12.67%	0.654	12.67%
S157	WF1SB	2-yr	WF	NT	SB	WO	23.729	55.33%	24.405	55.33%	22.746	55.33%	5.451	56.22%	5.622	56.22%	5.240	56.22%
S158	WF1SBFS	2-yr	WF	NT	SB	FS	2.548	5.56%	2.620	5.56%	2.442	5.56%	0.586	6.44%	0.604	6.89%	0.563	6.89%
S159	WF1DB	2-yr	WF	NT	DB	WO	23.294	54.89%	23.968	54.89%	22.338	54.89%	5.207	54.00%	5.371	54.00%	5.005	54.00%
S160	WF1DBFS	2-yr	WF	NT	DB	FS	2.501	5.11%	2.573	5.11%	2.398	5.11%	0.560	4.22%	0.577	4.22%	0.537	4.22%
S161	WC5SB	3-yr	WC	CT	SB	WO	46.261	90.44%	47.713	90.44%	44.468	90.44%	9.448	84.67%	9.749	84.67%	9.086	84.67%
S162	WC5SBFS	3-yr	WC	CT	SB	FS	4.967	40.67%	5.122	40.67%	4.774	40.67%	1.015	34.89%	1.047	34.89%	0.975	34.89%
S163	WC5DB	3-yr	WC	CT	DB	WO	45.238	89.56%	46.670	89.56%	43.496	89.56%	8.553	78.44%	8.825	78.44%	8.225	78.44%
S164	WC5DBFS	3-yr	WC	CT	DB	FS	4.857	39.78%	5.010	39.78%	4.669	39.78%	0.919	28.67%	0.947	28.67%	0.883	28.67%
S165	WC4SB	3-yr	WC	MT	SB	WO	41.866	84.67%	43.150	84.67%	40.216	84.67%	8.950	80.67%	9.231	81.11%	8.604	81.11%
S166	WC4SBFS	3-yr	WC	MT	SB	FS	4.495	34.89%	4.632	34.89%	4.317	34.89%	0.962	30.89%	0.991	31.33%	0.924	31.33%
S167	WC4DB	3-yr	WC	MT	DB	WO	40.841	84.22%	42.106	84.22%	39.242	84.22%	8.007	72.67%	8.258	72.67%	7.696	72.67%
S168	WC4DBFS	3-yr	WC	MT	DB	FS	4.385	34.44%	4.520	34.44%	4.213	34.44%	0.861	22.89%	0.886	22.89%	0.826	22.89%
S169	WC3SB	3-yr	WC	RT	SB	WO	33.271	71.33%	34.196	71.33%	31.870	71.33%	8.192	74.89%	8.438	74.89%	7.865	74.89%
S170	WC3SBFS	3-yr	WC	RT	SB	FS	3.572	21.56%	3.671	21.56%	3.421	21.56%	0.880	25.11%	0.906	25.11%	0.844	25.11%
S171	WC3DB	3-yr	WC	RT	DB	WO	32.236	68.22%	33.142	68.22%	30.888	68.22%	7.015	66.44%	7.226	66.00%	6.734	66.00%
S172	WC3DBFS	3-yr	WC	RT	DB	FS	3.461	18.44%	3.558	18.44%	3.316	18.44%	0.754	17.11%	0.776	16.67%	0.723	16.67%
S173	WC2SB	3-yr	WC	OT	SB	WO	36.203	76.67%	37.207	76.67%	34.677	76.67%	8.546	78.00%	8.803	78.00%	8.204	78.00%
S174	WC2SBFS	3-yr	WC	OT	SB	FS	3.887	26.89%	3.994	26.89%	3.723	26.89%	0.918	28.22%	0.945	28.22%	0.881	28.22%
S175	WC2DB	3-yr	WC	OT	DB	WO	35.049	73.56%	36.028	73.56%	33.578	73.56%	7.343	67.78%	7.563	67.78%	7.048	67.78%
S176	WC2DBFS	3-yr	WC	OT	DB	FS	3.763	23.78%	3.868	23.78%	3.605	23.78%	0.789	18.44%	0.812	18.44%	0.757	18.44%
S177	WC1SB	3-yr	WC	NT	SB	WO	27.048	60.67%	27.771	60.67%	25.882	60.67%	7.950	71.78%	8.192	71.78%	7.635	71.78%
S178	WC1SBFS	3-yr	WC	NT	SB	FS	2.904	10.89%	2.981	10.89%	2.778	10.89%	0.854	22.00%	0.879	22.00%	0.820	22.00%
S179	WC1DB	3-yr	WC	NT	DB	WO	25.312	57.56%	25.998	57.56%	24.230	57.56%	6.174	59.78%	6.362	59.78%	5.929	59.78%
S180	WC1DBFS	3-yr	WC	NT	DB	FS	2.718	7.78%	2.791	7.78%	2.601	7.78%	0.664	10.44%	0.683	10.44%	0.636	10.44%
S181	WG5SB	3-yr	WG	CT	SB	WO	44.879	88.22%	46.332	88.22%	43.181	88.22%	8.906	79.78%	9.196	79.78%	8.571	79.78%
S182	WG5SBFS	3-yr	WG	CT	SB	FS	4.818	38.44%	4.974	38.44%	4.635	38.44%	0.957	30.00%	0.987	30.00%	0.920	30.00%
S183	WG5DB	3-yr	WG	CT	DB	WO	43.745	86.44%	45.180	86.44%	42.107	86.44%	8.125	74.00%	8.388	74.00%	7.818	74.00%
S184	WG5DBFS	3-yr	WG	CT	DB	FS	4.697	36.67%	4.850	36.67%	4.520	36.67%	0.873	24.22%	0.900	24.22%	0.839	24.22%
S185	WG4SB	3-yr	WG	MT	SB	WO	36.864	78.89%	38.016	78.89%	35.431	78.89%	7.982	72.22%	8.235	72.22%	7.675	72.22%
S186	WG4SBFS	3-yr	WG	MT	SB	FS	3.958	29.11%	4.081	29.11%	3.803	29.11%	0.858	22.44%	0.884	22.44%	0.824	22.44%
S187	WG4DB	3-yr	WG	MT	DB	WO	38.588	83.33%	39.836	83.33%	37.127	83.33%	7.433	69.11%	7.673	69.11%	7.151	69.11%
S188	WG4DBFS	3-yr	WG	MT	DB	FS	4.143	33.56%	4.276	33.56%	3.986	33.56%	0.799	19.78%	0.824	19.78%	0.768	19.78%
S189	WG3SB	3-yr	WG	RT	SB	WO	30.545	63.33%	31.440	63.78%	29.302	63.78%	7.326	67.33%	7.552	67.33%	7.039	67.33%
S190	WG3SBFS	3-yr	WG	RT	SB	FS	3.279	13.56%	3.375	14.00%	3.146	14.00%	0.788	18.00%	0.811	18.00%	0.756	18.00%
S191	WG3DB	3-yr	WG	RT	DB	WO	29.448	62.00%	30.324	62.00%	28.262	62.00%	6.299	61.11%	6.492	61.11%	6.051	61.11%
S192	WG3DBFS	3-yr	WG	RT	DB	FS	3.162	12.22%	3.255	12.22%	3.034	12.22%	0.677	11.78%	0.697	11.78%	0.650	11.78%
S193	WG2SB	3-yr	WG	OT	SB	WO	33.673	72.22%	34.653	72.22%	32.297	72.22%	7.798	70.89%	8.036	70.89%	7.490	70.89%
S194	WG2SBFS	3-yr	WG	OT	SB	FS	3.615	22.44%	3.720	22.44%	3.467	22.44%	0.838	21.56%	0.863	21.56%	0.804	21.56%
S195	WG2DB	3-yr	WG	OT	DB	WO	32.459	69.11%	33.418	69.11%	31.145	69.11%	6.709	64.67%	6.914	64.22%	6.443	64.22%
S196	WG2DBFS	3-yr	WG	OT	DB	FS	3.485	19.33%	3.587	19.33%	3.343	19.33%	0.721	15.33%	0.742	14.89%	0.692	14.89%
S197	WG1SB	3-yr	WG	NT	SB	WO	23.969	55.78%	24.638	55.78%	22.963	55.78%	6.940	65.56%	7.153	65.56%	6.666	65.56%
S198	WG1SBFS	3-yr	WG	NT	SB	FS	2.574	6.00%	2.645	6.00%	2.465	6.00%	0.746	16.22%	0.768	16.22%	0.716	16.22%
S199	WG1DB	3-yr	WG	NT	DB	WO	22.490	54.00%	23.128	54.00%	21.555	54.00%	5.361	55.33%	5.527	55.33%	5.151	55.33%
S200	WG1DBFS	3-yr	WG	NT	DB	FS	2.415	4.67%	2.483	4.67%	2.314	4.67%	0.577	5.56%	0.593	5.56%	0.553	5.56%
S201	WGS5SB	3-yr	WGS	CT	SB	WO	47.964	91.78%	49.501	91.78%	46.134	91.78%	9.300	83.78%	9.601	83.78%	8.948	83.78%
S202	WGS5SBFS	3-yr	WGS	CT	SB	FS	5.149	42.00%	5.314	42.00%	4.952	42.00%	0.999	34.00%	1.031	34.00%	0.961	34.00%

SCEN	Abbrev.	RTYR	CROP	TILL	FERT	BMPS	TN:SUB		TN:AGH		TN:HRU		TP:SUB		TP:AGH		TP:HRU	
S203	WGS5DB	3-yr	WGS	CT	DB	WO	46.794	90.89%	48.315	90.89%	45.029	90.89%	8.136	74.44%	8.399	74.44%	7.828	74.44%
S204	WGS5DBFS	3-yr	WGS	CT	DB	FS	5.024	41.11%	5.187	41.11%	4.834	41.11%	0.874	24.67%	0.902	24.67%	0.840	24.67%
S205	WGS4SB	3-yr	WGS	MT	SB	WO	38.746	83.78%	39.938	83.78%	37.222	83.78%	8.372	75.78%	8.636	76.22%	8.049	76.22%
S206	WGS4SBFS	3-yr	WGS	MT	SB	FS	4.160	34.00%	4.287	34.00%	3.996	34.00%	0.900	26.00%	0.927	26.44%	0.864	26.44%
S207	WGS4DB	3-yr	WGS	MT	DB	WO	37.693	82.00%	38.869	82.44%	36.225	82.44%	7.012	66.00%	7.234	66.44%	6.742	66.44%
S208	WGS4DBFS	3-yr	WGS	MT	DB	FS	4.047	32.22%	4.172	32.67%	3.889	32.67%	0.754	16.67%	0.777	17.11%	0.724	17.11%
S209	WGS3SB	3-yr	WGS	RT	SB	WO	33.189	70.89%	34.153	70.89%	31.830	70.89%	8.460	77.56%	8.716	77.56%	8.123	77.56%
S210	WGS3SBFS	3-yr	WGS	RT	SB	FS	3.563	21.11%	3.666	21.11%	3.417	21.11%	0.909	27.78%	0.936	27.78%	0.872	27.78%
S211	WGS3DB	3-yr	WGS	RT	DB	WO	32.149	67.78%	33.095	67.78%	30.845	67.78%	6.656	63.78%	6.859	63.33%	6.393	63.33%
S212	WGS3DBFS	3-yr	WGS	RT	DB	FS	3.452	18.00%	3.553	18.00%	3.311	18.00%	0.716	14.44%	0.736	14.00%	0.686	14.00%
S213	WGS2SB	3-yr	WGS	OT	SB	WO	38.460	82.89%	39.633	82.89%	36.937	82.89%	9.138	82.89%	9.424	82.89%	8.784	82.89%
S214	WGS2SBFS	3-yr	WGS	OT	SB	FS	4.129	33.11%	4.255	33.11%	3.965	33.11%	0.982	33.11%	1.012	33.11%	0.943	33.11%
S215	WGS2DB	3-yr	WGS	OT	DB	WO	37.355	79.78%	38.508	80.22%	35.889	80.22%	7.366	68.22%	7.600	68.22%	7.083	68.22%
S216	WGS2DBFS	3-yr	WGS	OT	DB	FS	4.011	30.00%	4.134	30.44%	3.853	30.44%	0.792	18.89%	0.816	18.89%	0.760	18.89%
S217	WGS1SB	3-yr	WGS	NT	SB	WO	25.994	58.44%	26.725	58.00%	24.907	58.00%	9.080	82.00%	9.350	82.00%	8.714	82.00%
S218	WGS1SBFS	3-yr	WGS	NT	SB	FS	2.791	8.67%	2.869	8.22%	2.674	8.22%	0.976	32.22%	1.004	32.22%	0.935	32.22%
S219	WGS1DB	3-yr	WGS	NT	DB	WO	24.548	56.22%	25.247	56.67%	23.530	56.67%	5.991	58.89%	6.174	58.89%	5.755	58.89%
S220	WGS1DBFS	3-yr	WGS	NT	DB	FS	2.636	6.44%	2.710	6.89%	2.526	6.89%	0.644	9.56%	0.663	9.56%	0.618	9.56%
S221	NPBBLS	1-yr	BBLS	NP	NA	WO	2.117	2.44%	2.178	2.44%	2.029	2.44%	0.326	2.00%	0.335	2.00%	0.313	2.00%
S222	NPSWCH	1-yr	SWCH	NP	NA	WO	1.578	2.00%	1.615	2.00%	1.506	2.00%	0.351	2.44%	0.359	2.44%	0.335	2.44%
S223	NPFESC	1-yr	FESC	NP	NA	WO	2.333	3.78%	2.388	3.78%	2.225	3.78%	0.587	6.89%	0.601	6.44%	0.560	6.44%
S224	FSGZS0	1-yr	FESC	MO	NA	WO	12.496	51.33%	12.825	51.33%	11.953	51.33%	1.989	50.44%	2.042	50.44%	1.903	50.44%
S225	FSGZS1	1-yr	FESC	MO	NA	WO	22.609	54.44%	23.154	54.44%	21.579	54.44%	7.869	71.33%	8.060	71.33%	7.512	71.33%

Table C-2 Top and Bottom 20 Scenarios of Watershed Level Nutrient Loads

Stats	TN:SUB	TN:AGH	TN:HRU	TP:SUB	TP:AGH	TP:HRU
N	10296	43416	46584	10296	43416	46584
Min	1.266	1.308	1.219	0.243	0.250	0.233
Max	78.889	81.267	75.740	13.809	14.195	13.230

	TN Load Top 20			TN Load Bottom 20				TP Load Top 20			TP Load Bottom 20		
#	SUB	AGH	HRU	SUB	AGH	HRU	#	SUB	AGH	HRU	SUB	AGH	HRU
1	S23	S23	S23	S92	S92	S92	1	S37	S37	S37	S92	S92	S92
2	S21	S21	S21	S100	S100	S100	2	S29	S29	S29	S100	S100	S100
3	S25	S25	S25	S90	S90	S90	3	S33	S33	S33	S90	S90	S90
4	S27	S27	S27	S98	S98	S98	4	S25	S25	S25	S98	S98	S98
5	S1	S1	S1	S222	S222	S222	5	S21	S21	S21	S221	S221	S221
6	S29	S29	S29	S221	S221	S221	6	S9	S23	S23	S222	S222	S222
7	S3	S3	S3	S96	S96	S96	7	S23	S9	S9	S96	S96	S96
8	S41	S41	S41	S94	S94	S94	8	S17	S17	S17	S94	S94	S94
9	S31	S31	S31	S223	S223	S223	9	S13	S13	S13	S84	S84	S84
10	S43	S43	S43	S80	S80	S80	10	S5	S5	S5	S160	S160	S160
11	S121	S121	S121	S200	S200	S200	11	S1	S1	S1	S108	S108	S108
12	S61	S61	S61	S160	S160	S160	12	S129	S129	S129	S152	S152	S152
13	S123	S123	S123	S158	S158	S158	13	S41	S41	S41	S200	S200	S200
14	S33	S33	S33	S198	S198	S198	14	S121	S121	S121	S88	S88	S88
15	S63	S63	S63	S220	S78	S78	15	S137	S137	S137	S158	S223	S223
16	S5	S5	S5	S78	S220	S220	16	S69	S69	S69	S223	S158	S158
17	S7	S7	S7	S140	S140	S140	17	S77	S77	S77	S150	S82	S82
18	S35	S35	S35	S180	S180	S180	18	S133	S133	S133	S82	S150	S150
19	S201	S201	S201	S152	S218	S218	19	S61	S61	S61	S112	S112	S112
20	S37	S37	S37	S218	S152	S152	20	S125	S125	S125	S116	S116	S116

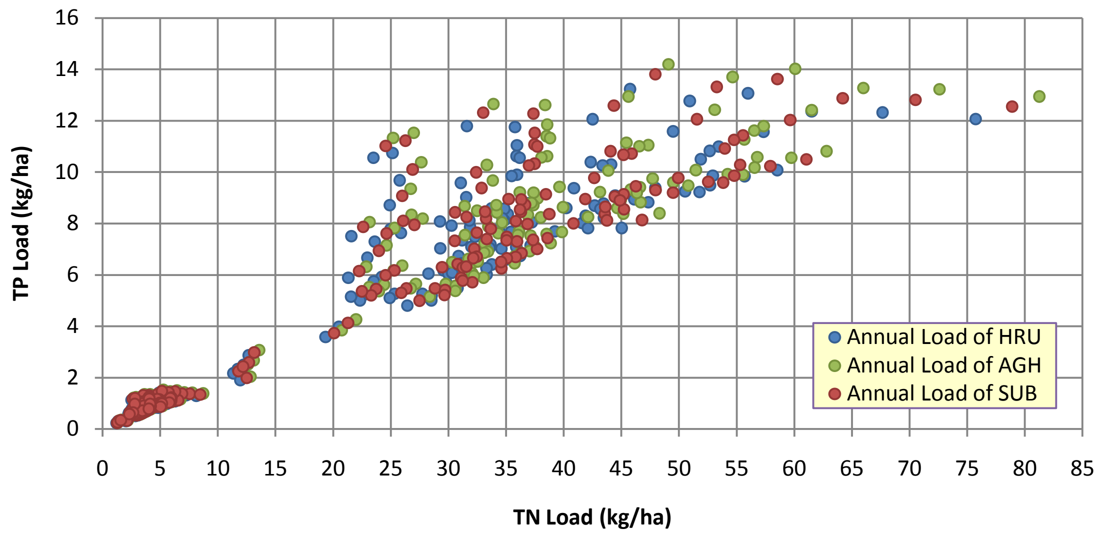


Figure C-1 Watershed Level Nutrient Load Distribution of Different Data Subsets

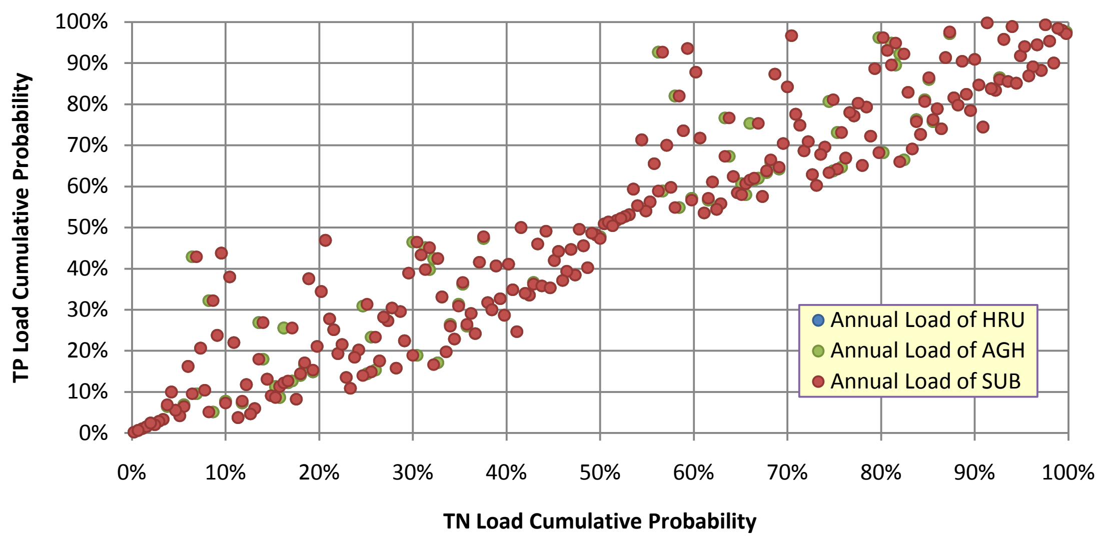


Figure C-2 Cumulative Probability Distribution of Different Data Subsets

SWAT models VFS with an empirical equation (Eq. 3-19). While the width of filed strip in each scenario is fixed, the nutrient load trapping efficiency is then also fixed around 90%. Therefore, if the difference between two scenarios is only the "with" and "without" VFS, the modeling output would be similar: the loads of "with VFS" scenario is almost one-tenth of the load of "without VFS" scenario.

To prevent un-willing results in post analyses, we dropped the "with VFS" scenarios from the analyzing dataset. The watershed level nutrient loads of without VFS scenarios were drawn as Figure C-3, and the cumulative probability of "without VFS" scenarios on watershed level nutrient load were drawn as Figure C-4. Ranking the nutrient loads of all scenarios excluded "with VFS", the top and bottom scenarios for maximum and minimum nutrient loads were listed in Table C-3. For scenarios in Table C-3, three grass scenarios (S221, S222, and S223) intend to produce the lower TN and TP loads than the others. The tall fescue with mowing scenario (S224) also performs good removal efficiency in nutrient load. However, the tall fescue with mowing and grazing events (S225), which has fresh manure applied on the ground after the fall harvesting, will produce more TP than the other scenarios.

Furthermore, as described previously, the patterns of scenario distribution in Figure C-4 for each data subset are similar; any one of three data subset can represent the trend for the others. However, some scenarios with a high ranking TN loads may not be also high in TP load. This might be caused by the solubility of TN and TP fertilizer as well as the method of fertilizer application.

In conclusion, the top and bottom scenarios of potential nutrient load are the high priority alternative scenarios for studying nutrient load reduction. The higher nutrient load scenarios represent a higher priority in trading list to maximize the load reduction by the other scenarios. However, the watershed level nutrient load comparisons only provide the rough trends for assessment. More detail subbasin level information is necessary for the assessment of an actual trade.

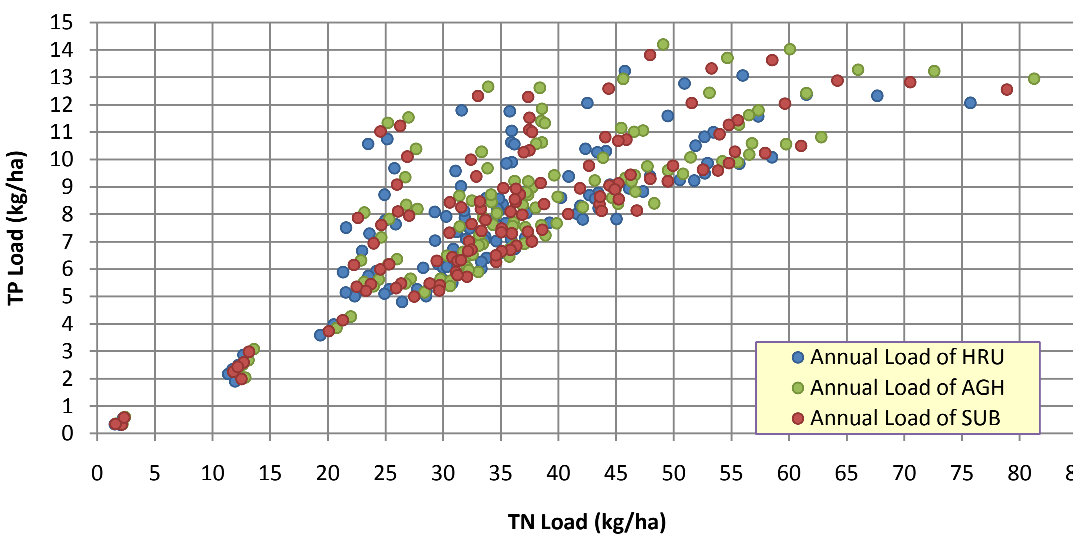


Figure C-3 Nutrient Load Distribution of "without VFS" Scenarios

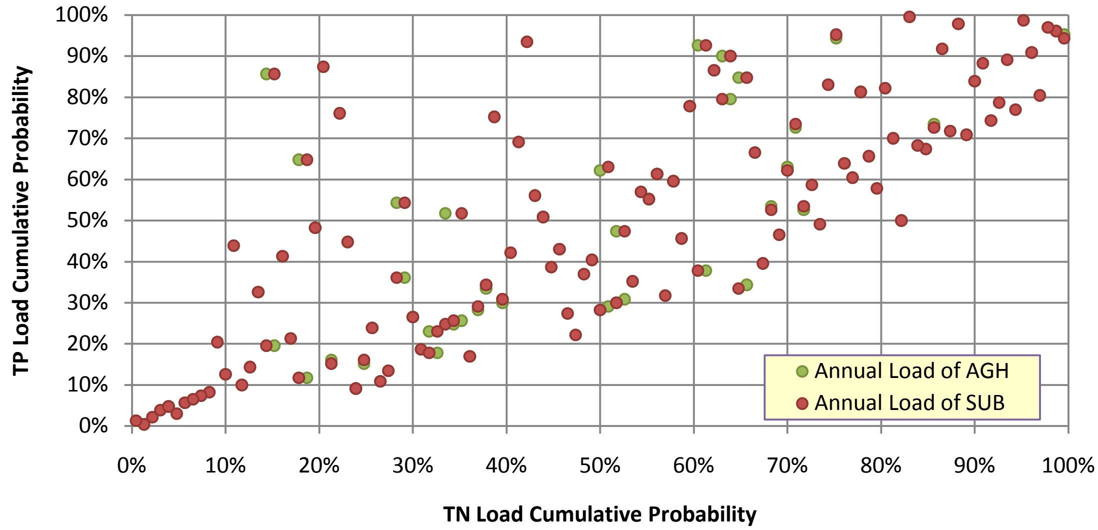


Figure C-4 Cumulative Probability Distribution of "without VFS" Scenarios

Table C-3 Top and Bottom 20 Annual Nutrient Loads of "without VFS" Scenarios

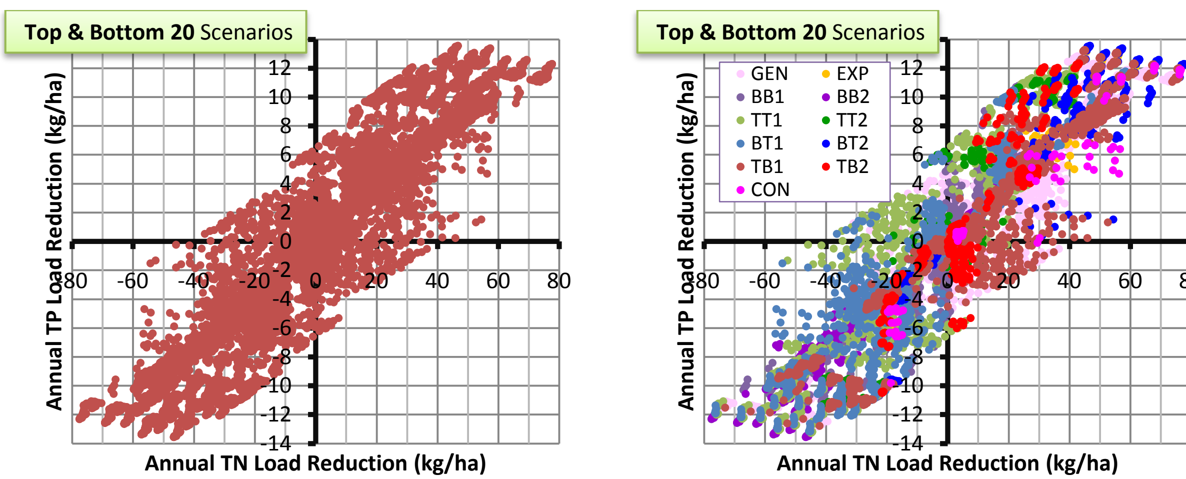
Stats	TN:SUB	TN:AGH	TN:HRU	TP:SUB	TP:AGH	TP:HRU
N	10296	43416	46584	10296	43416	46584
Min	1.578	1.615	1.506	0.326	0.335	0.313
Max	78.889	81.267	75.740	13.809	14.195	13.230

	TN Load Top 20			TN Load Bottom 20		
#	SUB	AGH	HRU	SUB	AGH	HRU
1	S23	S23	S23	S222	S222	S222
2	S21	S21	S21	S221	S221	S221
3	S25	S25	S25	S223	S223	S223
4	S27	S27	S27	S91	S91	S91
5	S1	S1	S1	S99	S99	S99
6	S29	S29	S29	S224	S224	S224
7	S3	S3	S3	S89	S89	S89
8	S41	S41	S41	S97	S97	S97
9	S31	S31	S31	S95	S95	S95
10	S43	S43	S43	S93	S93	S93
11	S121	S121	S121	S79	S79	S79
12	S61	S61	S61	S199	S199	S199
13	S123	S123	S123	S225	S225	S225
14	S33	S33	S33	S159	S159	S159
15	S63	S63	S63	S157	S157	S157
16	S5	S5	S5	S197	S197	S197
17	S7	S7	S7	S219	S77	S77
18	S35	S35	S35	S77	S219	S219
19	S201	S201	S201	S139	S139	S139
20	S37	S37	S37	S179	S179	S179

	TP Load Top 20			TP Load Bottom 20		
#	SUB	AGH	HRU	SUB	AGH	HRU
1	S37	S37	S37	S221	S221	S221
2	S29	S29	S29	S222	S222	S222
3	S33	S33	S33	S223	S223	S223
4	S25	S25	S25	S224	S224	S224
5	S21	S21	S21	S91	S91	S91
6	S9	S23	S23	S99	S99	S99
7	S23	S9	S9	S89	S89	S89
8	S17	S17	S17	S97	S97	S97
9	S13	S13	S13	S95	S95	S95
10	S5	S5	S5	S93	S93	S93
11	S1	S1	S1	S83	S83	S83
12	S129	S129	S129	S159	S159	S159
13	S41	S41	S41	S107	S107	S107
14	S121	S121	S121	S151	S151	S151
15	S137	S137	S137	S199	S199	S199
16	S69	S69	S69	S87	S87	S87
17	S77	S77	S77	S157	S157	S157
18	S133	S133	S133	S149	S81	S81
19	S61	S61	S61	S81	S149	S149
20	S125	S125	S125	S111	S111	S111

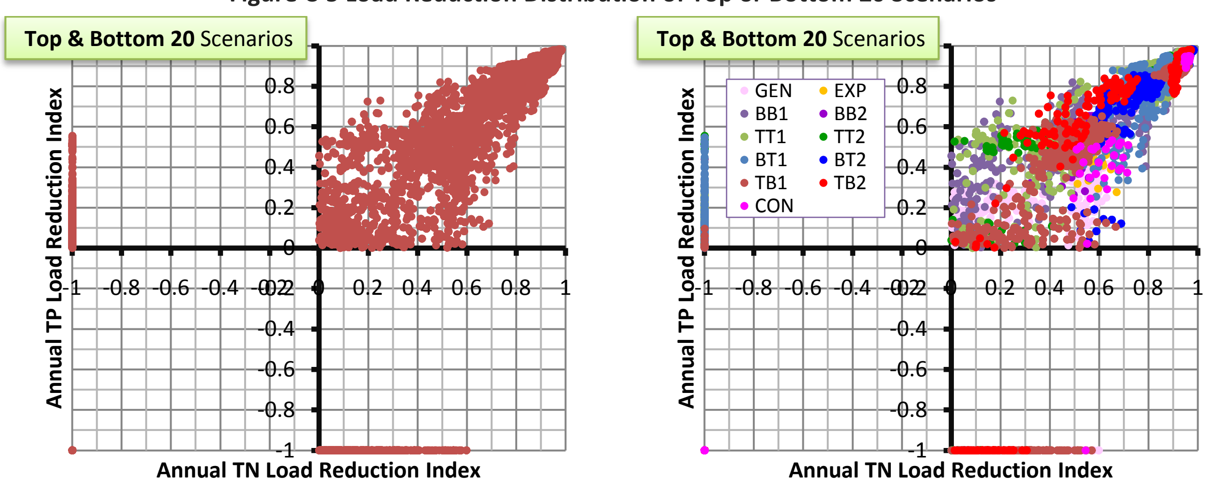
C.2 Potential Annual Nutrient Load Reduction

As discussed in Section: 3.5.2, Figure 3-12 (a) illustrates the potential watershed level nutrient load reduction for 225x225 scenario pairs and Figure 3-12 (b) displays the distribution of relative load reduction index for all scenario pairs. For the subset of only top and bottom 20 annual nutrient load scenarios, Figure C-5 (a) have more clearly NE-SW 45 degree trend than Figure 3-12 (a). Figure C-5 (b) classified the dots of Figure C-5 (a) into eleven. Figure C-6 illustrates the relative load reduction indexes for the same data subset. For an individual category of dots in Figure C-5 (b) and Figure C-6 (b), it seems some clusters exist. If we draw the scenarios in top to top (TT), top to bottom (TB), bottom to top (BT), bottom to bottom (BB) and others in five groups, the distributions of nutrient load reduction and reduction index, a clear trend for each group of scenarios can be found in Figure C-7 and Figure C-8.



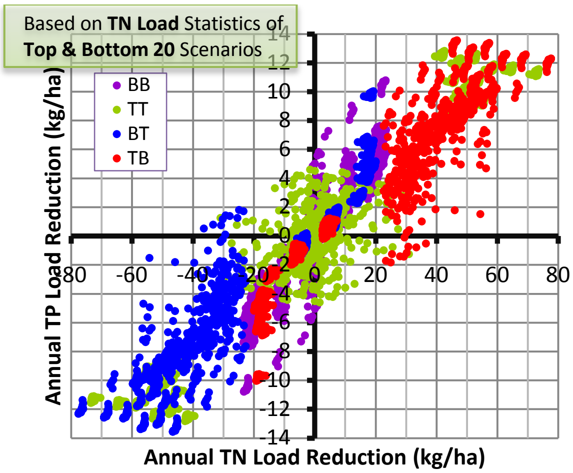
(a) Load Reduction **(b) Load Reduction Classified by Statistics Group**

Figure C-5 Load Reduction Distribution of Top or Bottom 20 Scenarios

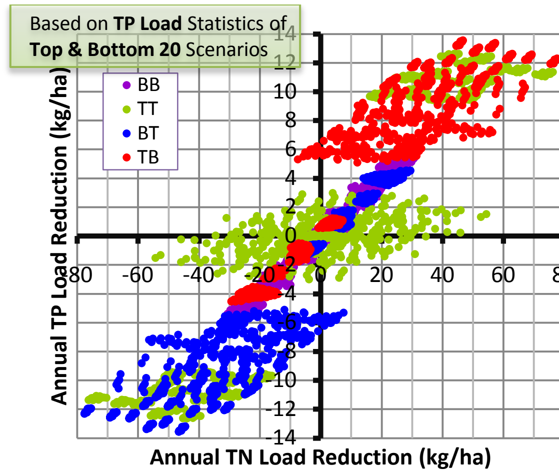


(a) Load Reduction Index **(b) Load Reduction Index Classified by Statistics Group**

Figure C-6 Load Reduction Index Distribution of Top or Bottom 20 Scenarios

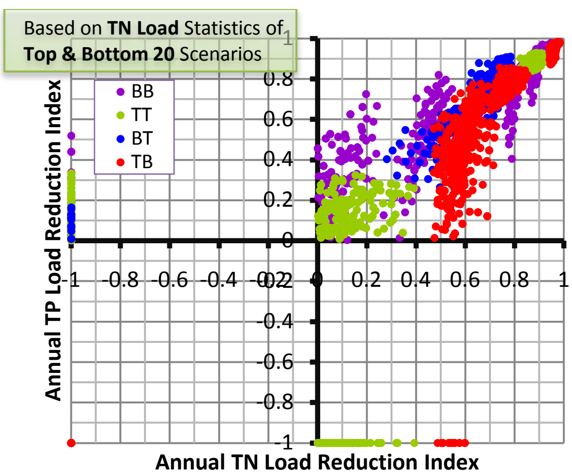


(a) Classified by TN Load

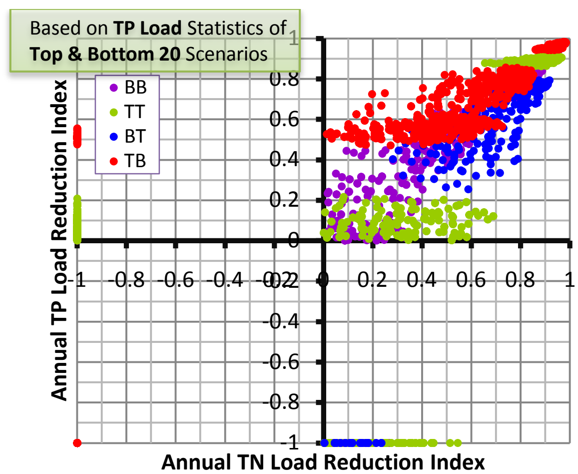


(b) Classified by TP Load

Figure C-7 Load Reduction Distribution of Top-Bottom 20 Scenarios



(a) Classified by TN Load



(b) Classified by TP Load

Figure C-8 Load Reduction Index Distribution of Top-Bottom 20 Scenarios

Table C-4 lists the statistics of potential nutrient load reduction and reduction index for the modeling scenarios, the top 50 nutrient load reductions and reduction indexes are also tabulated in Table C-5 through Table C-8. In these tables, S23, S21, S25, S27, and S1 provide the most top TN load reductions to the other alternative scenarios; S37, S29, S33, S25, and S21 dominant the top TP load reduction. However, there is no obvious trend in load reduction index statistics.

Table C-4 Load Reduction and Reduction Index Statistics of Modeling Scenarios

	Full Scenario Set				"without VFS" & Grass Scenarios			
Parameters	**TN Load**	**TP Load**	**TNRI**	**TPRI**	**TN Load**	**TP Load**	**TNRI**	**TPRI**
N	50625	50625	50625	50625	13225	13225	13225	13225
Max	77.623	13.565	0.98395	0.98237	77.312	13.483	0.98000	0.97643

Table C-5 Top 50 TN Load Reduction Scenarios

										TN Rank			
Scenario		Aggregated (Current-Alternative)				Cumulative Probability				Top Ranking			
CUR	ALT	CROP	TILL	FERT	BMPS	TN	TP	TNRI	TPRI	TN	TP	TNRI	TPRI
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	99.996%	99.860%	99.996%	99.868%	1	19	1	18
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	99.989%	99.868%	99.958%	99.936%	2	18	6	9
23	223	C-FESC	CT-NP	DB-NA	WO-WO	99.981%	99.830%	99.890%	98.854%	3	23	15	152
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	99.974%	99.905%	99.989%	99.883%	4	13	2	16
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	99.966%	99.913%	99.875%	99.966%	5	12	17	5
21	223	C-FESC	CT-NP	SB-NA	WO-WO	99.958%	99.875%	99.815%	98.900%	6	17	25	146
23	91	C-W	CT-RT	DB-DB	WO-WO	99.951%	99.331%	97.531%	97.312%	7	89	327	356
23	99	C-W	CT-NT	DB-DB	WO-WO	99.943%	99.263%	97.524%	97.153%	8	98	328	377
23	224	C-FESC	CT-MO	DB-NA	WO-WO	99.936%	99.452%	97.516%	97.463%	9	73	329	336
23	89	C-W	CT-RT	DB-SB	WO-WO	99.928%	99.180%	97.501%	96.964%	10	109	331	402
23	97	C-W	CT-NT	DB-SB	WO-WO	99.921%	98.960%	97.486%	96.442%	11	138	333	471
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	99.913%	99.921%	99.981%	99.890%	12	11	3	15
25	221	C-BBLS	MT-NP	SB-NA	WO-WO	99.905%	99.928%	99.822%	99.974%	13	10	24	4
25	223	C-FESC	MT-NP	SB-NA	WO-WO	99.898%	99.898%	99.686%	98.907%	14	14	42	145
27	222	C-SWCH	MT-NP	DB-NA	WO-WO	99.890%	99.278%	99.974%	99.588%	15	96	4	55
27	221	C-BBLS	MT-NP	DB-NA	WO-WO	99.883%	99.293%	99.784%	99.732%	16	94	29	36
23	95	C-W	CT-OT	DB-DB	WO-WO	99.875%	98.529%	96.767%	95.293%	17	195	428	623
21	91	C-W	CT-RT	SB-DB	WO-WO	99.868%	99.459%	97.478%	97.372%	18	72	334	348
27	223	C-FESC	MT-NP	DB-NA	WO-WO	99.860%	99.149%	99.648%	98.446%	19	113	47	206
21	99	C-W	CT-NT	SB-DB	WO-WO	99.853%	99.391%	97.463%	97.198%	20	81	336	371
1	222	CS-SWCH	CT-NP	SB-NA	WO-WO	99.845%	99.762%	99.966%	99.807%	21	32	5	26
21	224	C-FESC	CT-MO	SB-NA	WO-WO	99.837%	99.580%	97.448%	97.493%	22	56	338	332
21	89	C-W	CT-RT	SB-SB	WO-WO	99.830%	99.301%	97.425%	97.032%	23	93	341	393
23	93	C-W	CT-OT	DB-SB	WO-WO	99.822%	98.106%	96.571%	94.696%	24	251	454	702
1	221	CS-BBLS	CT-NP	SB-NA	WO-WO	99.815%	99.777%	99.747%	99.898%	25	30	34	14
21	97	C-W	CT-NT	SB-SB	WO-WO	99.807%	99.096%	97.403%	96.556%	26	120	344	456
1	223	CS-FESC	CT-NP	SB-NA	WO-WO	99.800%	99.732%	99.611%	98.741%	27	36	52	167
29	222	C-SWCH	RT-NP	SB-NA	WO-WO	99.792%	99.974%	99.951%	99.951%	28	4	7	7
23	79	C-G	CT-NT	DB-DB	WO-WO	99.784%	94.612%	96.352%	90.786%	29	713	483	1219
29	221	C-BBLS	RT-NP	SB-NA	WO-WO	99.777%	99.981%	99.709%	99.989%	30	3	39	2
23	199	C-WG	CT-NT	DB-DB	WO-WO	99.769%	96.359%	96.314%	92.790%	31	482	488	954
3	222	CS-SWCH	CT-NP	DB-NA	WO-WO	99.762%	99.112%	99.943%	99.543%	32	118	8	61
23	225	C-FESC	CT-MO	DB-NA	WO-WO	99.754%	88.238%	96.261%	83.323%	33	1556	495	2206
29	223	C-FESC	RT-NP	SB-NA	WO-WO	99.747%	99.958%	99.580%	99.043%	34	6	56	127
3	221	CS-BBLS	CT-NP	DB-NA	WO-WO	99.739%	99.142%	99.679%	99.679%	35	114	43	43
23	159	C-WF	CT-NT	DB-DB	WO-WO	99.732%	96.624%	96.163%	93.093%	36	447	508	914
3	223	CS-FESC	CT-NP	DB-NA	WO-WO	99.724%	99.006%	99.573%	98.378%	37	132	57	215
23	157	C-WF	CT-NT	DB-SB	WO-WO	99.716%	96.132%	96.102%	92.616%	38	512	516	977
23	197	C-WG	CT-NT	DB-SB	WO-WO	99.709%	92.102%	96.064%	88.011%	39	1045	521	1586
23	219	C-WGS	CT-NT	DB-DB	WO-WO	99.701%	94.953%	96.011%	91.323%	40	668	528	1148
23	77	C-G	CT-NT	DB-SB	WO-WO	99.694%	65.592%	96.004%	61.183%	41	4551	529	5134
23	139	C-GS	CT-NT	DB-DB	WO-WO	99.686%	89.524%	95.996%	84.783%	42	1386	530	2013
41	222	S-SWCH	CT-NP	SB-NA	WO-WO	99.679%	99.664%	99.936%	99.739%	43	45	9	35
31	222	C-SWCH	RT-NP	DB-NA	WO-WO	99.671%	99.164%	99.928%	99.558%	44	111	10	59
23	179	C-WC	CT-NT	DB-DB	WO-WO	99.664%	94.544%	95.860%	90.696%	45	722	548	1231
41	221	S-BBLS	CT-NP	SB-NA	WO-WO	99.656%	99.671%	99.656%	99.853%	46	44	46	20
41	223	S-FESC	CT-NP	SB-NA	WO-WO	99.648%	99.588%	99.512%	98.665%	47	55	65	177
43	222	S-SWCH	CT-NP	DB-NA	WO-WO	99.641%	98.930%	99.921%	99.490%	48	142	11	68
31	221	C-BBLS	RT-NP	DB-NA	WO-WO	99.633%	99.187%	99.641%	99.701%	49	108	48	40
121	222	GS-SWCH	CT-NP	SB-NA	WO-WO	99.626%	99.626%	99.913%	99.724%	50	50	12	37

Table C-6 Top 50 TP Load Reduction Scenarios

Scenario		Aggregated (Current-Alternative)				Cumulative Probability				TP Rank Top Ranking			
CUR	ALT	AGCROP	AGTILL	AGFERT	AGBMPS	TN	TP	TNRI	TPRI	TN	TP	TNRI	TPRI
37	221	C-BBLS	NT-NP	SB-NA	WO-WO	98.945%	99.996%	99.323%	99.996%	140	1	90	1
37	222	C-SWCH	NT-NP	SB-NA	WO-WO	99.028%	99.989%	99.830%	99.958%	129	2	23	6
29	221	C-BBLS	RT-NP	SB-NA	WO-WO	99.777%	99.981%	99.709%	99.989%	30	3	39	2
29	222	C-SWCH	RT-NP	SB-NA	WO-WO	99.792%	99.974%	99.951%	99.951%	28	4	7	7
37	223	C-FESC	NT-NP	SB-NA	WO-WO	98.907%	99.966%	99.074%	99.081%	145	5	123	122
29	223	C-FESC	RT-NP	SB-NA	WO-WO	99.747%	99.958%	99.580%	99.043%	34	6	56	127
33	221	C-BBLS	OT-NP	SB-NA	WO-WO	99.437%	99.951%	99.588%	99.981%	75	7	55	3
33	222	C-SWCH	OT-NP	SB-NA	WO-WO	99.474%	99.943%	99.883%	99.928%	70	8	16	10
33	223	C-FESC	OT-NP	SB-NA	WO-WO	99.414%	99.936%	99.361%	98.968%	78	9	85	137
25	221	C-BBLS	MT-NP	SB-NA	WO-WO	99.905%	99.928%	99.822%	99.974%	13	10	24	4
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	99.913%	99.921%	99.981%	99.890%	12	11	3	15
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	99.966%	99.913%	99.875%	99.966%	5	12	17	5
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	99.974%	99.905%	99.989%	99.883%	4	13	2	16
25	223	C-FESC	MT-NP	SB-NA	WO-WO	99.898%	99.898%	99.686%	98.907%	14	14	42	145
9	221	CS-BBLS	RT-NP	SB-NA	WO-WO	98.371%	99.890%	99.149%	99.943%	216	15	113	8
9	222	CS-SWCH	RT-NP	SB-NA	WO-WO	98.484%	99.883%	99.732%	99.875%	201	16	36	17
21	223	C-FESC	CT-NP	SB-NA	WO-WO	99.958%	99.875%	99.815%	98.900%	6	17	25	146
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	99.989%	99.868%	99.958%	99.936%	2	18	6	9
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	99.996%	99.860%	99.996%	99.868%	1	19	1	18
9	223	CS-FESC	RT-NP	SB-NA	WO-WO	98.287%	99.853%	98.885%	98.862%	227	20	148	151
17	221	CS-BBLS	NT-NP	SB-NA	WO-WO	94.749%	99.845%	98.393%	99.921%	695	21	213	11
17	222	CS-SWCH	NT-NP	SB-NA	WO-WO	95.051%	99.837%	99.142%	99.845%	655	22	114	21
23	223	C-FESC	CT-NP	DB-NA	WO-WO	99.981%	99.830%	99.890%	98.854%	3	23	15	152
13	221	CS-BBLS	OT-NP	SB-NA	WO-WO	96.904%	99.822%	98.741%	99.913%	410	24	167	12
13	222	CS-SWCH	OT-NP	SB-NA	WO-WO	97.123%	99.815%	99.474%	99.837%	381	25	70	22
37	224	C-FESC	NT-MO	SB-NA	WO-WO	97.017%	99.807%	96.715%	97.539%	395	26	435	326
5	221	CS-BBLS	MT-NP	SB-NA	WO-WO	99.361%	99.800%	99.535%	99.905%	85	27	62	13
17	223	CS-FESC	NT-NP	SB-NA	WO-WO	94.620%	99.792%	98.083%	98.809%	712	28	254	158
5	222	CS-SWCH	MT-NP	SB-NA	WO-WO	99.376%	99.784%	99.860%	99.815%	83	29	19	25
1	221	CS-BBLS	CT-NP	SB-NA	WO-WO	99.815%	99.777%	99.747%	99.898%	25	30	34	14
13	223	CS-FESC	OT-NP	SB-NA	WO-WO	96.798%	99.769%	98.469%	98.794%	424	31	203	160
1	222	CS-SWCH	CT-NP	SB-NA	WO-WO	99.845%	99.762%	99.966%	99.807%	21	32	5	26
29	224	C-FESC	RT-MO	SB-NA	WO-WO	99.006%	99.754%	97.236%	97.516%	132	33	366	329
37	91	C-W	NT-RT	SB-DB	WO-WO	97.214%	99.747%	96.851%	97.440%	369	34	417	339
5	223	CS-FESC	MT-NP	SB-NA	WO-WO	99.331%	99.739%	99.270%	98.749%	89	35	97	166
1	223	CS-FESC	CT-NP	SB-NA	WO-WO	99.800%	99.732%	99.611%	98.741%	27	36	52	167
37	99	C-W	NT-NT	SB-DB	WO-WO	97.100%	99.724%	96.783%	97.365%	384	37	426	349
29	91	C-W	RT-RT	SB-DB	WO-WO	99.096%	99.716%	97.327%	97.410%	120	38	354	343
33	224	C-FESC	OT-MO	SB-NA	WO-WO	97.992%	99.709%	96.987%	97.509%	266	39	399	330
37	89	C-W	NT-RT	SB-SB	WO-WO	96.881%	99.701%	96.654%	97.221%	413	40	443	368
129	221	GS-BBLS	RT-NP	SB-NA	WO-WO	96.987%	99.694%	98.764%	99.860%	399	41	164	19
29	99	C-W	RT-NT	SB-DB	WO-WO	99.021%	99.686%	97.282%	97.335%	130	42	360	353
129	222	GS-SWCH	RT-NP	SB-NA	WO-WO	97.146%	99.679%	99.505%	99.754%	378	43	66	33
41	221	S-BBLS	CT-NP	SB-NA	WO-WO	99.656%	99.671%	99.656%	99.853%	46	44	46	20
41	222	S-SWCH	CT-NP	SB-NA	WO-WO	99.679%	99.664%	99.936%	99.739%	43	45	9	35
33	91	C-W	OT-RT	SB-DB	WO-WO	98.151%	99.656%	97.146%	97.403%	245	46	378	344
29	89	C-W	RT-RT	SB-SB	WO-WO	98.953%	99.648%	97.198%	97.191%	139	47	371	372
129	223	GS-FESC	RT-NP	SB-NA	WO-WO	96.866%	99.641%	98.499%	98.681%	415	48	199	175
121	221	GS-BBLS	CT-NP	SB-NA	WO-WO	99.580%	99.633%	99.618%	99.830%	56	49	51	23
121	222	GS-SWCH	CT-NP	SB-NA	WO-WO	99.626%	99.626%	99.913%	99.724%	50	50	12	37

Table C-7 Top 50 TN Load Reduction Index (TNRI) Scenarios

Scenario		Aggregated (Current-Alternative)				Cumulative Probability				TNRI Rank Top Ranking			
CUR	ALT	AGCROP	AGTILL	AGFERT	AGBMPS	TN	TP	TNRI	TPRI	TN	TP	TNRI	TPRI
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	99.996%	99.860%	99.996%	99.868%	1	19	1	18
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	99.974%	99.905%	99.989%	99.883%	4	13	2	16
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	99.913%	99.921%	99.981%	99.890%	12	11	3	15
27	222	C-SWCH	MT-NP	DB-NA	WO-WO	99.890%	99.278%	99.974%	99.588%	15	96	4	55
1	222	CS-SWCH	CT-NP	SB-NA	WO-WO	99.845%	99.762%	99.966%	99.807%	21	32	5	26
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	99.989%	99.868%	99.958%	99.936%	2	18	6	9
29	222	C-SWCH	RT-NP	SB-NA	WO-WO	99.792%	99.974%	99.951%	99.951%	28	4	7	7
3	222	CS-SWCH	CT-NP	DB-NA	WO-WO	99.762%	99.112%	99.943%	99.543%	32	118	8	61
41	222	S-SWCH	CT-NP	SB-NA	WO-WO	99.679%	99.664%	99.936%	99.739%	43	45	9	35
31	222	C-SWCH	RT-NP	DB-NA	WO-WO	99.671%	99.164%	99.928%	99.558%	44	111	10	59
43	222	S-SWCH	CT-NP	DB-NA	WO-WO	99.641%	98.930%	99.921%	99.490%	48	142	11	68
121	222	GS-SWCH	CT-NP	SB-NA	WO-WO	99.626%	99.626%	99.913%	99.724%	50	50	12	37
61	222	G-SWCH	CT-NP	SB-NA	WO-WO	99.535%	99.467%	99.905%	99.656%	62	71	13	46
123	222	GS-SWCH	CT-NP	DB-NA	WO-WO	99.527%	98.794%	99.898%	99.399%	63	160	14	80
23	223	C-FESC	CT-NP	DB-NA	WO-WO	99.981%	99.830%	99.890%	98.854%	3	23	15	152
33	222	C-SWCH	OT-NP	SB-NA	WO-WO	99.474%	99.943%	99.883%	99.928%	70	8	16	10
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	99.966%	99.913%	99.875%	99.966%	5	12	17	5
63	222	G-SWCH	CT-NP	DB-NA	WO-WO	99.422%	98.824%	99.868%	99.414%	77	156	18	78
5	222	CS-SWCH	MT-NP	SB-NA	WO-WO	99.376%	99.784%	99.860%	99.815%	83	29	19	25
7	222	CS-SWCH	MT-NP	DB-NA	WO-WO	99.301%	98.870%	99.853%	99.452%	93	150	20	73
35	222	C-SWCH	OT-NP	DB-NA	WO-WO	99.240%	98.567%	99.845%	99.338%	101	190	21	88
201	222	WGS-SWCH	CT-NP	SB-NA	WO-WO	99.036%	98.612%	99.837%	99.361%	128	184	22	85
37	222	C-SWCH	NT-NP	SB-NA	WO-WO	99.028%	99.989%	99.830%	99.958%	129	2	23	6
25	221	C-BBLS	MT-NP	SB-NA	WO-WO	99.905%	99.928%	99.822%	99.974%	13	10	24	4
21	223	C-FESC	CT-NP	SB-NA	WO-WO	99.958%	99.875%	99.815%	98.900%	6	17	25	146
203	222	WGS-SWCH	CT-NP	DB-NA	WO-WO	98.870%	97.282%	99.807%	99.036%	150	360	26	128
161	222	WC-SWCH	CT-NP	SB-NA	WO-WO	98.839%	98.733%	99.800%	99.391%	154	168	27	81
45	222	S-SWCH	MT-NP	SB-NA	WO-WO	98.794%	99.384%	99.792%	99.626%	160	82	28	50
27	221	C-BBLS	MT-NP	DB-NA	WO-WO	99.883%	99.293%	99.784%	99.732%	16	94	29	36
163	222	WC-SWCH	CT-NP	DB-NA	WO-WO	98.688%	97.841%	99.777%	99.149%	174	286	30	113
47	222	S-SWCH	MT-NP	DB-NA	WO-WO	98.681%	98.476%	99.769%	99.323%	175	202	31	90
65	222	G-SWCH	MT-NP	SB-NA	WO-WO	98.665%	99.346%	99.762%	99.618%	177	87	32	51
181	222	WG-SWCH	CT-NP	SB-NA	WO-WO	98.628%	98.242%	99.754%	99.240%	182	233	33	101
1	221	CS-BBLS	CT-NP	SB-NA	WO-WO	99.815%	99.777%	99.747%	99.898%	25	30	34	14
127	222	GS-SWCH	MT-NP	DB-NA	WO-WO	98.499%	98.408%	99.739%	99.285%	199	211	35	95
9	222	CS-SWCH	RT-NP	SB-NA	WO-WO	98.484%	99.883%	99.732%	99.875%	201	16	36	17
125	222	GS-SWCH	MT-NP	SB-NA	WO-WO	98.408%	99.429%	99.724%	99.641%	211	76	37	48
183	222	WG-SWCH	CT-NP	DB-NA	WO-WO	98.348%	97.267%	99.716%	99.028%	219	362	38	129
29	221	C-BBLS	RT-NP	SB-NA	WO-WO	99.777%	99.981%	99.709%	99.989%	30	3	39	2
67	222	G-SWCH	MT-NP	DB-NA	WO-WO	98.302%	97.947%	99.701%	99.180%	225	272	40	109
39	222	C-SWCH	NT-NP	DB-NA	WO-WO	98.280%	97.614%	99.694%	99.096%	228	316	41	120
25	223	C-FESC	MT-NP	SB-NA	WO-WO	99.898%	99.898%	99.686%	98.907%	14	14	42	145
3	221	CS-BBLS	CT-NP	DB-NA	WO-WO	99.739%	99.142%	99.679%	99.679%	35	114	43	43
11	222	CS-SWCH	RT-NP	DB-NA	WO-WO	98.038%	98.877%	99.671%	99.459%	260	149	44	72
165	222	WC-SWCH	MT-NP	SB-NA	WO-WO	97.917%	98.302%	99.664%	99.255%	276	225	45	99
41	221	S-BBLS	CT-NP	SB-NA	WO-WO	99.656%	99.671%	99.656%	99.853%	46	44	46	20
27	223	C-FESC	MT-NP	DB-NA	WO-WO	99.860%	99.149%	99.648%	98.446%	19	113	47	206
31	221	C-BBLS	RT-NP	DB-NA	WO-WO	99.633%	99.187%	99.641%	99.701%	49	108	48	40
167	222	WC-SWCH	MT-NP	DB-NA	WO-WO	97.750%	97.123%	99.633%	98.991%	298	381	49	134
43	221	S-BBLS	CT-NP	DB-NA	WO-WO	99.588%	98.953%	99.626%	99.611%	55	139	50	52

Table C-8 Top 50 TP Load Reduction Index (TPRI) Scenarios

Scenario		Aggregated (Current-Alternative)				Cumulative Probability				TPRI Rank Top Ranking			
CUR	ALT	AGCROP	AGTILL	AGFERT	AGBMPS	TN	TP	TNRI	TPRI	TN	TP	TNRI	TPRI
37	221	C-BBLS	NT-NP	SB-NA	WO-WO	98.945%	99.996%	99.323%	99.996%	140	1	90	1
29	221	C-BBLS	RT-NP	SB-NA	WO-WO	99.777%	99.981%	99.709%	99.989%	30	3	39	2
33	221	C-BBLS	OT-NP	SB-NA	WO-WO	99.437%	99.951%	99.588%	99.981%	75	7	55	3
25	221	C-BBLS	MT-NP	SB-NA	WO-WO	99.905%	99.928%	99.822%	99.974%	13	10	24	4
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	99.966%	99.913%	99.875%	99.966%	5	12	17	5
37	222	C-SWCH	NT-NP	SB-NA	WO-WO	99.028%	99.989%	99.830%	99.958%	129	2	23	6
29	222	C-SWCH	RT-NP	SB-NA	WO-WO	99.792%	99.974%	99.951%	99.951%	28	4	7	7
9	221	CS-BBLS	RT-NP	SB-NA	WO-WO	98.371%	99.890%	99.149%	99.943%	216	15	113	8
23	221	C-BBLS	CT-NP	DB-NA	WO-WO	99.989%	99.868%	99.958%	99.936%	2	18	6	9
33	222	C-SWCH	OT-NP	SB-NA	WO-WO	99.474%	99.943%	99.883%	99.928%	70	8	16	10
17	221	CS-BBLS	NT-NP	SB-NA	WO-WO	94.749%	99.845%	98.393%	99.921%	695	21	213	11
13	221	CS-BBLS	OT-NP	SB-NA	WO-WO	96.904%	99.822%	98.741%	99.913%	410	24	167	12
5	221	CS-BBLS	MT-NP	SB-NA	WO-WO	99.361%	99.800%	99.535%	99.905%	85	27	62	13
1	221	CS-BBLS	CT-NP	SB-NA	WO-WO	99.815%	99.777%	99.747%	99.898%	25	30	34	14
25	222	C-SWCH	MT-NP	SB-NA	WO-WO	99.913%	99.921%	99.981%	99.890%	12	11	3	15
21	222	C-SWCH	CT-NP	SB-NA	WO-WO	99.974%	99.905%	99.989%	99.883%	4	13	2	16
9	222	CS-SWCH	RT-NP	SB-NA	WO-WO	98.484%	99.883%	99.732%	99.875%	201	16	36	17
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	99.996%	99.860%	99.996%	99.868%	1	19	1	18
129	221	GS-BBLS	RT-NP	SB-NA	WO-WO	96.987%	99.694%	98.764%	99.860%	399	41	164	19
41	221	S-BBLS	CT-NP	SB-NA	WO-WO	99.656%	99.671%	99.656%	99.853%	46	44	46	20
17	222	CS-SWCH	NT-NP	SB-NA	WO-WO	95.051%	99.837%	99.142%	99.845%	655	22	114	21
13	222	CS-SWCH	OT-NP	SB-NA	WO-WO	97.123%	99.815%	99.474%	99.837%	381	25	70	22
121	221	GS-BBLS	CT-NP	SB-NA	WO-WO	99.580%	99.633%	99.618%	99.830%	56	49	51	23
137	221	GS-BBLS	NT-NP	SB-NA	WO-WO	90.567%	99.618%	97.849%	99.822%	1248	51	285	24
5	222	CS-SWCH	MT-NP	SB-NA	WO-WO	99.376%	99.784%	99.860%	99.815%	83	29	19	25
1	222	CS-SWCH	CT-NP	SB-NA	WO-WO	99.845%	99.762%	99.966%	99.807%	21	32	5	26
69	221	G-BBLS	RT-NP	SB-NA	WO-WO	96.957%	99.565%	98.749%	99.800%	403	58	166	27
77	221	G-BBLS	NT-NP	SB-NA	WO-WO	88.813%	99.543%	97.788%	99.792%	1480	61	293	28
133	221	GS-BBLS	OT-NP	SB-NA	WO-WO	97.070%	99.535%	98.779%	99.784%	388	62	162	29
61	221	G-BBLS	CT-NP	SB-NA	WO-WO	99.505%	99.474%	99.603%	99.777%	66	70	53	30
125	221	GS-BBLS	MT-NP	SB-NA	WO-WO	98.272%	99.444%	99.127%	99.769%	229	74	116	31
45	221	S-BBLS	MT-NP	SB-NA	WO-WO	98.711%	99.399%	99.240%	99.762%	171	80	101	32
129	222	GS-SWCH	RT-NP	SB-NA	WO-WO	97.146%	99.679%	99.505%	99.754%	378	43	66	33
65	221	G-BBLS	MT-NP	SB-NA	WO-WO	98.597%	99.376%	99.210%	99.747%	186	83	105	34
41	222	S-SWCH	CT-NP	SB-NA	WO-WO	99.679%	99.664%	99.936%	99.739%	43	45	9	35
27	221	C-BBLS	MT-NP	DB-NA	WO-WO	99.883%	99.293%	99.784%	99.732%	16	94	29	36
121	222	GS-SWCH	CT-NP	SB-NA	WO-WO	99.626%	99.626%	99.913%	99.724%	50	50	12	37
137	222	GS-SWCH	NT-NP	SB-NA	WO-WO	91.081%	99.595%	98.612%	99.716%	1180	54	184	38
49	221	S-BBLS	RT-NP	SB-NA	WO-WO	96.964%	99.210%	98.756%	99.709%	402	105	165	39
31	221	C-BBLS	RT-NP	DB-NA	WO-WO	99.633%	99.187%	99.641%	99.701%	49	108	48	40
69	222	G-SWCH	RT-NP	SB-NA	WO-WO	97.130%	99.558%	99.490%	99.694%	380	59	68	41
73	221	G-BBLS	OT-NP	SB-NA	WO-WO	96.760%	99.172%	98.718%	99.686%	429	110	170	42
3	221	CS-BBLS	CT-NP	DB-NA	WO-WO	99.739%	99.142%	99.679%	99.679%	35	114	43	43
77	222	G-SWCH	NT-NP	SB-NA	WO-WO	89.372%	99.520%	98.378%	99.671%	1406	64	215	44
133	222	GS-SWCH	OT-NP	SB-NA	WO-WO	97.206%	99.512%	99.527%	99.664%	370	65	63	45
61	222	G-SWCH	CT-NP	SB-NA	WO-WO	99.535%	99.467%	99.905%	99.656%	62	71	13	46
57	221	S-BBLS	NT-NP	SB-NA	WO-WO	91.180%	99.081%	97.871%	99.648%	1167	122	282	47
125	222	GS-SWCH	MT-NP	SB-NA	WO-WO	98.408%	99.429%	99.724%	99.641%	211	76	37	48
53	221	S-BBLS	OT-NP	SB-NA	WO-WO	94.476%	99.013%	98.295%	99.633%	731	131	226	49
45	222	S-SWCH	MT-NP	SB-NA	WO-WO	98.794%	99.384%	99.792%	99.626%	160	82	28	50

C.3 Uncertainty Ratio for Potential Load Reduction

C.3.1 Uncertainty Ratio Statistics

As described in Section: 3.5.3, the load reduction R_Us can be calculated with Eq. 3-13 for paired (PD) and Eq. 3-14 for unpaired (UP) analysis. Table C-9 lists the statistics of the R_Us with both PD and UP analyses for potential TN and TP load reduction. Within the total 50400 alternative scenario pairs, more than half R_Us are equal to 1 and around 35% to 45% R_Us are less than 0.33. However, less than 2% of total R_Us are larger than 0.33.

For more advanced analysis of R_U, it eliminates one of each alternative scenario pair set which load reduction should be negative from the observations. In other words, for any S1-S2/S2-S1 alternative scenario pair set, at least one of them, either S1-S2 or S2-S1, its load reduction will be negative. The R_Us for each potential TN or TP load reduction at three different confidence levels are calculated in Table C-10. For each group of R_U, the column "S1=S2" represents the load reduction between S1 and S2 are not statistical significant. Conversely, the column "Base" represents the number of observations which load reduction is statistics significant. The other columns in the table represent the percentage of number of R_U is larger than the specific value. For "< 0.01" column, even though their load reduction is statistical significant, the R_U is less than 1% and small enough can be neglected in practice. For "> 0.9" column, their uncertainties are higher than 90% and TR will then be higher than 10:1; it would not be a good alternative scenario due to its high risk.

Table C-9 Statistics of Load Reduction Uncertainty Ratio for PD-UP Analyses

(a) PD Analysis for TN Load Reduction

CL	#Obs	R_U=1	> 0.01	> 0.33	> 0.50	> 0.80	> 0.90
90%	50400	50.36%	34.37%	0.35%	0.17%	0.05%	0.04%
95%	50400	50.47%	38.39%	0.44%	0.31%	0.05%	0.02%
97.5%	50400	50.52%	47.57%	0.55%	0.38%	0.05%	0.04%

(b) UP Analysis for TN Load Reduction

CL	#Obs	R_U=1	> 0.01	> 0.33	> 0.50	> 0.80	> 0.90
90%	50400	50.64%	36.62%	0.76%	0.50%	0.09%	0.04%
95%	50400	50.79%	44.48%	0.79%	0.73%	0.14%	0.07%
97.5%	50400	50.94%	46.98%	0.95%	0.86%	0.14%	0.12%

(c) PD Analysis for TP Load Reduction

CL	#Obs	R_U=1	> 0.01	> 0.33	> 0.50	> 0.80	> 0.90
90%	50400	50.26%	34.00%	0.25%	0.18%	0.01%	0.02%
95%	50400	50.29%	38.44%	0.31%	0.21%	0.05%	0.03%
97.5%	50400	50.35%	48.81%	0.35%	0.30%	0.04%	0.05%

(d) UP Analysis for TP Load Reduction

CL	#Obs	R_U=1	> 0.01	> 0.33	> 0.50	> 0.80	> 0.90
90%	50400	50.54%	36.80%	0.54%	0.43%	0.08%	0.03%
95%	50400	50.65%	45.70%	0.76%	0.56%	0.10%	0.08%
97.5%	50400	50.78%	47.40%	0.93%	0.63%	0.14%	0.11%

Table C-10 Advanced Statistics of Load Reduction Uncertainty Ratio for PD-UP Analyses

	CL	S1=S2	Base	< 0.01	> 0.01	> 0.091	> 0.167	> 0.231	>0.286	> 0.333	> 0.5	> 0.8	> 0.9
PD TN Load Reduction	90%	179	25021	29.52%	64.31%	2.91%	1.04%	0.61%	0.37%	0.71%	0.35%	0.10%	0.09%
	95%	235	24965	20.83%	71.48%	3.61%	1.27%	0.71%	0.44%	0.90%	0.62%	0.09%	0.05%
	97.5%	260	24940	1.81%	89.16%	4.21%	1.45%	0.75%	0.57%	1.11%	0.77%	0.10%	0.08%

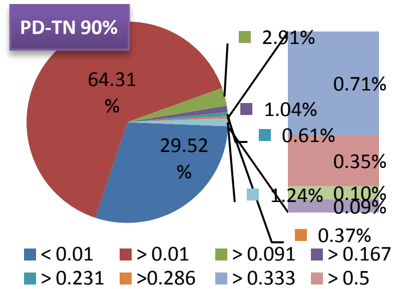
	CL	S1=S2	Base	< 0.01	> 0.01	> 0.091	> 0.167	> 0.231	>0.286	> 0.333	> 0.5	> 0.8	> 0.9
PD TP Load Reduction	90%	132	25068	30.72%	64.30%	2.55%	0.92%	0.36%	0.23%	0.50%	0.37%	0.02%	0.04%
	95%	148	25052	21.44%	71.93%	3.32%	1.21%	0.58%	0.31%	0.63%	0.42%	0.10%	0.07%
	97.5%	177	25023	0.21%	91.87%	3.96%	1.35%	0.69%	0.45%	0.70%	0.60%	0.07%	0.11%

	CL	S1=S2	Base	< 0.01	> 0.01	> 0.091	> 0.167	> 0.231	>0.286	> 0.333	> 0.5	> 0.8	> 0.9
UP TN Load Reduction	90%	323	24877	23.01%	65.51%	5.16%	1.85%	0.96%	0.70%	1.55%	1.00%	0.17%	0.08%
	95%	397	24803	6.09%	79.29%	6.83%	2.27%	1.15%	0.86%	1.60%	1.48%	0.29%	0.15%
	97.5%	473	24727	0.02%	82.62%	8.31%	2.60%	1.36%	0.88%	1.94%	1.75%	0.28%	0.25%

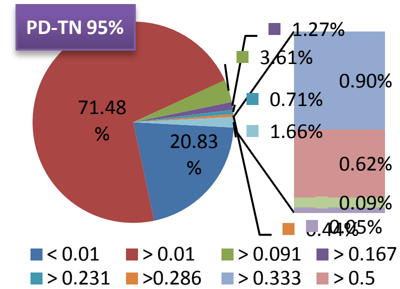
	CL	S1=S2	Base	< 0.01	> 0.01	> 0.091	> 0.167	> 0.231	>0.286	> 0.333	> 0.5	> 0.8	> 0.9
UP TP Load Reduction	90%	270	24930	23.42%	65.19%	5.76%	1.89%	0.91%	0.65%	1.10%	0.87%	0.16%	0.06%
	95%	330	24870	4.37%	81.08%	7.17%	2.46%	1.09%	0.80%	1.54%	1.13%	0.19%	0.16%
	97.5%	395	24805	0.00%	82.74%	8.53%	2.76%	1.51%	0.78%	1.90%	1.28%	0.29%	0.21%

C.3.2 Confidence Level Comparison

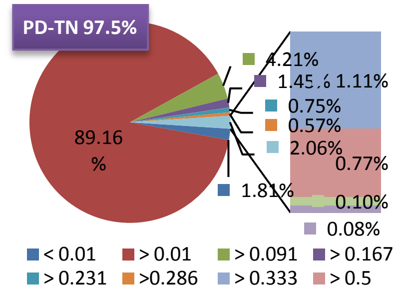
Within Table C-10, for each group of uncertainty ratio, the higher confidence level will have more number of observations in each column except “Base” and “< 0.01” columns. The number of observations in both “S1=S2” and “> 0.9” are increased while confidence level increased. These trends represent that higher confidence level might increase the distinguish ability of the load reduction uncertainty. However, the higher uncertainty ratios also imply a higher TR and potential higher cost of a trade. As implementing these analyses for a trading program, the selection of confidence level would be a critical problem. Figure C-9 and Figure C-10 illustrate the percentage of total observations for each uncertainty ratio value range for TN or TP load reduction with paired and unpaired analysis methods at 90%, 95% and 97.5% confidence levels. For the uncertainty ratio analysis of both TN and TP load reduction with two different methods, the trends are similar to each other, even though the potential TN load reduction is around 5 to 8 times the TP load reduction of the same alternative scenario from previous analyses.



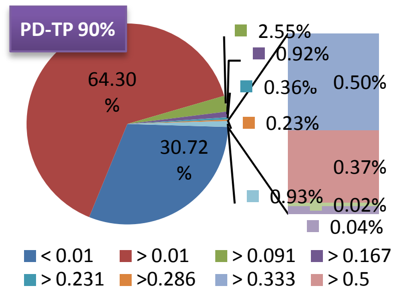
(a) PD TN Load Reduction R_U at 90% CL



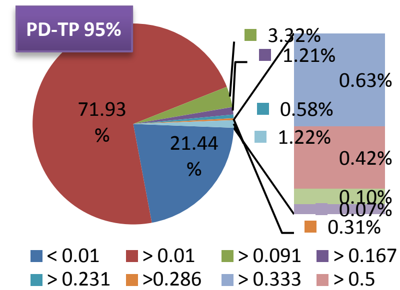
(b) PD TN Load Reduction R_U at 95% CL



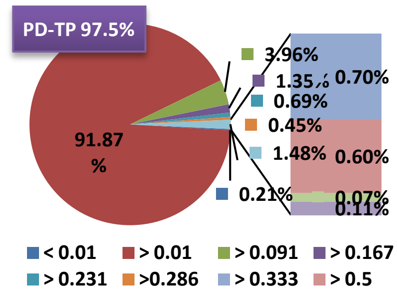
(c) PD TN Load Reduction R_U at 97.5% CL



(d) PD TP Load Reduction R_U at 90% CL

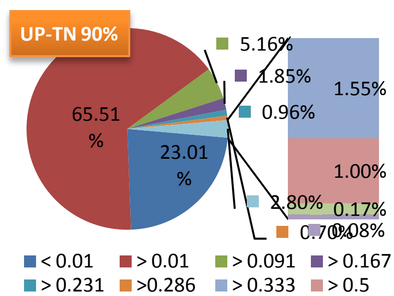


(e) PD TP Load Reduction R_U at 95% CL

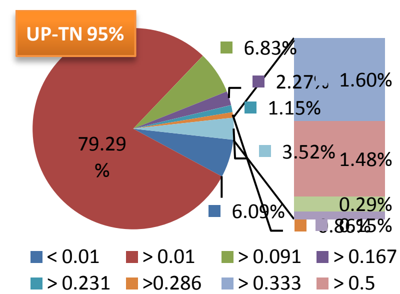


(f) PD TP Load Reduction R_U at 97.5% CL

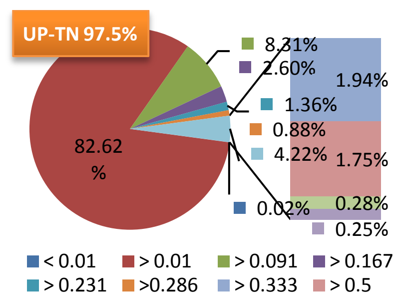
Figure C-9 Statistics of PD Analysis Load Reduction Uncertainty Ratio



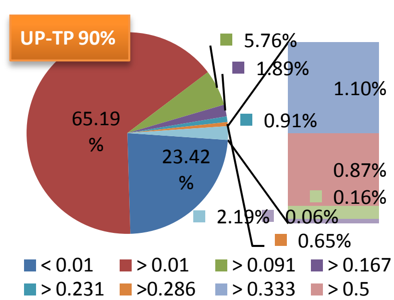
(a) UP TN Load Reduction R_U at 90% CL



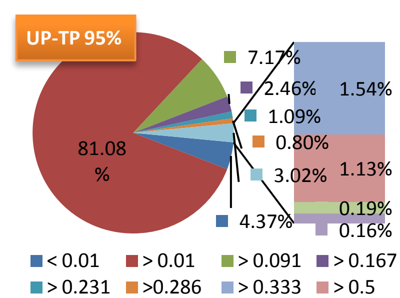
(b) UP TN Load Reduction R_U at 95% CL



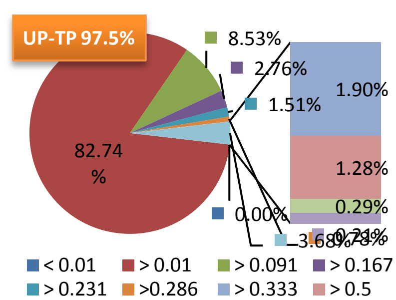
(c) UP TN Load Reduction R_U at 97.5% CL



(d) UP TP Load Reduction R_U at 90% CL



(e) UP TP Load Reduction R_U at 95% CL



(f) UP TP Load Reduction R_U at 97.5% CL

Figure C-10 Statistics of UP Analysis Load Reduction Uncertainty Ratio

C.3.3 Paired and Unpaired Analysis Comparison

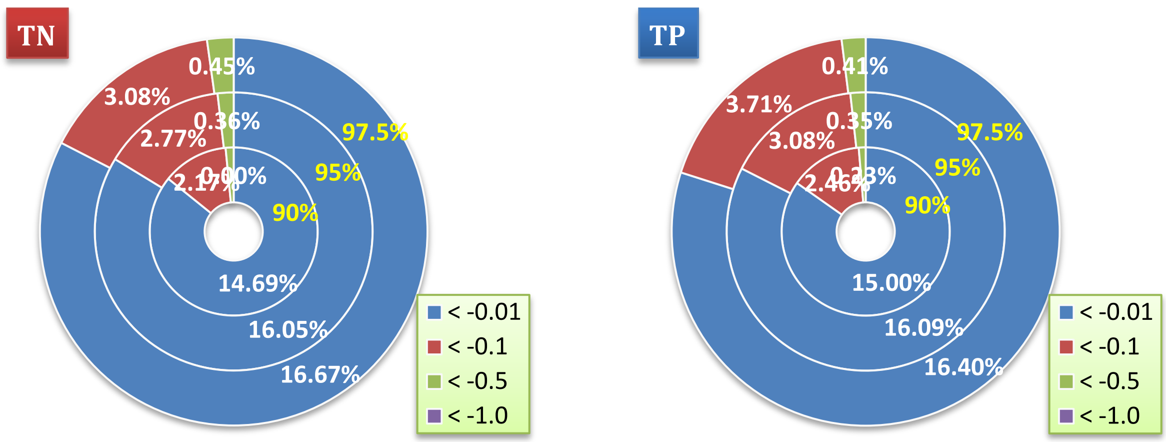
Table C-12 is an example of R_U difference comparison for the first 20 alternative scenarios between paired analyses (PD) to unpaired analysis (UP) method in TN load reduction at 95% confidence level. The complete comparisons are listed in several matrices where the top first row presents the potential current management scenarios and the very first column presents the potential alternative management scenarios. Both column and row scenarios are ranged from S1 to S225 represent the scenario to scenario 225 which described previously in Table A-20. The value in the intersection of current scenario column and alternative management scenario row is the potential nutrient load reduction R_U. More details comparison at specific confidence level (90%, 95%, and 97.5%) or full matrices can be enquired from research website or the digital annex.

In the Table C-12, different color in the cell represents the different magnitude of the difference in R_U. For example, the black block represents a positive value which means the PD's value is larger than UP. Similarly, greenish block represents the PD - UP value is less than 0 but larger than -0.1 while lime colored block is the value less than -0.1 but larger than -0.5. For an extremely case, the blue block means the value is between -0.5 to -1.

For the difference of R_U at the same confidence level, unpaired (UP) analysis will produce higher R_U than paired (PD) analysis method for both TN and TP load reduction. UP analysis will also generate higher TR than PD except some special cases. Table C-11 and Figure C-11 illustrates the percentage of the R_U comparisons between PD and UP analysis method. Around 80% to 82% alternative scenarios, their R_U s with either PD or UP analysis method are almost identical. In other words, the difference of R_U between PD and UP analyses is less than 0.01 or 1% in the value of R_U. However, there are around 18% to 20% alternative scenarios reports higher R_Us with UP analysis than PD analysis. But interesting, none (0%) alternative scenario presents lower R_U with UP analysis than PD analysis.

Table C-11 Nutrient Load Reduction Uncertainty Ratio Comparison between PD and UP Analyses

	CL	**Obs**	**PD > UP**	**PD = UP**	**PD < UP**		**< -0.01**	**< -0.1**	**< -0.5**	**< -1.0**
TN Load Reduction	90%	50400	0.00%	82.88%	17.12%	**PD < UP**	14.69%	2.17%	0.26%	0.00%
	95%	50400	0.00%	80.83%	19.17%		16.05%	2.77%	0.36%	0.00%
	97.5%	50400	0.00%	79.81%	20.19%		16.67%	3.08%	0.45%	0.00%
	CL	**Obs**	**PD > UP**	**PD = UP**	**PD < UP**		**< -0.01**	**< -0.1**	**< -0.5**	**< -1.0**
TP Load Reduction	90%	50400	0.00%	82.31%	17.69%	**PD < UP**	15.00%	2.46%	0.23%	0.00%
	95%	50400	0.00%	80.49%	19.51%		16.09%	3.08%	0.35%	0.00%
	97.5%	50400	0.00%	79.47%	20.53%		16.40%	3.71%	0.41%	0.00%



(a) TN Load Reduction R_U Difference **(b) TP Load Reduction R_U Difference**

Figure C-11 Load Reduction Uncertainty Ratio Difference between PD and UP Analyses

Table C-12 TN Load Reduction Uncertainty Ratio Difference between PD-UP Analyses at 95% CL

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	-0.444	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	0	-0.444	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	-0.070	0	-0.088	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	-0.070	0	-0.088	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
S7	-0.057	0	-0.070	0	-0.378	0		0	0	0	0	0	0	0	0	0	0	0	0	0
S8	0	-0.057	0	-0.070	0	-0.378	0		0	0	0	0	0	0	0	0	0	0	0	0
S9	-0.028	0	-0.032	0	-0.070	0	-0.089	0		0	0	0	0	0	0	0	0	0	0	0
S10	0	-0.028	0	-0.032	0	-0.070	0	-0.089	0		0	0	0	0	0	0	0	0	0	0
S11	-0.025	0	-0.028	0	-0.055	0	-0.067	0	-0.300	0		0	0	0	0	0	0	0	0	0
S12	0	-0.025	0	-0.028	0	-0.055	0	-0.067	0	-0.300	0		0	0	0	0	0	0	0	0
S13	-0.015	0	-0.017	0	-0.026	0	-0.030	0	-0.052	0	-0.069	0		0	0	0	0	0	0	0
S14	0	-0.015	0	-0.017	0	-0.026	0	-0.030	0	-0.052	0	-0.069	0		0	0	0	0	0	0
S15	-0.013	0	-0.015	0	-0.021	0	-0.024	0	-0.037	0	-0.047	0	-0.199	0		0	0	0	0	0
S16	0	-0.013	0	-0.015	0	-0.021	0	-0.024	0	-0.037	0	-0.047	0	-0.199	0		0	0	0	0
S17	0	0	-0.011	0	-0.016	0	-0.018	0	-0.028	0	-0.033	0	-0.069	0	-0.125	0		0	0	0
S18	0	0	0	-0.011	0	-0.016	0	-0.018	0	-0.028	0	-0.033	0	-0.069	0	-0.125	0		0	0
S19	0	0	0	0	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.045	0	-0.064	0	-0.129	0		0
S20	0	0	0	0	0	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.045	0	-0.064	0	-0.129	0	

C.4 Trading Ratio

C.4.1 In-Field Trading Ratio Statistics

As described in Section: 3.5.4, the R_U can be calculated with Eq. 3-13 for PD and Eq. 3-14 for UP analyses. Therefore, the in-field TR can be calculated with Eq. 3-15 in either PD or UP analysis. Table C-13 lists the statistics of the TR with both paired and unpaired analysis method for potential TN and TP load reduction. Within the total 50400 alternative scenario pairs, more than half TR observations are equal to 0 and around 35% to 48% TR observations is greater than 1 but less than 1.5. However, less than 2% observations have their TR greater than 1.5.

In order to eliminate the negative load reduction effect, in each alternative scenario pair set, one of which observation should be negative and need to be deleted. In other words, for any S1-S2/S2-S1 alternative scenario pair set, at least one of them, either S1-S2 or S2-S1, its load reduction will be negative. The TRs for each potential TN or TP load reduction at three different confidence levels are then calculated in Table C-14. For each group of TR, the column "S1=S2" represents the load reduction between S1 and S2 are not statistical significant. Conversely, the column "Base" represents the number of alternative scenario which load reduction is statistics significant. The other columns in the table represent the percentage of observations of TR is less than or larger than the specific value. For "< 1.01" column, even though their load reduction is statistical significant, the TR increasing is less than 1% and small enough can be neglected in practice. For "> 10.0" column, the TR is more than 10 of these observations that means a 10:1 ratio is required to apply or higher than 90% uncertainty exist the trade; it would not be a good alternative scenario due to its high risk.

Table C-13 Statistics of Load Reduction TR for PD-UP Analyses

(a) PD Analysis for TN Load Reduction

CL	#Obs	TR = 0	> 1.01	> 1.5	> 2	> 5	> 10
90%	50400	64.79%	34.60%	0.35%	0.17%	0.05%	0.04%
95%	50400	60.05%	39.13%	0.44%	0.31%	0.05%	0.02%
97.5%	50400	51.18%	47.80%	0.55%	0.38%	0.05%	0.04%

(b) UP Analysis for TN Load Reduction

CL	#Obs	TR = 0	> 1.01	> 1.5	> 2	> 5	> 10
90%	50400	61.91%	36.71%	0.76%	0.50%	0.09%	0.04%
95%	50400	53.16%	45.11%	0.79%	0.73%	0.14%	0.07%
97.5%	50400	50.94%	46.99%	0.95%	0.86%	0.14%	0.12%

(c) PD Analysis for TP Load Reduction

CL	#Obs	TR = 0	> 1.01	> 1.5	> 2	> 5	> 10
90%	50400	65.05%	34.48%	0.25%	0.18%	0.01%	0.02%
95%	50400	60.25%	39.14%	0.31%	0.21%	0.05%	0.03%
97.5%	50400	50.41%	48.85%	0.35%	0.30%	0.04%	0.05%

(d) UP Analysis for TP Load Reduction

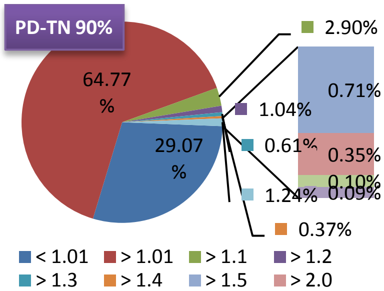
CL	#Obs	TR = 0	> 1.01	> 1.5	> 2	> 5	> 10
90%	50400	62.06%	36.86%	0.54%	0.43%	0.08%	0.03%
95%	50400	52.27%	46.24%	0.76%	0.56%	0.10%	0.08%
97.5%	50400	50.78%	47.40%	0.93%	0.63%	0.14%	0.11%

Table C-14 Advanced Statistics of Load Reduction TR for PD-UP Analyses

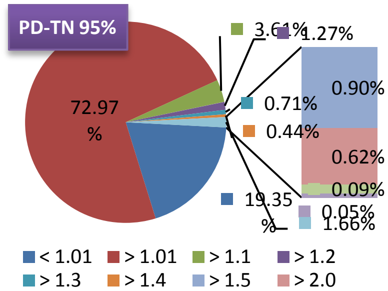
	CL	S1=S2	Base	< 1.01	> 1.01	> 1.1	> 1.2	> 1.3	> 1.4	> 1.5	> 2.0	> 5.0	> 10.0
PD TN Load Reduction	90%	179	25021	29.07%	64.77%	2.90%	1.04%	0.61%	0.37%	0.71%	0.35%	0.10%	0.09%
	95%	235	24965	19.35%	72.97%	3.61%	1.27%	0.71%	0.44%	0.90%	0.62%	0.09%	0.05%
	97.5%	260	24940	1.35%	89.62%	4.21%	1.45%	0.75%	0.57%	1.11%	0.77%	0.10%	0.08%
PD TP Load Reduction	90%	132	25068	29.74%	65.27%	2.55%	0.92%	0.36%	0.23%	0.50%	0.37%	0.02%	0.04%
	95%	148	25052	20.03%	73.33%	3.32%	1.21%	0.58%	0.31%	0.63%	0.42%	0.10%	0.07%
	97.5%	177	25023	0.13%	91.95%	3.96%	1.34%	0.70%	0.45%	0.70%	0.60%	0.07%	0.11%
UP TN Load Reduction	90%	323	24877	22.83%	65.70%	5.15%	1.85%	0.96%	0.70%	1.55%	1.00%	0.17%	0.08%
	95%	397	24803	4.82%	80.57%	6.82%	2.27%	1.15%	0.86%	1.60%	1.48%	0.29%	0.15%
	97.5%	473	24727	0.00%	82.63%	8.31%	2.60%	1.36%	0.88%	1.94%	1.75%	0.28%	0.25%
UP TP Load Reduction	90%	270	24930	23.29%	65.32%	5.75%	1.89%	0.91%	0.65%	1.10%	0.87%	0.16%	0.06%
	95%	330	24870	3.27%	82.18%	7.17%	2.46%	1.10%	0.80%	1.54%	1.13%	0.19%	0.16%
	97.5%	395	24805	0.00%	82.75%	8.53%	2.76%	1.51%	0.78%	1.90%	1.28%	0.29%	0.21%

C.4.2 Confidence Level Comparison

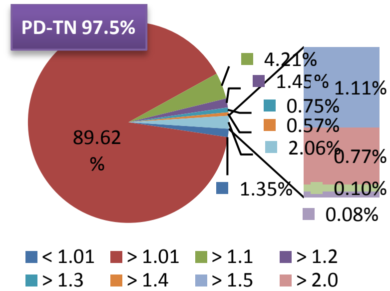
Within Table C-14, for each group of TR, the higher confidence level will have more number of observations in each column except “Base” and “< 1.01” columns. The number of observations in both “S1=S2” and “> 10.0” are increased while confidence level increased. These trends are similar to the uncertainty ratio, which represent that higher confidence level might increase the distinguish ability of the load reduction uncertainty. In other words, higher confidence level will either increase the number of non-significant scenarios or increase the number of higher TR. Furthermore, the higher TR and uncertainty ratio also imply the higher risk of and potential higher cost of a trade. When implementing these analyses for a trading program, the selection of confidence level would be a critical issue. Figure C-12 and Figure C-13 illustrate the percentage of total observations for each TR value range of TN or TP load reduction with paired and unpaired analysis methods at 90%, 95% and 97.5% confidence levels. For the TR analysis of both TN and TP load reduction with two different methods, the trends are similar to each other, just also having the similar trend to uncertainty ratio analyses.



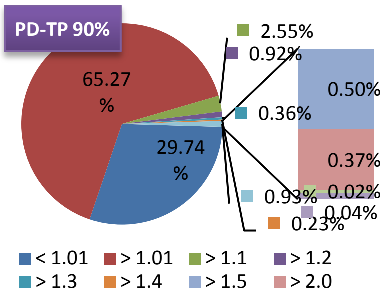
(a) PD TN Load TR at 90% CL



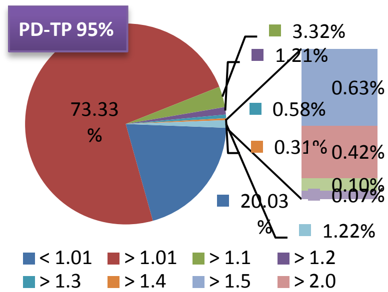
(b) PD TN Load TR at 95% CL



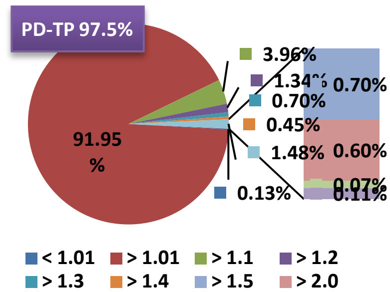
(c) PD TN Load TR at 97.5% CL



(d) PD TP Load TR at 90% CL

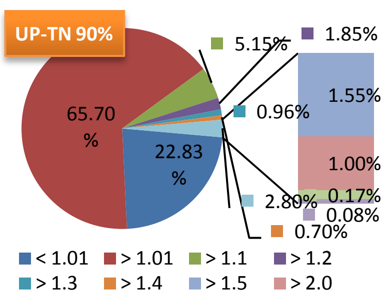


(e) PD TP Load TR at 95% CL

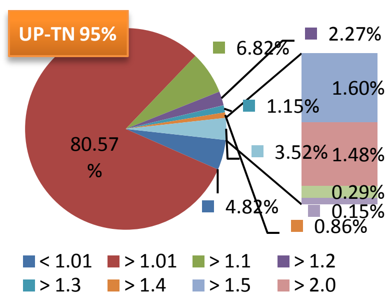


(f) PD TP Load TR at 97.5% CL

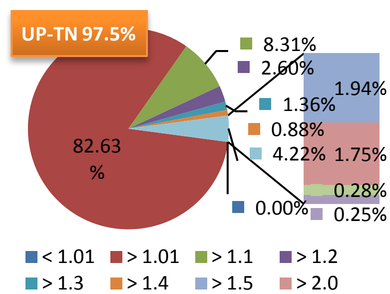
Figure C-12 Statistics of PD Analysis Load Reduction Trading Ratio



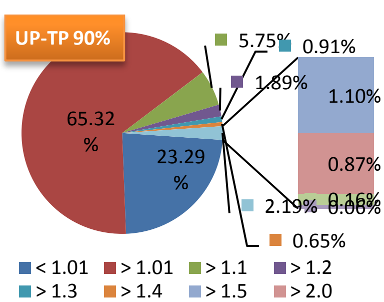
(a) UP TN Load TR at 90% CL



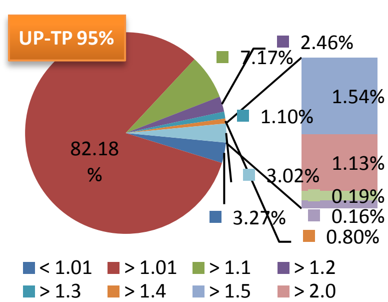
(b) UP TN Load TR at 95% CL



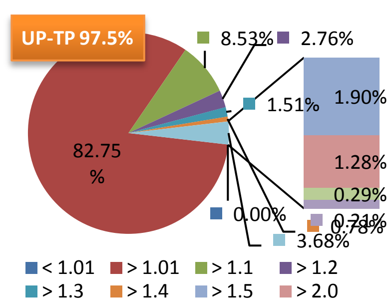
(c) UP TN Load TR at 97.5% CL



(d) UP TP Load TR at 90% CL



(e) UP TP Load TR at 95% CL



(f) UP TP Load TR at 97.5% CL

Figure C-13 Statistics of UP Analysis Load Reduction Trading Ratio

C.4.3 Paired and Unpaired Analysis Comparison

Table C-16 is the example of comparisons between PD-UP analyses for TN load reduction TR at 95% confidence level (CL). The original comparison results are listed in a 225 by 225 matrix where the top first row presents the current management scenarios and the first column represents the potential alternative management scenarios. Both column and row are ranged from S1 to S225 to represent scenario 1 to scenario 255 which described in Table A-20. The cell value in the intersection of each column and row is the potential nutrient load reduction TR for land management practice changed from specific current scenario to alternative one. More details of TR comparison and full matrix can be found in the research website or the digital annex.

As the similar color-symbolic system applied in previous uncertain ratio matrix, different color represents the different magnitude of the difference in TR. For instant, the black block in Table C-16 represents the PD-UP value is larger than 0.01. Similarly, greenish block represents the PD - UP value is less than 0 but larger than -0.01 while lime colored block is the value less than -0.1 but larger than -0.5. For some extremely cases, the blue block means the value is between -0.5 to -1.0 and red block means the value less than -1.

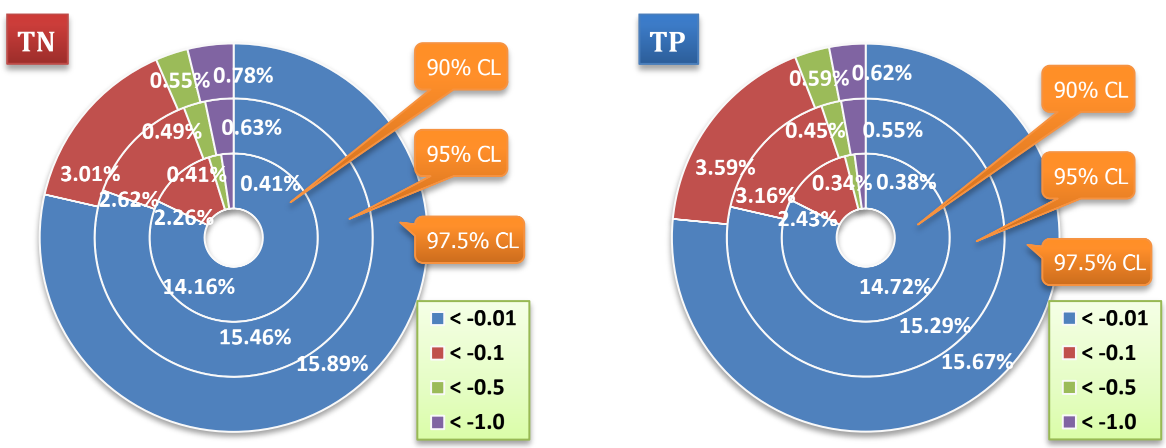
For the difference of TR at the same confidence level, most cases will generate higher TR with unpaired (UP) analysis method than paired (PD) method for both TN and TP load reduction, except some special cases which difference is less than 0.5%. Table C-15 and Figure C-14 illustrate the percentage of TR comparisons between PD and UP analyses. Around 80% to 82% alternative scenarios, their TR which calculated with either PD or UP analysis are almost identical. In other words, the difference of TR between these two methods is less than 0.01 or 1% in the value of TR. Moreover, there are around 18% to 20% alternative scenarios report higher TRs with UP analysis than PD analysis. Although less than 1% alternative scenario present lower TR with UP analysis than PD analysis, it is an interesting difference between TR and uncertainty ratio analysis.

Figure C-15 illustrates the percentage of the difference of uncertainty ratio (R_U) and TR (TR) between PD and UP analyses. The uncertainty ratio difference in Figure C-15 (a) is similar to the TR difference in Figure C-15 (b). The reason for the PD-UP difference of R_U and TR have so similar distribution pattern is because the definition of uncertainty ratio and TR in Eq. 3-13, Eq. 3-14 and Eq. 3-15. In these equations, the TR is equal to one divided by 1 minus uncertainty ratio. Therefore, the unpaired (UP) method will tend to generate a higher TR than paired (PD) method.

Furthermore, from the definition of both paired and unpaired analyzing method, UP analysis assumes all the observations (the value of nutrient load in each year) are independent but PD analysis assumes at least one modeling factor such as precipitation are identical among these scenarios. In other words, the observations (annual values) of these scenarios are dependent. Although the PD definition seems correctly to represent the actual modeling processes, the UP definition is much more reasonable in practice. According to above analyses, the unpaired method would be a better analysis option for implementing TR and uncertainty ratio in the WQT program.

Table C-15 Nutrient Load Reduction TR Comparison between PD and UP Analyses

	CL	**Obs**	**PD > UP**	**PD = UP**	**PD < UP**		**< -0.01**	**< -0.1**	**< -0.5**	**< -1.0**
TN Load Reduction	90%	50400	0.29%	82.48%	17.24%	**PD < UP**	14.16%	2.26%	0.41%	0.41%
	95%	50400	0.32%	80.48%	19.20%		15.46%	2.62%	0.49%	0.63%
	97.5%	50400	0.42%	79.35%	20.22%		15.89%	3.01%	0.55%	0.78%
	CL	**Obs**	**PD > UP**	**PD = UP**	**PD < UP**		**< -0.01**	**< -0.1**	**< -0.5**	**< -1.0**
TP Load Reduction	90%	50400	0.27%	81.87%	17.86%	**PD < UP**	14.72%	2.43%	0.34%	0.38%
	95%	50400	0.36%	80.17%	19.46%		15.29%	3.16%	0.45%	0.55%
	97.5%	50400	0.43%	79.09%	20.47%		15.67%	3.59%	0.59%	0.62%

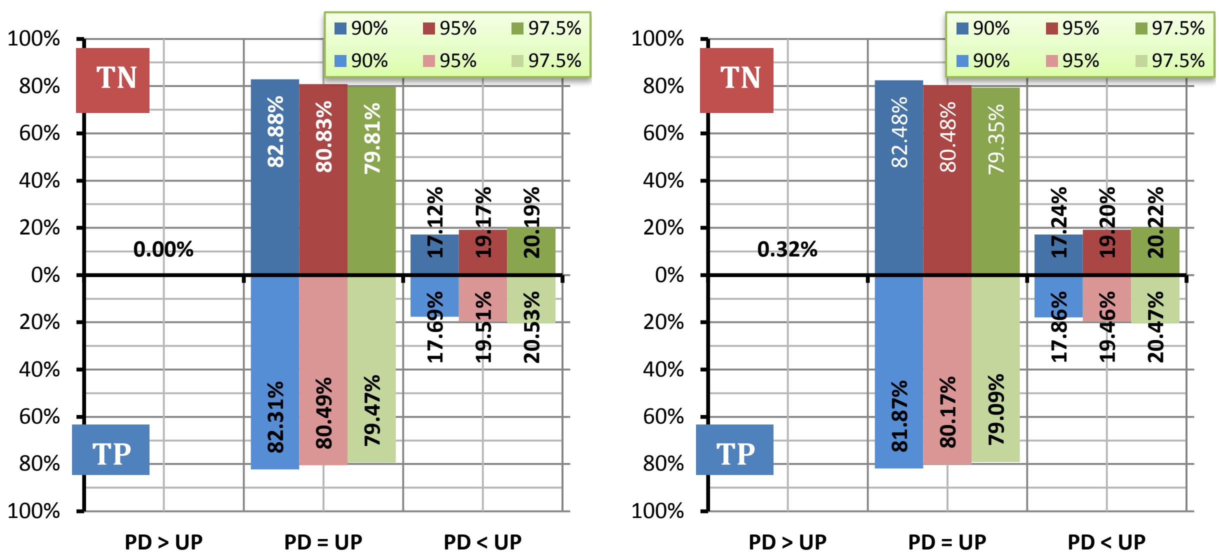


(a) TN Load Reduction TR Difference **(b) TP Load Reduction TR Difference**

Figure C-14 Load Reduction TR Difference between PD and UP Analyses

Table C-16 TN Load Reduction Uncertainty Ratio Difference between PD-UP Analyses at 95% CL

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	-0.847	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	0	-0.847	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	-0.078	0	-0.102	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	-0.078	0	-0.102	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
S7	-0.063	0	-0.078	0	-0.644	0		0	0	0	0	0	0	0	0	0	0	0	0	0
S8	0	-0.063	0	-0.078	0	-0.644	0		0	0	0	0	0	0	0	0	0	0	0	0
S9	-0.030	0	-0.034	0	-0.077	0	-0.101	0		0	0	0	0	0	0	0	0	0	0	0
S10	0	-0.030	0	-0.034	0	-0.077	0	-0.101	0		0	0	0	0	0	0	0	0	0	0
S11	-0.026	0	-0.029	0	-0.059	0	-0.074	0	-0.451	0		0	0	0	0	0	0	0	0	0
S12	0	-0.026	0	-0.029	0	-0.059	0	-0.074	0	-0.451	0		0	0	0	0	0	0	0	0
S13	-0.016	0	-0.018	0	-0.028	0	-0.032	0	-0.057	0	-0.079	0		0	0	0	0	0	0	0
S14	0	-0.016	0	-0.018	0	-0.028	0	-0.032	0	-0.057	0	-0.079	0		0	0	0	0	0	0
S15	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.040	0	-0.052	0	-0.261	0		0	0	0	0	0
S16	0	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.040	0	-0.052	0	-0.261	0		0	0	0	0
S17	-0.010	0	-0.011	0	-0.017	0	-0.018	0	-0.030	0	-0.035	0	-0.078	0	-0.166	0		0	0	0
S18	0	-0.010	0	-0.011	0	-0.017	0	-0.018	0	-0.030	0	-0.035	0	-0.078	0	-0.166	0		0	0
S19	0	0	0	0	-0.014	0	-0.016	0	-0.023	0	-0.027	0	-0.048	0	-0.072	0	-0.155	0		0
S20	0	0	0	0	0	-0.014	0	-0.016	0	-0.023	0	-0.027	0	-0.048	0	-0.072	0	-0.155	0	



(a) Nutrient Load Reduction R_U (b) Nutrient Load Reduction TR

Figure C-15 Difference between PD and UP Analyses at Different Confidence Levels

C.4.4 Ranks of Uncertainty Ratio and Trading Ratio

As it analyzed previously with nutrient load reduction and reduction index, we sorted the TN and TP load reduction means, uncertainty ratios, and TRs for all 225 by 225 alternative scenario pairs. Based on the ranking results, higher TN load reduction alternative scenarios don't mean a higher uncertainty or TR. On the contrary, the uncertainty ratio and TR for the top 60 TN load reduction alternative scenarios are around 0.01 and 1.01, respectively. In contrast, higher uncertainty ratio alternative scenarios are usually producing smaller amount of TN load reduction which less than 0.3 kg/ha. This is a relative small value compare to the positive means average of 20.264 kg/ha. TP load reduction also has similar trend. The top 60 TP load reduction TR scenarios have a small load reduction of 0.05 kg/ha comparing to positive means average of 4.507 kg/ha.

Table C-17 lists the top 60 alternative scenarios for TN and TP average load reduction as well as TN and TP's TR or uncertainty ratio at 90%, 95%, and 97.5% confidence level. The TR and uncertainty ratio have identical ranks. In Tab, the top scenario sequences tend to repeat at different confidence level. For example, for TN load reduction, the first scenario pair "S138-S152" of top 60 scenarios of TR at 97.5% confidence level will appear again in the 26th rank of TR at 95% confidence. Similarly, the first scenario pair "S132-S102" of top 60 scenarios of TR at 95% confidence level will appear again in the 57th rank of TR at 90% confidence. The lower confidence level means the more alternative scenarios will not exceed p-value of t-test statistics and then eligible to be traded. TP load also have similar trend but different alternative scenario pairs. For instant, S72-S168 are ranked the top first TR at 97.5% confidence level, but it will be the 30th and 46th TR at 95% and 90% confidence level, respectively.

Furthermore, as we described previously, the S23 scenario (1yr-C-CT-DB-WO) provide the most top 60 TN load reductions to other alternative scenarios as well as S37 (1yr-C-NT-SB-WO) and S29 (1yr-C-RT-SB-WO) dominant the top 60 TP load reduction. However, there is no this kind of dominant scenario in the TR or R_U ranks.

Table C-17 Top 60 Alternative Scenarios for Nutrient Load Reduction, TR, and Uncertainty Ratio

Rank	TN SCN	97.5%CL	95%CL	90%CL	TP SCN	97.5%CL	95%CL	90%CL
1	S23-S92	S138-S152	S132-S102	S169-S17	S37-S92	S72-S168	S49-S73	S88-S200
2	S23-S100	S138-S218	S131-S101	S170-S18	S37-S100	S71-S167	S50-S74	S50-S32
3	S23-S90	S137-S217	S170-S118	S66-S182	S37-S90	S46-S66	S201-S35	S49-S31
4	S23-S98	S137-S151	S169-S117	S65-S181	S37-S98	S60-S168	S202-S36	S198-S142
5	S23-S222	S143-S175	S49-S13	S41-S31	S37-S221	S6-S2	S152-S108	S20-S206
6	S23-S221	S144-S176	S50-S14	S42-S32	S37-S222	S45-S65	S169-S59	S36-S214
7	S23-S96	S56-S86	S86-S106	S54-S212	S37-S96	S5-S1	S170-S204	S35-S213
8	S23-S94	S55-S85	S85-S105	S53-S211	S29-S92	S59-S167	S103-S179	S197-S141
9	S23-S223	S51-S173	S134-S216	S185-S141	S37-S94	S157-S199	S151-S107	S177-S225
10	S23-S80	S52-S174	S133-S215	S186-S142	S29-S100	S67-S173	S170-S60	S19-S205
11	S23-S200	S171-S153	S16-S148	S149-S59	S29-S90	S158-S200	S169-S203	S105-S153
12	S23-S160	S171-S155	S15-S147	S150-S60	S29-S98	S170-S72	S185-S225	S105-S155
13	S23-S158	S172-S154	S96-S221	S126-S184	S29-S221	S169-S71	S104-S180	S106-S154
14	S23-S198	S172-S156	S83-S177	S125-S183	S29-S222	S68-S174	S76-S110	S106-S156
15	S23-S220	S76-S148	S84-S178	S48-S182	S37-S84	S18-S14	S75-S109	S120-S104
16	S23-S78	S75-S147	S211-S153	S47-S181	S37-S160	S220-S86	S174-S136	S119-S103
17	S23-S140	S199-S79	S211-S155	S196-S112	S37-S108	S17-S13	S173-S135	S49-S73
18	S23-S180	S200-S80	S212-S154	S195-S111	S37-S152	S219-S85	S127-S165	S50-S74
19	S23-S152	S85-S189	S212-S156	S113-S211	S37-S200	S87-S151	S128-S166	S201-S35
20	S23-S218	S86-S190	S76-S104	S109-S17	S37-S88	S88-S152	S136-S206	S202-S36
21	S23-S60	S140-S78	S75-S103	S114-S212	S29-S96	S67-S163	S209-S39	S152-S108
22	S23-S138	S139-S77	S181-S127	S110-S18	S37-S158	S68-S164	S135-S205	S169-S59
23	S23-S150	S111-S55	S182-S128	S210-S118	S37-S223	S32-S4	S210-S40	S170-S204
24	S23-S58	S112-S56	S181-S9	S209-S117	S37-S150	S173-S19	S216-S190	S103-S179
25	S23-S178	S223-S94	S182-S10	S161-S45	S37-S82	S174-S20	S215-S189	S151-S107
26	S23-S84	S154-S106	S138-S152	S162-S46	S37-S112	S31-S3	S141-S195	S170-S60
27	S23-S82	S156-S106	S138-S218	S54-S112	S37-S116	S221-S98	S142-S196	S169-S203
28	S23-S192	S153-S105	S137-S217	S53-S111	S29-S94	S188-S102	S214-S128	S185-S225
29	S23-S108	S155-S105	S137-S151	S141-S71	S37-S86	S187-S101	S213-S127	S104-S180
30	S23-S88	S101-S145	S143-S175	S142-S72	S37-S220	S163-S135	S72-S168	S76-S110
31	S23-S190	S102-S146	S144-S176	S136-S102	S37-S80	S164-S136	S71-S167	S75-S109
32	S23-S20	S10-S184	S56-S86	S135-S101	S37-S180	S172-S142	S46-S66	S174-S136
33	S23-S106	S9-S183	S55-S85	S176-S104	S37-S104	S171-S141	S60-S168	S173-S135
34	S23-S86	S192-S82	S51-S173	S175-S103	S37-S120	S212-S148	S6-S2	S127-S165
35	S23-S116	S191-S81	S52-S174	S132-S144	S37-S192	S211-S147	S45-S65	S128-S166
36	S23-S120	S134-S130	S171-S153	S131-S143	S37-S154	S167-S225	S5-S1	S136-S206
37	S23-S154	S133-S129	S171-S155	S111-S153	S37-S156	S205-S55	S59-S167	S209-S39
38	S23-S156	S14-S186	S172-S154	S111-S155	S37-S106	S149-S199	S157-S199	S135-S205
39	S23-S56	S13-S185	S172-S156	S207-S13	S37-S148	S206-S56	S67-S173	S210-S40
40	S23-S112	S85-S19	S76-S148	S112-S154	S37-S146	S207-S141	S158-S200	S216-S190
41	S23-S212	S86-S20	S75-S147	S112-S156	S37-S212	S208-S142	S170-S72	S215-S189
42	S23-S172	S147-S193	S199-S79	S208-S14	S37-S144	S150-S200	S169-S71	S141-S195
43	S23-S54	S148-S194	S200-S80	S149-S217	S29-S84	S194-S114	S68-S174	S142-S196
44	S23-S196	S52-S144	S85-S189	S150-S218	S37-S196	S193-S113	S18-S14	S214-S128
45	S23-S114	S51-S143	S86-S190	S117-S195	S33-S92	S81-S199	S220-S86	S213-S127
46	S23-S118	S117-S53	S140-S78	S118-S196	S37-S142	S218-S16	S17-S13	S72-S168
47	S23-S18	S118-S54	S139-S77	S56-S116	S29-S160	S82-S200	S219-S85	S71-S167
48	S23-S210	S72-S146	S111-S55	S55-S115	S29-S108	S217-S15	S87-S151	S46-S66
49	S23-S170	S71-S145	S112-S56	S216-S74	S37-S198	S166-S182	S88-S152	S60-S168
50	S23-S110	S225-S79	S223-S94	S215-S73	S33-S100	S163-S19	S67-S163	S6-S2
51	S23-S194	S74-S142	S154-S106	S143-S15	S29-S152	S165-S181	S68-S164	S45-S65
52	S23-S148	S73-S141	S156-S106	S144-S16	S37-S208	S164-S20	S32-S4	S5-S1
53	S23-S104	S18-S196	S153-S105	S174-S72	S37-S172	S223-S200	S173-S19	S59-S167
54	S23-S176	S17-S195	S155-S105	S173-S71	S29-S200	S36-S48	S174-S20	S157-S199
55	S23-S76	S14-S74	S101-S145	S56-S120	S29-S88	S153-S179	S31-S3	S67-S173
56	S23-S146	S151-S179	S102-S146	S55-S119	S29-S158	S155-S179	S221-S98	S158-S200
57	S23-S16	S13-S73	S10-S184	S132-S102	S29-S223	S154-S180	S188-S102	S170-S72
58	S23-S144	S152-S180	S9-S183	S131-S101	S33-S90	S156-S180	S187-S101	S169-S71
59	S23-S72	S216-S142	S192-S82	S170-S118	S29-S150	S35-S217	S163-S135	S68-S174
60	S23-S102	S215-S141	S191-S81	S169-S117	S29-S82	S35-S47	S164-S136	S18-S14

Appendix D Result Matrices

D.1 Annual Load Reduction Related Matrices

Based on the Eq. 3-1 through Eq. 3-15, the WQT in-field parameters for entire watershed, individual subbasin, and each HRU are calculated. Table D-1 through Table D-8 list selected scenarios from the original 225x225 matrices of annual nutrient load reduction, reduction index, uncertainty ratio, and trading ratio with unpaired analysis method at 95% confidence level (CL). In these matrices, the first (top) row presents current scenarios and the first column contains potential alternative scenarios. Both current scenario columns and alternative scenario rows ranged from S1 to S225 to represent scenarios #1 to #225 as described in Table A-20. Therefore, in each column, we have 225 potential load reductions (or R_U, TR) for each specific current scenario in changing to alternative scenarios. Conversely, each row contains 225 potential load reductions (or R_U, TR) for each specific alternative scenario as it changed from the current scenario. The cell value in each column and row intersection is the potential nutrient load reduction (or R_U, TR) if the management practice changed from the selected current scenario to the alternative one.

Table D-1 Excerpt of Watershed Level TN Load Reduction for Each Scenario

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1		-53.2	-1.72	-53.4	-8.1	-54.1	-9.71	-54.3	-15.3	-54.9	-17	-55.1	-22.3	-55.6	-24.4	-55.9	-26.6	-56.1	-29.1	-56.4
S2	53.2		51.5	-0.18	45.1	-0.87	43.5	-1.04	38.0	-1.64	36.2	-1.82	31.0	-2.39	28.8	-2.62	26.6	-2.86	24.2	-3.12
S3	1.7	-51.5		-51.7	-6.38	-52.4	-7.99	-52.6	-13.6	-53.2	-15.3	-53.3	-20.6	-53.9	-22.7	-54.1	-24.9	-54.4	-27.4	-54.6
S4	53.4	0.2	51.7		45.3	-0.68	43.7	-0.86	38.1	-1.46	36.4	-1.64	31.2	-2.21	29.0	-2.44	26.8	-2.67	24.4	-2.94
S5	8.1	-45.1	6.4	-45.3		-46	-1.61	-46.2	-7.19	-46.8	-8.9	-47	-14.2	-47.5	-16.3	-47.8	-18.5	-48	-21	-48.3
S6	54.1	0.9	52.4	0.7	46.0		44.4	-0.17	38.8	-0.77	37.1	-0.96	31.8	-1.52	29.7	-1.75	27.5	-1.99	25.0	-2.25
S7	9.7	-43.5	8.0	-43.7	1.6	-44.4		-44.6	-5.58	-45.2	-7.29	-45.4	-12.6	-45.9	-14.7	-46.2	-16.9	-46.4	-19.4	-46.7
S8	54.3	1.0	52.6	0.9	46.2	0.2	44.6		39.0	-0.6	37.3	-0.78	32.0	-1.35	29.9	-1.58	27.7	-1.82	25.2	-2.08
S9	15.3	-38	13.6	-38.1	7.2	-38.8	5.6	-39		-39.6	-1.71	-39.8	-6.99	-40.3	-9.14	-40.6	-11.3	-40.8	-13.8	-41.1
S10	54.9	1.6	53.2	1.5	46.8	0.8	45.2	0.6	39.6		37.9	-0.18	32.6	-0.75	30.5	-0.98	28.3	-1.22	25.8	-1.48
S11	17.0	-36.2	15.3	-36.4	8.9	-37.1	7.3	-37.3	1.7	-37.9		-38.1	-5.28	-38.6	-7.43	-38.9	-9.64	-39.1	-12.1	-39.4
S12	55.1	1.8	53.3	1.6	47.0	1.0	45.4	0.8	39.8	0.2	38.1		32.8	-0.57	30.6	-0.8	28.4	-1.03	26.0	-1.3
S13	22.3	-31	20.6	-31.2	14.2	-31.8	12.6	-32	7.0	-32.6	5.3	-32.8		-33.4	-2.15	-33.6	-4.35	-33.8	-6.8	-34.1
S14	55.6	2.4	53.9	2.2	47.5	1.5	45.9	1.3	40.3	0.8	38.6	0.6	33.4		31.2	-0.23	29.0	-0.47	26.6	-0.73
S15	24.4	-28.8	22.7	-29	16.3	-29.7	14.7	-29.9	9.1	-30.5	7.4	-30.6	2.1	-31.2		-31.4	-2.21	-31.7	-4.65	-31.9
S16	55.9	2.6	54.1	2.4	47.8	1.8	46.2	1.6	40.6	1.0	38.9	0.8	33.6	0.2	31.4		29.2	-0.24	26.8	-0.5
S17	26.6	-26.6	24.9	-26.8	18.5	-27.5	16.9	-27.7	11.3	-28.3	9.6	-28.4	4.4	-29	2.2	-29.2		-29.5	-2.45	-29.7
S18	56.1	2.9	54.4	2.7	48.0	2.0	46.4	1.8	40.8	1.2	39.1	1.0	33.8	0.5	31.7	0.2	29.5		27.0	-0.26
S19	29.1	-24.2	27.4	-24.4	21.0	-25	19.4	-25.2	13.8	-25.8	12.1	-26	6.8	-26.6	4.7	-26.8	2.4	-27		-27.3
S20	56.4	3.1	54.6	2.9	48.3	2.3	46.7	2.1	41.1	1.5	39.4	1.3	34.1	0.7	31.9	0.5	29.7	0.3	27.3	
S21	-10.9	-64.1	-12.6	-64.3	-19	-65	-20.6	-65.2	-26.2	-65.8	-27.9	-65.9	-33.2	-66.5	-35.3	-66.7	-37.5	-67	-40	-67.2
S22	52.1	-1.17	50.4	-1.35	44.0	-2.04	42.4	-2.21	36.8	-2.81	35.1	-2.99	29.8	-3.56	27.6	-3.79	25.4	-4.03	23.0	-4.29
S23	-19.2	-72.5	-21	-72.7	-27.3	-73.4	-29	-73.5	-34.5	-74.1	-36.2	-74.3	-41.5	-74.9	-43.7	-75.1	-45.9	-75.3	-48.3	-75.6
S24	51.2	-2.07	49.5	-2.25	43.1	-2.93	41.5	-3.11	35.9	-3.71	34.2	-3.89	28.9	-4.46	26.8	-4.69	24.5	-4.92	22.1	-5.19
S25	-4.55	-57.8	-6.28	-58	-12.7	-58.7	-14.3	-58.8	-19.8	-59.4	-21.5	-59.6	-26.8	-60.2	-29	-60.4	-31.2	-60.7	-33.6	-60.9
S26	52.8	-0.49	51.0	-0.67	44.7	-1.36	43.0	-1.53	37.5	-2.13	35.8	-2.31	30.5	-2.88	28.3	-3.11	26.1	-3.35	23.7	-3.61
S27	-1.4	-54.6	-3.12	-54.8	-9.5	-55.5	-11.1	-55.7	-16.7	-56.3	-18.4	-56.5	-23.7	-57	-25.8	-57.3	-28	-57.5	-30.5	-57.8
S28	53.1	-0.15	51.4	-0.34	45.0	-1.02	43.4	-1.19	37.8	-1.79	36.1	-1.98	30.8	-2.54	28.7	-2.77	26.5	-3.01	24.0	-3.27
S29	1.1	-52.1	-0.61	-52.3	-6.99	-53	-8.6	-53.2	-14.2	-53.8	-15.9	-54	-21.2	-54.5	-23.3	-54.8	-25.5	-55	-28	-55.3
S30	53.4	0.1	51.6	-0.07	45.3	-0.75	43.7	-0.92	38.1	-1.52	36.4	-1.71	31.1	-2.27	28.9	-2.5	26.7	-2.74	24.3	-3
S31	4.3	-48.9	2.6	-49.1	-3.76	-49.8	-5.38	-50	-11	-50.6	-12.7	-50.7	-17.9	-51.3	-20.1	-51.5	-22.3	-51.8	-24.7	-52
S32	53.7	0.5	52.0	0.3	45.6	-0.4	44.0	-0.58	38.4	-1.18	36.7	-1.36	31.4	-1.93	29.3	-2.16	27.1	-2.39	24.6	-2.66
S33	6.4	-46.9	4.7	-47.1	-1.72	-47.7	-3.34	-47.9	-8.92	-48.5	-10.6	-48.7	-15.9	-49.3	-18.1	-49.5	-20.3	-49.7	-22.7	-50
S34	53.9	0.7	52.2	0.5	45.8	-0.18	44.2	-0.36	38.6	-0.96	36.9	-1.14	31.7	-1.71	29.5	-1.94	27.3	-2.17	24.8	-2.44
S35	10.2	-43.1	8.4	-43.3	2.1	-44	0.4	-44.1	-5.13	-44.7	-6.84	-44.9	-12.1	-45.5	-14.3	-45.7	-16.5	-45.9	-18.9	-46.2
S36	54.3	1.1	52.6	0.9	46.2	0.2	44.6	0.0	39.0	-0.55	37.3	-0.73	32.1	-1.3	29.9	-1.53	27.7	-1.77	25.3	-2.03
S37	11.7	-41.5	10.0	-41.7	3.6	-42.4	2.0	-42.6	-3.58	-43.2	-5.29	-43.4	-10.6	-43.9	-12.7	-44.2	-14.9	-44.4	-17.4	-44.7
S38	54.5	1.3	52.8	1.1	46.4	0.4	44.8	0.2	39.2	-0.38	37.5	-0.57	32.2	-1.13	30.1	-1.37	27.9	-1.6	25.4	-1.86
S39	16.1	-37.2	14.4	-37.4	8.0	-38	6.4	-38.2	0.8	-38.8	-0.92	-39	-6.2	-39.6	-8.35	-39.8	-10.6	-40	-13	-40.3
S40	55.0	1.7	53.2	1.5	46.9	0.9	45.3	0.7	39.7	0.1	38.0	-0.1	32.7	-0.67	30.5	-0.9	28.3	-1.13	25.9	-1.4
S41	4.1	-49.2	2.4	-49.3	-4.01	-50	-5.63	-50.2	-11.2	-50.8	-12.9	-51	-18.2	-51.6	-20.3	-51.8	-22.5	-52	-25	-52.3
S42	53.7	0.4	52.0	0.3	45.6	-0.43	44.0	-0.6	38.4	-1.2	36.7	-1.39	31.4	-1.95	29.3	-2.18	27.1	-2.42	24.6	-2.68
S43	4.9	-48.4	3.1	-48.6	-3.24	-49.3	-4.85	-49.4	-10.4	-50	-12.1	-50.2	-17.4	-50.8	-19.6	-51	-21.8	-51.2	-24.2	-51.5
S44	53.8	0.5	52.0	0.3	45.7	-0.35	44.1	-0.52	38.5	-1.12	36.8	-1.3	31.5	-1.87	29.3	-2.1	27.1	-2.34	24.7	-2.6
S45	13.7	-39.5	12.0	-39.7	5.6	-40.4	4.0	-40.5	-1.55	-41.1	-3.25	-41.3	-8.53	-41.9	-10.7	-42.1	-12.9	-42.4	-15.3	-42.6
S46	54.7	1.5	53.0	1.3	46.6	0.6	45.0	0.4	39.4	-0.17	37.7	-0.35	32.4	-0.92	30.3	-1.15	28.1	-1.38	25.6	-1.65
S47	14.4	-38.8	12.7	-39	6.3	-39.7	4.7	-39.8	-0.85	-40.4	-2.56	-40.6	-7.84	-41.2	-9.99	-41.4	-12.2	-41.7	-14.6	-41.9
S48	54.8	1.5	53.1	1.4	46.7	0.7	45.1	0.5	39.5	-0.09	37.8	-0.27	32.5	-0.84	30.4	-1.07	28.2	-1.31	25.7	-1.57
S49	22.2	-31.1	20.5	-31.3	14.1	-31.9	12.5	-32.1	6.9	-32.7	5.2	-32.9	-0.1	-33.5	-2.25	-33.7	-4.46	-33.9	-6.9	-34.2
S50	55.6	2.4	53.9	2.2	47.5	1.5	45.9	1.3	40.3	0.7	38.6	0.6	33.3	-0.01	31.2	-0.24	29.0	-0.48	26.5	-0.74
S51	23.0	-30.3	21.3	-30.4	14.9	-31.1	13.3	-31.3	7.7	-31.9	6.0	-32.1	0.7	-32.6	-1.44	-32.9	-3.64	-33.1	-6.09	-33.4
S52	55.7	2.5	54.0	2.3	47.6	1.6	46.0	1.4	40.4	0.8	38.7	0.6	33.4	0.1	31.3	-0.15	29.1	-0.39	26.6	-0.65
S53	27.3	-26	25.5	-26.2	19.2	-26.9	17.5	-27	12.0	-27.6	10.3	-27.8	5.0	-28.4	2.8	-28.6	0.6	-28.9	-1.83	-29.1
S54	56.2	2.9	54.4	2.7	48.1	2.1	46.5	1.9	40.9	1.3	39.2	1.1	33.9	0.5	31.7	0.3	29.5	0.1	27.1	-0.2
S55	28.1	-25.2	26.4	-25.3	20.0	-26	18.4	-26.2	12.8	-26.8	11.1	-27	5.8	-27.6	3.7	-27.8	1.4	-28	-1	-28.3
S56	56.3	3.0	54.5	2.8	48.2	2.1	46.5	2.0	41.0	1.4	39.3	1.2	34.0	0.6	31.8	0.4	29.6	0.2	27.2	-0.11
S57	32.7	-20.5	31.0	-20.7	24.6	-21.4	23.0	-21.5	17.5	-22.1	15.8	-22.3	10.5	-22.9	8.3	-23.1	6.1	-23.4	3.7	-23.6
S58	56.8	3.5	55.0	3.3	48.7	2.6	47.0	2.5	41.5	1.9	39.8	1.7	34.5	1.1	32.3	0.9	30.1	0.7	27.7	0.4
S59	33.6	-19.7	31.9	-19.9	25.5	-20.5	23.9	-20.7	18.3	-21.3	16.6	-21.5	11.3	-22.1	9.1	-22.3	6.9	-22.5	4.5	-22.8
S60	56.8	3.6	55.1	3.4	48.8	2.7	47.1	2.6	41.6	2.0	39.9	1.8	34.6	1.2	32.4	1.0	30.2	0.7	27.8	0.5

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	10.9	-52.1	19.2	-51.2	4.6	-52.8	1.4	-53.1	-1.11	-53.4	-4.33	-53.7	-6.37	-53.9	-10.2	-54.3	-11.7	-54.5	-16.1	-55.0
S2	64.1	1.2	72.5	2.1	57.8	0.5	54.6	0.2	52.1	-0.12	48.9	-0.47	46.9	-0.68	43.1	-1.09	41.5	-1.3	37.2	-1.7
S3	12.6	-50.4	21.0	-49.5	6.3	-51	3.1	-51.4	0.6	-51.6	-2.61	-52	-4.65	-52.2	-8.44	-52.6	-10.0	-52.8	-14.4	-53.2
S4	64.3	1.4	72.7	2.3	58.0	0.7	54.8	0.3	52.3	0.1	49.1	-0.28	47.1	-0.5	43.3	-0.91	41.7	-1.1	37.4	-1.5
S5	19.0	-44	27.3	-43.1	12.7	-44.7	9.5	-45	7.0	-45.3	3.8	-45.6	1.7	-45.8	-2.06	-46.2	-3.6	-46.4	-8.0	-46.9
S6	65.0	2.0	73.4	2.9	58.7	1.4	55.5	1.0	53.0	0.8	49.8	0.4	47.7	0.2	44.0	-0.22	42.4	-0.4	38.0	-0.9
S7	20.6	-42.4	29.0	-41.5	14.3	-43	11.1	-43.4	8.6	-43.7	5.4	-44	3.3	-44.2	-0.45	-44.6	-2.0	-44.8	-6.4	-45.3
S8	65.2	2.2	73.5	3.1	58.8	1.5	55.7	1.2	53.2	0.9	50.0	0.6	47.9	0.4	44.1	-0.05	42.6	-0.2	38.2	-0.7
S9	26.2	-36.8	34.5	-35.9	19.8	-37.5	16.7	-37.8	14.2	-38.1	11.0	-38.4	8.9	-38.6	5.1	-39	3.6	-39.2	-0.8	-39.7
S10	65.8	2.8	74.1	3.7	59.4	2.1	56.3	1.8	53.8	1.5	50.6	1.2	48.5	1.0	44.7	0.6	43.2	0.4	38.8	-0.1
S11	27.9	-35.1	36.2	-34.2	21.5	-35.8	18.4	-36.1	15.9	-36.4	12.7	-36.7	10.6	-36.9	6.8	-37.3	5.3	-37.5	0.9	-38.0
S12	65.9	3.0	74.3	3.9	59.6	2.3	56.5	2.0	54.0	1.7	50.7	1.4	48.7	1.1	44.9	0.7	43.4	0.6	39.0	0.1
S13	33.2	-29.8	41.5	-28.9	26.8	-30.5	23.7	-30.8	21.2	-31.1	17.9	-31.4	15.9	-31.7	12.1	-32.1	10.6	-32.2	6.2	-32.7
S14	66.5	3.6	74.9	4.5	60.2	2.9	57.0	2.5	54.5	2.3	51.3	1.9	49.3	1.7	45.5	1.3	43.9	1.1	39.6	0.7
S15	35.3	-27.6	43.7	-26.8	29.0	-28.3	25.8	-28.7	23.3	-28.9	20.1	-29.3	18.1	-29.5	14.3	-29.9	12.7	-30.1	8.3	-30.5
S16	66.7	3.8	75.1	4.7	60.4	3.1	57.3	2.8	54.8	2.5	51.5	2.2	49.5	1.9	45.7	1.5	44.2	1.4	39.8	0.9
S17	37.5	-25.4	45.9	-24.5	31.2	-26.1	28.0	-26.5	25.5	-26.7	22.3	-27.1	20.3	-27.3	16.5	-27.7	14.9	-27.9	10.6	-28.3
S18	67.0	4.0	75.3	4.9	60.7	3.3	57.5	3.0	55.0	2.7	51.8	2.4	49.7	2.2	45.9	1.8	44.4	1.6	40.0	1.1
S19	40.0	-23	48.3	-22.1	33.6	-23.7	30.5	-24	28.0	-24.3	24.7	-24.6	22.7	-24.8	18.9	-25.3	17.4	-25.4	13.0	-25.9
S20	67.2	4.3	75.6	5.2	60.9	3.6	57.8	3.3	55.3	3.0	52.0	2.7	50.0	2.4	46.2	2.0	44.7	1.9	40.3	1.4
S21		-63	8.4	-62.1	-6.32	-63.6	-9.47	-64	-12	-64.2	-15.2	-64.6	-17.2	-64.8	-21	-65.2	-22.6	-65.4	-27	-65.8
S22	63.0		71.3	0.9	56.6	-0.68	53.5	-1.02	51.0	-1.29	47.7	-1.63	45.7	-1.85	41.9	-2.26	40.4	-2.42	36.0	-2.89
S23	-8.37	-71.3		-70.4	-14.7	-72	-17.8	-72.3	-20.4	-72.6	-23.6	-73	-25.6	-73.2	-29.4	-73.6	-30.9	-73.7	-35.3	-74.2
S24	62.1	-0.9	70.4		55.7	-1.58	52.6	-1.91	50.1	-2.18	46.8	-2.53	44.8	-2.75	41.0	-3.16	39.5	-3.32	35.1	-3.79
S25	6.3	-56.6	14.7	-55.7		-57.3	-3.15	-57.6	-5.66	-57.9	-8.89	-58.3	-10.9	-58.5	-14.7	-58.9	-16.3	-59.1	-20.6	-59.5
S26	63.6	0.7	72.0	1.6	57.3		54.2	-0.34	51.6	-0.61	48.4	-0.95	46.4	-1.17	42.6	-1.58	41.0	-1.75	36.7	-2.21
S27	9.5	-53.5	17.8	-52.6	3.2	-54.2		-54.5	-2.51	-54.8	-5.74	-55.1	-7.78	-55.3	-11.6	-55.7	-13.1	-55.9	-17.5	-56.4
S28	64.0	1.0	72.3	1.9	57.6	0.3	54.5		52.0	-0.27	48.8	-0.62	46.7	-0.83	42.9	-1.24	41.4	-1.41	37.0	-1.88
S29	12.0	-51	20.4	-50.1	5.7	-51.6	2.5	-52		-52.3	-3.22	-52.6	-5.26	-52.8	-9.05	-53.2	-10.6	-53.4	-15	-53.9
S30	64.2	1.3	72.6	2.2	57.9	0.6	54.8	0.3	52.3		49.0	-0.35	47.0	-0.57	43.2	-0.97	41.7	-1.14	37.3	-1.61
S31	15.2	-47.7	23.6	-46.8	8.9	-48.4	5.7	-48.8	3.2	-49		-49.4	-2.04	-49.6	-5.82	-50	-7.37	-50.2	-11.7	-50.6
S32	64.6	1.6	73.0	2.5	58.3	1.0	55.1	0.6	52.6	0.3	49.4		47.3	-0.22	43.6	-0.63	42.0	-0.79	37.6	-1.26
S33	17.2	-45.7	25.6	-44.8	10.9	-46.4	7.8	-46.7	5.3	-47	2.0	-47.3		-47.6	-3.78	-48	-5.33	-48.1	-9.7	-48.6
S34	64.8	1.9	73.2	2.7	58.5	1.2	55.3	0.8	52.8	0.6	49.6	0.2	47.6		43.8	-0.41	42.2	-0.57	37.9	-1.04
S35	21.0	-41.9	29.4	-41	14.7	-42.6	11.6	-42.9	9.0	-43.2	5.8	-43.6	3.8	-43.8		-44.2	-1.55	-44.3	-5.92	-44.8
S36	65.2	2.3	73.6	3.2	58.9	1.6	55.7	1.2	53.2	1.0	50.0	0.6	48.0	0.4	44.2		42.6	-0.17	38.3	-0.64
S37	22.6	-40.4	30.9	-39.5	16.3	-41	13.1	-41.4	10.6	-41.7	7.4	-42	5.3	-42.2	1.5	-42.6		-42.8	-4.37	-43.3
S38	65.4	2.4	73.7	3.3	59.1	1.7	55.9	1.4	53.4	1.1	50.2	0.8	48.1	0.6	44.3	0.2	42.8		38.4	-0.47
S39	27.0	-36	35.3	-35.1	20.6	-36.7	17.5	-37	15.0	-37.3	11.7	-37.6	9.7	-37.9	5.9	-38.3	4.4	-38.4		-38.9
S40	65.8	2.9	74.2	3.8	59.5	2.2	56.4	1.9	53.9	1.6	50.6	1.3	48.6	1.0	44.8	0.6	43.3	0.5	38.9	
S41	15.0	-48	23.3	-47.1	8.6	-48.7	5.5	-49	3.0	-49.3	-0.25	-49.6	-2.29	-49.8	-6.07	-50.2	-7.62	-50.4	-12	-50.9
S42	64.6	1.6	72.9	2.5	58.2	0.9	55.1	0.6	52.6	0.3	49.3	-0.03	47.3	-0.25	43.5	-0.65	42.0	-0.82	37.6	-1.29
S43	15.7	-47.2	24.1	-46.3	9.4	-47.9	6.3	-48.2	3.7	-48.5	0.5	-48.9	-1.52	-49.1	-5.3	-49.5	-6.85	-49.6	-11.2	-50.1
S44	64.6	1.7	73.0	2.6	58.3	1.0	55.2	0.7	52.7	0.4	49.4	0.1	47.4	-0.16	43.6	-0.57	42.1	-0.74	37.7	-1.2
S45	24.6	-38.3	33.0	-37.4	18.3	-39	15.1	-39.3	12.6	-39.6	9.4	-40	7.4	-40.2	3.6	-40.6	2.0	-40.8	-2.33	-41.2
S46	65.6	2.6	74.0	3.5	59.3	2.0	56.1	1.6	53.6	1.4	50.4	1.0	48.3	0.8	44.6	0.4	43.0	0.2	38.6	-0.25
S47	25.3	-37.6	33.7	-36.7	19.0	-38.3	15.8	-38.7	13.3	-38.9	10.1	-39.3	8.1	-39.5	4.3	-39.9	2.7	-40.1	-1.64	-40.5
S48	65.7	2.7	74.0	3.6	59.3	2.0	56.2	1.7	53.7	1.4	50.5	1.1	48.4	0.9	44.6	0.5	43.1	0.3	38.7	-0.18
S49	33.1	-29.9	41.4	-29	26.7	-30.6	23.6	-30.9	21.1	-31.2	17.8	-31.5	15.8	-31.8	12.0	-32.2	10.5	-32.3	6.1	-32.8
S50	66.5	3.5	74.9	4.4	60.2	2.9	57.0	2.5	54.5	2.3	51.3	1.9	49.3	1.7	45.5	1.3	43.9	1.1	39.5	0.7
S51	33.9	-29.1	42.2	-28.2	27.5	-29.8	24.4	-30.1	21.9	-30.4	18.7	-30.7	16.6	-30.9	12.8	-31.3	11.3	-31.5	6.9	-32
S52	66.6	3.6	75.0	4.5	60.3	3.0	57.1	2.6	54.6	2.3	51.4	2.0	49.3	1.8	45.6	1.4	44.0	1.2	39.6	0.7
S53	38.1	-24.8	46.5	-23.9	31.8	-25.5	28.7	-25.8	26.1	-26.1	22.9	-26.5	20.9	-26.7	17.1	-27.1	15.5	-27.3	11.2	-27.7
S54	67.0	4.1	75.4	5.0	60.7	3.4	57.6	3.1	55.1	2.8	51.8	2.5	49.8	2.2	46.0	1.8	44.5	1.7	40.1	1.2
S55	39.0	-24	47.3	-23.1	32.6	-24.7	29.5	-25	27.0	-25.3	23.7	-25.6	21.7	-25.8	17.9	-26.3	16.4	-26.4	12.0	-26.9
S56	67.1	4.2	75.5	5.1	60.8	3.5	57.7	3.2	55.1	2.9	51.9	2.5	49.9	2.3	46.1	1.9	44.6	1.8	40.2	1.3
S57	43.6	-19.3	52.0	-18.4	37.3	-20	34.1	-20.3	31.6	-20.6	28.4	-21	26.4	-21.2	22.6	-21.6	21.0	-21.8	16.7	-22.2
S58	67.6	4.7	76.0	5.6	61.3	4.0	58.2	3.7	55.6	3.4	52.4	3.1	50.4	2.8	46.6	2.4	45.1	2.3	40.7	1.8
S59	44.4	-18.5	52.8	-17.6	38.1	-19.2	35.0	-19.5	32.5	-19.8	29.2	-20.1	27.2	-20.4	23.4	-20.8	21.9	-20.9	17.5	-21.4
S60	67.7	4.8	76.1	5.7	61.4	4.1	58.3	3.8	55.7	3.5	52.5	3.1	50.5	2.9	46.7	2.5	45.1	2.3	40.8	1.9

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	-4.09	-53.7	-4.86	-53.8	-13.7	-54.7	-14.4	-54.8	-22.2	-55.6	-23	-55.7	-27.3	-56.2	-28.1	-56.3	-32.7	-56.8	-33.6	-56.8
S2	49.2	-0.44	48.4	-0.52	39.5	-1.48	38.8	-1.55	31.1	-2.38	30.3	-2.47	26.0	-2.93	25.2	-3.01	20.5	-3.52	19.7	-3.6
S3	-2.36	-52	-3.14	-52	-12	-53	-12.7	-53.1	-20.5	-53.9	-21.3	-54	-25.5	-54.4	-26.4	-54.5	-31	-55	-31.9	-55.1
S4	49.3	-0.25	48.6	-0.34	39.7	-1.29	39.0	-1.37	31.3	-2.2	30.4	-2.28	26.2	-2.74	25.3	-2.83	20.7	-3.33	19.9	-3.42
S5	4.0	-45.6	3.2	-45.7	-5.65	-46.6	-6.34	-46.7	-14.1	-47.5	-14.9	-47.6	-19.2	-48.1	-20	-48.2	-24.6	-48.7	-25.5	-48.8
S6	50.0	0.4	49.3	0.3	40.4	-0.61	39.7	-0.68	31.9	-1.51	31.1	-1.6	26.9	-2.06	26.0	-2.15	21.4	-2.65	20.5	-2.73
S7	5.6	-44	4.9	-44.1	-4.03	-45	-4.73	-45.1	-12.5	-45.9	-13.3	-46	-17.5	-46.5	-18.4	-46.5	-23	-47	-23.9	-47.1
S8	50.2	0.6	49.4	0.5	40.5	-0.43	39.8	-0.51	32.1	-1.34	31.3	-1.43	27.0	-1.88	26.2	-1.97	21.5	-2.47	20.7	-2.56
S9	11.2	-38.4	10.4	-38.5	1.5	-39.4	0.9	-39.5	-6.88	-40.3	-7.7	-40.4	-12	-40.9	-12.8	-41	-17.5	-41.5	-18.3	-41.6
S10	50.8	1.2	50.0	1.1	41.1	0.2	40.4	0.1	32.7	-0.74	31.9	-0.83	27.6	-1.28	26.8	-1.37	22.1	-1.87	21.3	-1.96
S11	12.9	-36.7	12.1	-36.8	3.3	-37.7	2.6	-37.8	-5.18	-38.6	-5.99	-38.7	-10.3	-39.2	-11.1	-39.3	-15.8	-39.8	-16.6	-39.9
S12	51.0	1.4	50.2	1.3	41.3	0.3	40.6	0.3	32.9	-0.56	32.1	-0.64	27.8	-1.1	27.0	-1.19	22.3	-1.69	21.5	-1.78
S13	18.2	-31.4	17.4	-31.5	8.5	-32.4	7.8	-32.5	0.1	-33.3	-0.71	-33.4	-4.97	-33.9	-5.8	-34	-10.5	-34.5	-11.3	-34.6
S14	51.6	2.0	50.8	1.9	41.9	0.9	41.2	0.8	33.5	0.0	32.6	-0.08	28.4	-0.53	27.6	-0.62	22.9	-1.12	22.1	-1.21
S15	20.3	-29.3	19.6	-29.3	10.7	-30.3	10.0	-30.4	2.3	-31.2	1.4	-31.3	-2.82	-31.7	-3.65	-31.8	-8.32	-32.3	-9.15	-32.4
S16	51.8	2.2	51.0	2.1	42.1	1.1	41.4	1.1	33.7	0.2	32.9	0.2	28.6	-0.3	27.8	-0.39	23.1	-0.89	22.3	-0.98
S17	22.5	-27.1	21.8	-27.1	12.9	-28.1	12.2	-28.2	4.5	-29	3.6	-29.1	-0.62	-29.5	-1.45	-29.6	-6.11	-30.1	-6.94	-30.2
S18	52.0	2.4	51.2	2.3	42.4	1.4	41.7	1.3	33.9	0.5	33.1	0.4	28.9	-0.07	28.0	-0.16	23.4	-0.66	22.5	-0.75
S19	25.0	-24.6	24.2	-24.7	15.3	-25.6	14.6	-25.7	6.9	-26.5	6.1	-26.6	1.8	-27.1	1.0	-27.2	-3.67	-27.7	-4.49	-27.8
S20	52.3	2.7	51.5	2.6	42.6	1.6	41.9	1.6	34.2	0.7	33.4	0.7	29.1	0.2	28.3	0.1	23.6	-0.39	22.8	-0.48
S21	-15	-64.6	-15.7	-64.6	-24.6	-65.6	-25.3	-65.7	-33.1	-66.5	-33.9	-66.6	-38.1	-67	-39	-67.1	-43.6	-67.6	-44.4	-67.7
S22	48.0	-1.61	47.2	-1.69	38.3	-2.64	37.6	-2.72	29.9	-3.55	29.1	-3.64	24.8	-4.09	24.0	-4.18	19.3	-4.68	18.5	-4.77
S23	-23.3	-72.9	-24.1	-73	-33	-74	-33.7	-74	-41.4	-74.9	-42.2	-75	-46.5	-75.4	-47.3	-75.5	-52	-76	-52.8	-76.1
S24	47.1	-2.5	46.3	-2.59	37.4	-3.54	36.7	-3.62	29.0	-4.45	28.2	-4.53	23.9	-4.99	23.1	-5.08	18.4	-5.58	17.6	-5.67
S25	-8.64	-58.2	-9.41	-58.3	-18.3	-59.3	-19	-59.3	-26.7	-60.2	-27.5	-60.3	-31.8	-60.7	-32.6	-60.8	-37.3	-61.3	-38.1	-61.4
S26	48.7	-0.93	47.9	-1.01	39.0	-1.96	38.3	-2.04	30.6	-2.87	29.8	-2.96	25.5	-3.41	24.7	-3.5	20.0	-4	19.2	-4.09
S27	-5.49	-55.1	-6.26	-55.2	-15.1	-56.1	-15.8	-56.2	-23.6	-57	-24.4	-57.1	-28.7	-57.6	-29.5	-57.7	-34.1	-58.2	-35	-58.3
S28	49.0	-0.59	48.2	-0.67	39.3	-1.63	38.7	-1.7	30.9	-2.53	30.1	-2.62	25.8	-3.08	25.0	-3.17	20.3	-3.67	19.5	-3.75
S29	-2.98	-52.6	-3.75	-52.7	-12.6	-53.6	-13.3	-53.7	-21.1	-54.5	-21.9	-54.6	-26.1	-55.1	-27	-55.1	-31.6	-55.6	-32.5	-55.7
S30	49.3	-0.32	48.5	-0.4	39.6	-1.36	38.9	-1.43	31.2	-2.26	30.4	-2.35	26.1	-2.81	25.3	-2.9	20.6	-3.4	19.8	-3.48
S31	0.2	-49.3	-0.52	-49.4	-9.41	-50.4	-10.1	-50.5	-17.8	-51.3	-18.7	-51.4	-22.9	-51.8	-23.7	-51.9	-28.4	-52.4	-29.2	-52.5
S32	49.6	0.0	48.9	-0.06	40.0	-1.01	39.3	-1.08	31.5	-1.92	30.7	-2	26.5	-2.46	25.6	-2.55	21.0	-3.05	20.1	-3.14
S33	2.3	-47.3	1.5	-47.4	-7.37	-48.3	-8.06	-48.4	-15.8	-49.3	-16.6	-49.3	-20.9	-49.8	-21.7	-49.9	-26.4	-50.4	-27.2	-50.5
S34	49.8	0.2	49.1	0.2	40.2	-0.79	39.5	-0.87	31.8	-1.7	30.9	-1.78	26.7	-2.24	25.8	-2.33	21.2	-2.83	20.4	-2.92
S35	6.1	-43.5	5.3	-43.6	-3.59	-44.6	-4.28	-44.6	-12	-45.5	-12.8	-45.6	-17.1	-46	-17.9	-46.1	-22.6	-46.6	-23.4	-46.7
S36	50.2	0.7	49.5	0.6	40.6	-0.38	39.9	-0.46	32.2	-1.29	31.3	-1.38	27.1	-1.83	26.3	-1.92	21.6	-2.42	20.8	-2.51
S37	7.6	-42	6.8	-42.1	-2.04	-43	-2.73	-43.1	-10.5	-43.9	-11.3	-44	-15.5	-44.5	-16.4	-44.6	-21	-45.1	-21.9	-45.1
S38	50.4	0.8	49.6	0.7	40.8	-0.22	40.1	-0.29	32.3	-1.12	31.5	-1.21	27.3	-1.67	26.4	-1.76	21.8	-2.26	20.9	-2.35
S39	12.0	-37.6	11.2	-37.7	2.3	-38.6	1.6	-38.7	-6.1	-39.5	-6.91	-39.6	-11.2	-40.1	-12	-40.2	-16.7	-40.7	-17.5	-40.8
S40	50.9	1.3	50.1	1.2	41.2	0.3	40.5	0.2	32.8	-0.65	32.0	-0.74	27.7	-1.2	26.9	-1.29	22.2	-1.79	21.4	-1.88
S41		-49.6	-0.77	-49.7	-9.66	-50.6	-10.4	-50.7	-18.1	-51.5	-18.9	-51.6	-23.2	-52.1	-24	-52.2	-28.7	-52.7	-29.5	-52.8
S42	49.6		48.8	-0.08	39.9	-1.04	39.2	-1.11	31.5	-1.94	30.7	-2.03	26.4	-2.49	25.6	-2.58	20.9	-3.08	20.1	-3.17
S43	0.8	-48.8		-48.9	-8.89	-49.9	-9.58	-49.9	-17.3	-50.8	-18.1	-50.9	-22.4	-51.3	-23.2	-51.4	-27.9	-51.9	-28.7	-52
S44	49.7	0.1	48.9		40.0	-0.95	39.3	-1.03	31.6	-1.86	30.8	-1.95	26.5	-2.4	25.7	-2.49	21.0	-2.99	20.2	-3.08
S45	9.7	-39.9	8.9	-40		-41	-0.69	-41.1	-8.43	-41.9	-9.25	-42	-13.5	-42.4	-14.3	-42.5	-19	-43	-19.8	-43.1
S46	50.6	1.0	49.9	1.0	41.0		40.3	-0.07	32.5	-0.91	31.7	-0.99	27.5	-1.45	26.6	-1.54	22.0	-2.04	21.1	-2.13
S47	10.4	-39.2	9.6	-39.3	0.7	-40.3		-40.4	-7.74	-41.2	-8.55	-41.3	-12.8	-41.7	-13.6	-41.8	-18.3	-42.3	-19.1	-42.4
S48	50.7	1.1	49.9	1.0	41.1	0.1	40.4		32.6	-0.83	31.8	-0.92	27.5	-1.38	26.7	-1.46	22.0	-1.97	21.2	-2.05
S49	18.1	-31.5	17.3	-31.6	8.4	-32.5	7.7	-32.6		-33.5	-0.81	-33.5	-5.08	-34	-5.91	-34.1	-10.6	-34.6	-11.4	-34.7
S50	51.5	1.9	50.8	1.9	41.9	0.9	41.2	0.8	33.5		32.6	-0.09	28.4	-0.54	27.5	-0.63	22.9	-1.14	22.1	-1.22
S51	18.9	-30.7	18.1	-30.8	9.2	-31.7	8.6	-31.8	0.8	-32.6		-32.7	-4.26	-33.2	-5.09	-33.3	-9.76	-33.8	-10.6	-33.9
S52	51.6	2.0	50.9	1.9	42.0	1.0	41.3	0.9	33.5	0.1	32.7		28.5	-0.46	27.6	-0.55	23.0	-1.05	22.1	-1.14
S53	23.2	-26.4	22.4	-26.5	13.5	-27.5	12.8	-27.5	5.1	-28.4	4.3	-28.5		-28.9	-0.83	-29	-5.5	-29.5	-6.32	-29.6
S54	52.1	2.5	51.3	2.4	42.4	1.4	41.7	1.4	34.0	0.5	33.2	0.5	28.9		28.1	-0.09	23.4	-0.59	22.6	-0.68
S55	24.0	-25.6	23.2	-25.7	14.3	-26.6	13.6	-26.7	5.9	-27.5	5.1	-27.6	0.8	-28.1		-28.2	-4.67	-28.7	-5.49	-28.8
S56	52.2	2.6	51.4	2.5	42.5	1.5	41.8	1.5	34.1	0.6	33.3	0.5	29.0	0.1	28.2		23.5	-0.5	22.7	-0.59
S57	28.7	-20.9	27.9	-21	19.0	-22	18.3	-22	10.6	-22.9	9.8	-23	5.5	-23.4	4.7	-23.5		-24	-0.83	-24.1
S58	52.7	3.1	51.9	3.0	43.0	2.0	42.3	2.0	34.6	1.1	33.8	1.0	29.5	0.6	28.7	0.5	24.0		23.2	-0.09
S59	29.5	-20.1	28.7	-20.2	19.8	-21.1	19.1	-21.2	11.4	-22.1	10.6	-22.1	6.3	-22.6	5.5	-22.7	0.8	-23.2		-23.3
S60	52.8	3.2	52.0	3.1	43.1	2.1	42.4	2.1	34.7	1.2	33.9	1.1	29.6	0.7	28.8	0.6	24.1	0.1	23.3	

Table D-2 Excerpt of Watershed Level TP Load Reduction for Each Scenario

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1		-10.7	-1.8	-10.9	0.0	-10.7	-2.26	-11	0.6	-10.7	-2.26	-11	0.2	-10.7	-3.08	-11.1	0.3	-10.7	-3.6	-11.1
S2	10.7		8.9	-0.19	10.8	0.0	8.5	-0.24	11.3	0.1	8.5	-0.24	11.0	0.0	7.7	-0.33	11.0	0.0	7.1	-0.39
S3	1.8	-8.94		-9.13	1.8	-8.94	-0.46	-9.18	2.4	-8.88	-0.46	-9.18	2.0	-8.91	-1.28	-9.27	2.1	-8.91	-1.8	-9.33
S4	10.9	0.2	9.1		11.0	0.2	8.7	-0.05	11.5	0.3	8.7	-0.05	11.2	0.2	7.9	-0.14	11.2	0.2	7.3	-0.19
S5	-0.03	-10.8	-1.83	-11		-10.8	-2.29	-11	0.5	-10.7	-2.29	-11	0.2	-10.7	-3.11	-11.1	0.3	-10.7	-3.63	-11.2
S6	10.7	0	8.9	-0.2	10.8		8.5	-0.25	11.3	0.1	8.5	-0.25	11.0	0.0	7.7	-0.33	11.0	0.0	7.1	-0.39
S7	2.3	-8.48	0.5	-8.67	2.3	-8.48		-8.72	2.8	-8.42	0.0	-8.72	2.5	-8.46	-0.82	-8.81	2.5	-8.45	-1.34	-8.87
S8	11.0	0.2	9.2	0.0	11.0	0.2	8.7		11.5	0.3	8.7	0.0	11.2	0.3	7.9	-0.09	11.3	0.3	7.4	-0.14
S9	-0.56	-11.3	-2.35	-11.5	-0.53	-11.3	-2.81	-11.5		-11.2	-2.81	-11.5	-0.31	-11.3	-3.63	-11.6	-0.27	-11.3	-4.15	-11.7
S10	10.7	-0.06	8.9	-0.25	10.7	-0.06	8.4	-0.3	11.2		8.4	-0.3	10.9	-0.03	7.6	-0.39	11.0	-0.03	7.1	-0.45
S11	2.3	-8.48	0.5	-8.67	2.3	-8.48	0	-8.72	2.8	-8.42		-8.72	2.5	-8.46	-0.82	-8.81	2.5	-8.45	-1.34	-8.87
S12	11.0	0.2	9.2	0.0	11.0	0.2	8.7	0	11.5	0.3	8.7		11.2	0.3	7.9	-0.09	11.3	0.3	7.4	-0.14
S13	-0.25	-11	-2.05	-11.2	-0.22	-11	-2.51	-11.2	0.3	-10.9	-2.51	-11.2		-11	-3.32	-11.3	0.0	-11	-3.84	-11.4
S14	10.7	-0.03	8.9	-0.22	10.7	-0.02	8.5	-0.27	11.3	0.0	8.5	-0.27	11.0		7.6	-0.36	11.0	0.0	7.1	-0.41
S15	3.1	-7.66	1.3	-7.86	3.1	-7.66	0.8	-7.91	3.6	-7.6	0.8	-7.91	3.3	-7.64		-7.99	3.4	-7.63	-0.52	-8.05
S16	11.1	0.3	9.3	0.1	11.1	0.3	8.8	0.1	11.6	0.4	8.8	0.1	11.3	0.4	8.0		11.4	0.4	7.5	-0.06
S17	-0.29	-11	-2.08	-11.2	-0.26	-11	-2.54	-11.3	0.3	-11	-2.54	-11.3	-0.04	-11	-3.36	-11.4		-11	-3.88	-11.4
S18	10.7	-0.03	8.9	-0.22	10.7	-0.03	8.5	-0.27	11.3	0.0	8.5	-0.27	11.0	0	7.6	-0.36	11.0		7.1	-0.42
S19	3.6	-7.14	1.8	-7.34	3.6	-7.14	1.3	-7.39	4.2	-7.08	1.3	-7.39	3.8	-7.12	0.5	-7.47	3.9	-7.11		-7.53
S20	11.1	0.4	9.3	0.2	11.2	0.4	8.9	0.1	11.7	0.4	8.9	0.1	11.4	0.4	8.0	0.1	11.4	0.4	7.5	
S21	-0.79	-11.5	-2.58	-11.7	-0.76	-11.5	-3.04	-11.8	-0.23	-11.5	-3.04	-11.8	-0.54	-11.5	-3.86	-11.9	-0.5	-11.5	-4.38	-11.9
S22	10.7	-0.08	8.9	-0.28	10.7	-0.08	8.4	-0.33	11.2	-0.02	8.4	-0.33	10.9	-0.06	7.6	-0.41	10.9	-0.05	7.1	-0.47
S23	-0.52	-11.3	-2.32	-11.4	-0.49	-11.3	-2.78	-11.5	0.0	-11.2	-2.78	-11.5	-0.27	-11.2	-3.59	-11.6	-0.23	-11.2	-4.11	-11.6
S24	10.7	-0.06	8.9	-0.25	10.7	-0.05	8.4	-0.3	11.2	0.0	8.4	-0.3	10.9	-0.03	7.6	-0.39	11.0	-0.02	7.1	-0.44
S25	-0.85	-11.6	-2.65	-11.8	-0.82	-11.6	-3.1	-11.8	-0.29	-11.5	-3.1	-11.8	-0.6	-11.6	-3.92	-11.9	-0.56	-11.6	-4.44	-12
S26	10.6	-0.09	8.8	-0.28	10.7	-0.09	8.4	-0.33	11.2	-0.03	8.4	-0.33	10.9	-0.06	7.6	-0.42	10.9	-0.06	7.1	-0.48
S27	1.5	-9.2	-0.26	-9.39	1.6	-9.2	-0.72	-9.44	2.1	-9.14	-0.72	-9.44	1.8	-9.18	-1.54	-9.53	1.8	-9.17	-2.06	-9.59
S28	10.9	0.2	9.1	-0.03	10.9	0.2	8.6	-0.08	11.5	0.2	8.6	-0.08	11.2	0.2	7.8	-0.17	11.2	0.2	7.3	-0.22
S29	-1.59	-12.3	-3.39	-12.5	-1.56	-12.3	-3.85	-12.6	-1.04	-12.3	-3.85	-12.6	-1.35	-12.3	-4.67	-12.7	-1.31	-12.3	-5.19	-12.7
S30	10.6	-0.17	8.8	-0.36	10.6	-0.17	8.3	-0.41	11.1	-0.11	8.3	-0.41	10.8	-0.14	7.5	-0.5	10.9	-0.14	7.0	-0.56
S31	1.7	-8.99	-0.05	-9.18	1.8	-8.99	-0.51	-9.23	2.3	-8.93	-0.51	-9.23	2.0	-8.97	-1.33	-9.32	2.0	-8.96	-1.85	-9.38
S32	10.9	0.2	9.1	-0.01	11.0	0.2	8.7	-0.05	11.5	0.2	8.7	-0.05	11.2	0.2	7.9	-0.14	11.2	0.2	7.3	-0.2
S33	-1.29	-12	-3.08	-12.2	-1.26	-12	-3.54	-12.3	-0.73	-12	-3.54	-12.3	-1.04	-12	-4.36	-12.4	-1	-12	-4.88	-12.4
S34	10.6	-0.14	8.8	-0.33	10.6	-0.13	8.3	-0.38	11.2	-0.08	8.3	-0.38	10.8	-0.11	7.5	-0.47	10.9	-0.11	7.0	-0.52
S35	2.8	-7.91	1.0	-8.11	2.9	-7.91	0.6	-8.16	3.4	-7.85	0.6	-8.16	3.1	-7.89	-0.25	-8.24	3.1	-7.88	-0.77	-8.3
S36	11.0	0.3	9.2	0.1	11.1	0.3	8.8	0.1	11.6	0.4	8.8	0.1	11.3	0.3	8.0	-0.03	11.3	0.3	7.4	-0.08
S37	-1.78	-12.5	-3.58	-12.7	-1.75	-12.5	-4.03	-12.8	-1.22	-12.5	-4.03	-12.8	-1.53	-12.5	-4.85	-12.8	-1.49	-12.5	-5.37	-12.9
S38	10.5	-0.19	8.7	-0.38	10.6	-0.19	8.3	-0.43	11.1	-0.13	8.3	-0.43	10.8	-0.16	7.5	-0.52	10.8	-0.16	7.0	-0.58
S39	3.7	-7.08	1.9	-7.27	3.7	-7.08	1.4	-7.32	4.2	-7.02	1.4	-7.32	3.9	-7.05	0.6	-7.41	3.9	-7.05	0.1	-7.47
S40	11.1	0.4	9.3	0.2	11.2	0.4	8.9	0.2	11.7	0.5	8.9	0.2	11.4	0.4	8.1	0.1	11.4	0.4	7.5	0.0
S41	0.6	-10.1	-1.19	-10.3	0.6	-10.1	-1.65	-10.4	1.2	-10.1	-1.65	-10.4	0.9	-10.1	-2.47	-10.5	0.9	-10.1	-2.99	-10.5
S42	10.8	0.1	9.0	-0.13	10.8	0.1	8.5	-0.18	11.4	0.1	8.5	-0.18	11.1	0.1	7.7	-0.27	11.1	0.1	7.2	-0.32
S43	2.2	-8.57	0.4	-8.76	2.2	-8.57	-0.09	-8.81	2.7	-8.51	-0.09	-8.81	2.4	-8.54	-0.91	-8.9	2.5	-8.54	-1.43	-8.96
S44	11.0	0.2	9.2	0.0	11.0	0.2	8.7	-0.01	11.5	0.3	8.7	-0.01	11.2	0.3	7.9	-0.1	11.3	0.3	7.4	-0.15
S45	1.3	-9.43	-0.49	-9.62	1.3	-9.43	-0.95	-9.67	1.9	-9.37	-0.95	-9.67	1.6	-9.4	-1.77	-9.76	1.6	-9.4	-2.29	-9.82
S46	10.9	0.1	9.1	-0.05	10.9	0.1	8.6	-0.1	11.4	0.2	8.6	-0.1	11.1	0.2	7.8	-0.19	11.2	0.2	7.3	-0.25
S47	2.9	-7.84	1.1	-8.03	2.9	-7.84	0.6	-8.08	3.5	-7.78	0.6	-8.08	3.1	-7.81	-0.18	-8.17	3.2	-7.81	-0.7	-8.23
S48	11.1	0.3	9.3	0.1	11.1	0.3	8.8	0.1	11.6	0.4	8.8	0.1	11.3	0.3	8.0	-0.02	11.3	0.3	7.5	-0.07
S49	1.7	-9.04	-0.1	-9.23	1.7	-9.03	-0.55	-9.28	2.3	-8.98	-0.55	-9.28	2.0	-9.01	-1.37	-9.37	2.0	-9.01	-1.89	-9.42
S50	10.9	0.2	9.1	-0.01	11.0	0.2	8.7	-0.06	11.5	0.2	8.7	-0.06	11.2	0.2	7.8	-0.15	11.2	0.2	7.3	-0.2
S51	3.3	-7.43	1.5	-7.63	3.3	-7.43	1.0	-7.68	3.9	-7.37	1.0	-7.68	3.6	-7.41	0.2	-7.76	3.6	-7.4	-0.29	-7.82
S52	11.1	0.4	9.3	0.2	11.1	0.4	8.8	0.1	11.7	0.4	8.8	0.1	11.3	0.4	8.0	0.0	11.4	0.4	7.5	-0.03
S53	2.0	-8.7	0.2	-8.89	2.1	-8.7	-0.22	-8.94	2.6	-8.64	-0.22	-8.94	2.3	-8.68	-1.04	-9.03	2.3	-8.67	-1.56	-9.09
S54	11.0	0.2	9.2	0.0	11.0	0.2	8.7	-0.02	11.5	0.3	8.7	-0.02	11.2	0.2	7.9	-0.11	11.2	0.2	7.4	-0.17
S55	3.8	-6.96	2.0	-7.15	3.8	-6.96	1.5	-7.2	4.3	-6.9	1.5	-7.2	4.0	-6.94	0.7	-7.29	4.1	-6.93	0.2	-7.35
S56	11.1	0.4	9.3	0.2	11.2	0.4	8.9	0.2	11.7	0.5	8.9	0.2	11.4	0.4	8.1	0.1	11.4	0.4	7.5	0.0
S57	1.9	-8.81	0.1	-9	2.0	-8.81	-0.33	-9.05	2.5	-8.75	-0.33	-9.05	2.2	-8.78	-1.15	-9.14	2.2	-8.78	-1.67	-9.2
S58	10.9	0.2	9.1	0.0	11.0	0.2	8.7	-0.04	11.5	0.3	8.7	-0.04	11.2	0.2	7.9	-0.12	11.2	0.2	7.3	-0.18
S59	3.9	-6.81	2.1	-7.01	4.0	-6.81	1.7	-7.05	4.5	-6.75	1.7	-7.05	4.2	-6.79	0.9	-7.14	4.2	-6.78	0.3	-7.2
S60	11.2	0.4	9.4	0.2	11.2	0.4	8.9	0.2	11.7	0.5	8.9	0.2	11.4	0.4	8.1	0.1	11.4	0.5	7.6	0.0

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	0.8	-10.7	0.5	-10.7	0.8	-10.6	-1.54	-10.9	1.6	-10.6	-1.75	-10.9	1.3	-10.6	-2.83	-11	1.8	-10.5	-3.7	-11.1
S2	11.5	0.1	11.3	0.1	11.6	0.1	9.2	-0.17	12.3	0.2	9.0	-0.19	12.0	0.1	7.9	-0.3	12.5	0.2	7.1	-0.4
S3	2.6	-8.86	2.3	-8.89	2.6	-8.85	0.3	-9.11	3.4	-8.77	0.1	-9.13	3.1	-8.8	-1.03	-9.24	3.6	-8.7	-1.9	-9.3
S4	11.7	0.3	11.4	0.2	11.8	0.3	9.4	0.0	12.5	0.4	9.2	0.0	12.2	0.3	8.1	-0.11	12.7	0.4	7.3	-0.2
S5	0.8	-10.7	0.5	-10.7	0.8	-10.7	-1.57	-10.9	1.6	-10.6	-1.78	-11	1.3	-10.6	-2.86	-11.1	1.7	-10.6	-3.7	-11.2
S6	11.5	0.1	11.3	0.1	11.6	0.1	9.2	-0.17	12.3	0.2	9.0	-0.19	12.0	0.1	7.9	-0.31	12.5	0.2	7.1	-0.4
S7	3.0	-8.4	2.8	-8.43	3.1	-8.39	0.7	-8.65	3.9	-8.31	0.5	-8.67	3.5	-8.34	-0.57	-8.78	4.0	-8.3	-1.4	-8.9
S8	11.8	0.3	11.5	0.3	11.8	0.3	9.4	0.1	12.6	0.4	9.2	0.1	12.3	0.4	8.2	-0.06	12.8	0.4	7.3	-0.2
S9	0.2	-11.2	-0.04	-11.2	0.3	-11.2	-2.09	-11.5	1.0	-11.1	-2.3	-11.5	0.7	-11.2	-3.38	-11.6	1.2	-11.1	-4.2	-11.7
S10	11.5	0.0	11.2	0	11.5	0.0	9.1	-0.22	12.3	0.1	8.9	-0.25	12.0	0.1	7.9	-0.36	12.5	0.1	7.0	-0.5
S11	3.0	-8.4	2.8	-8.43	3.1	-8.39	0.7	-8.65	3.9	-8.31	0.5	-8.67	3.5	-8.34	-0.57	-8.79	4.0	-8.3	-1.4	-8.9
S12	11.8	0.3	11.5	0.3	11.8	0.3	9.4	0.1	12.6	0.4	9.2	0.1	12.3	0.4	8.2	-0.06	12.8	0.4	7.3	-0.2
S13	0.5	-10.9	0.3	-10.9	0.6	-10.9	-1.79	-11.2	1.3	-10.8	-2	-11.2	1.0	-10.8	-3.07	-11.3	1.5	-10.8	-3.9	-11.4
S14	11.5	0.1	11.2	0.0	11.6	0.1	9.2	-0.19	12.3	0.1	9.0	-0.21	12.0	0.1	7.9	-0.33	12.5	0.2	7.1	-0.4
S15	3.9	-7.58	3.6	-7.61	3.9	-7.57	1.5	-7.83	4.7	-7.49	1.3	-7.85	4.4	-7.53	0.3	-7.97	4.9	-7.5	-0.6	-8.1
S16	11.9	0.4	11.6	0.4	11.9	0.4	9.5	0.2	12.7	0.5	9.3	0.1	12.4	0.5	8.2	0.0	12.8	0.5	7.4	-0.1
S17	0.5	-10.9	0.2	-11	0.6	-10.9	-1.82	-11.2	1.3	-10.9	-2.03	-11.2	1.0	-10.9	-3.11	-11.3	1.5	-10.8	-3.9	-11.4
S18	11.5	0.1	11.2	0.0	11.6	0.1	9.2	-0.2	12.3	0.1	9.0	-0.22	12.0	0.1	7.9	-0.33	12.5	0.2	7.1	-0.4
S19	4.4	-7.06	4.1	-7.09	4.4	-7.05	2.1	-7.31	5.2	-6.97	1.8	-7.33	4.9	-7	0.8	-7.45	5.4	-7.0	-0.1	-7.5
S20	11.9	0.5	11.6	0.4	12.0	0.5	9.6	0.2	12.7	0.6	9.4	0.2	12.4	0.5	8.3	0.1	12.9	0.6	7.5	0.0
S21		-11.4	-0.27	-11.5	0.1	-11.4	-2.32	-11.7	0.8	-11.4	-2.53	-11.7	0.5	-11.4	-3.61	-11.8	1.0	-11.3	-4.4	-11.9
S22	11.4		11.2	-0.03	11.5	0.0	9.1	-0.25	12.2	0.1	8.9	-0.27	11.9	0.1	7.8	-0.39	12.4	0.1	7.0	-0.5
S23	0.3	-11.2		-11.2	0.3	-11.2	-2.06	-11.4	1.1	-11.1	-2.27	-11.4	0.8	-11.1	-3.34	-11.6	1.3	-11.1	-4.2	-11.6
S24	11.5	0.0	11.2		11.5	0.0	9.1	-0.22	12.3	0.1	8.9	-0.24	12.0	0.1	7.9	-0.36	12.5	0.1	7.0	-0.4
S25	-0.06	-11.5	-0.33	-11.5		-11.5	-2.38	-11.8	0.7	-11.4	-2.59	-11.8	0.4	-11.4	-3.67	-11.9	0.9	-11.4	-4.5	-12.0
S26	11.4	-0.01	11.2	-0.04	11.5		9.1	-0.26	12.2	0.1	8.9	-0.28	11.9	0.0	7.8	-0.39	12.4	0.1	7.0	-0.5
S27	2.3	-9.12	2.1	-9.15	2.4	-9.11		-9.37	3.1	-9.03	-0.21	-9.39	2.8	-9.06	-1.29	-9.51	3.3	-9.0	-2.1	-9.6
S28	11.7	0.2	11.4	0.2	11.8	0.3	9.4		12.5	0.3	9.2	-0.02	12.2	0.3	8.1	-0.14	12.7	0.4	7.2	-0.2
S29	-0.81	-12.2	-1.08	-12.3	-0.75	-12.2	-3.13	-12.5		-12.2	-3.34	-12.5	-0.31	-12.2	-4.42	-12.6	0.2	-12.1	-5.25	-12.7
S30	11.4	-0.09	11.1	-0.12	11.4	-0.08	9.0	-0.34	12.2		8.8	-0.36	11.9	-0.03	7.7	-0.47	12.3	0.0	6.9	-0.56
S31	2.5	-8.91	2.3	-8.94	2.6	-8.9	0.2	-9.16	3.3	-8.82		-9.18	3.0	-8.85	-1.08	-9.3	3.5	-8.8	-1.91	-9.38
S32	11.7	0.3	11.4	0.2	11.8	0.3	9.4	0.0	12.5	0.4	9.2		12.2	0.3	8.1	-0.12	12.7	0.4	7.3	-0.21
S33	-0.5	-11.9	-0.77	-12	-0.44	-11.9	-2.82	-12.2	0.3	-11.9	-3.03	-12.2		-11.9	-4.11	-12.3	0.5	-11.8	-4.94	-12.4
S34	11.4	-0.05	11.1	-0.08	11.4	-0.05	9.1	-0.3	12.2	0.0	8.9	-0.33	11.9		7.8	-0.44	12.4	0.1	6.9	-0.53
S35	3.6	-7.83	3.3	-7.86	3.7	-7.82	1.3	-8.08	4.4	-7.74	1.1	-8.1	4.1	-7.78		-8.22	4.6	-7.72	-0.83	-8.31
S36	11.8	0.4	11.6	0.4	11.9	0.4	9.5	0.1	12.6	0.5	9.3	0.1	12.3	0.4	8.2		12.8	0.5	7.4	-0.09
S37	-0.99	-12.4	-1.26	-12.5	-0.93	-12.4	-3.31	-12.7	-0.18	-12.3	-3.52	-12.7	-0.49	-12.4	-4.6	-12.8		-12.3	-5.44	-12.9
S38	11.3	-0.11	11.1	-0.14	11.4	-0.1	9.0	-0.36	12.1	-0.02	8.8	-0.38	11.8	-0.05	7.7	-0.49	12.3		6.9	-0.58
S39	4.4	-7	4.2	-7.03	4.5	-6.99	2.1	-7.25	5.3	-6.91	1.9	-7.27	4.9	-6.94	0.8	-7.38	5.4	-6.89		-7.47
S40	11.9	0.5	11.6	0.4	12.0	0.5	9.6	0.2	12.7	0.6	9.4	0.2	12.4	0.5	8.3	0.1	12.9	0.6	7.5	
S41	1.4	-10.1	1.1	-10.1	1.5	-10	-0.93	-10.3	2.2	-9.96	-1.14	-10.3	1.9	-10	-2.22	-10.4	2.4	-9.94	-3.05	-10.5
S42	11.6	0.1	11.3	0.1	11.7	0.2	9.3	-0.1	12.4	0.2	9.1	-0.12	12.1	0.2	8.0	-0.24	12.6	0.3	7.1	-0.33
S43	3.0	-8.49	2.7	-8.52	3.0	-8.48	0.6	-8.74	3.8	-8.4	0.4	-8.76	3.5	-8.43	-0.66	-8.87	3.9	-8.38	-1.49	-8.96
S44	11.8	0.3	11.5	0.3	11.8	0.3	9.4	0.1	12.6	0.4	9.2	0.0	12.3	0.4	8.1	-0.07	12.7	0.4	7.3	-0.16
S45	2.1	-9.35	1.8	-9.37	2.2	-9.34	-0.23	-9.59	2.9	-9.26	-0.44	-9.62	2.6	-9.29	-1.52	-9.73	3.1	-9.24	-2.35	-9.82
S46	11.7	0.2	11.4	0.2	11.7	0.2	9.3	-0.02	12.5	0.3	9.1	-0.05	12.2	0.3	8.1	-0.16	12.7	0.3	7.2	-0.25
S47	3.7	-7.76	3.4	-7.78	3.7	-7.75	1.4	-8.01	4.5	-7.67	1.2	-8.03	4.2	-7.7	0.1	-8.14	4.7	-7.65	-0.76	-8.23
S48	11.8	0.4	11.6	0.4	11.9	0.4	9.5	0.1	12.6	0.5	9.3	0.1	12.3	0.4	8.2	0.0	12.8	0.5	7.4	-0.08
S49	2.5	-8.95	2.2	-8.98	2.5	-8.94	0.2	-9.2	3.3	-8.86	-0.04	-9.22	3.0	-8.9	-1.12	-9.34	3.5	-8.85	-1.95	-9.43
S50	11.7	0.3	11.4	0.2	11.8	0.3	9.4	0.0	12.5	0.4	9.2	0	12.2	0.3	8.1	-0.12	12.7	0.4	7.3	-0.21
S51	4.1	-7.35	3.8	-7.38	4.2	-7.34	1.8	-7.6	4.9	-7.26	1.6	-7.62	4.6	-7.3	0.5	-7.74	5.1	-7.24	-0.35	-7.83
S52	11.9	0.4	11.6	0.4	11.9	0.4	9.6	0.2	12.7	0.5	9.3	0.2	12.4	0.5	8.3	0.1	12.9	0.5	7.4	-0.04
S53	2.8	-8.62	2.6	-8.65	2.9	-8.61	0.5	-8.87	3.6	-8.53	0.3	-8.89	3.3	-8.56	-0.79	-9	3.8	-8.51	-1.62	-9.09
S54	11.7	0.3	11.5	0.3	11.8	0.3	9.4	0.1	12.6	0.4	9.2	0.0	12.2	0.4	8.1	-0.08	12.7	0.4	7.3	-0.17
S55	4.6	-6.88	4.3	-6.91	4.6	-6.87	2.2	-7.13	5.4	-6.79	2.0	-7.15	5.1	-6.82	1.0	-7.27	5.6	-6.77	0.1	-7.35
S56	11.9	0.5	11.7	0.5	12.0	0.5	9.6	0.2	12.7	0.6	9.4	0.2	12.4	0.5	8.3	0.1	12.9	0.6	7.5	0.0
S57	2.7	-8.73	2.4	-8.76	2.8	-8.72	0.4	-8.98	3.5	-8.64	0.2	-9	3.2	-8.67	-0.9	-9.11	3.7	-8.62	-1.73	-9.2
S58	11.7	0.3	11.5	0.3	11.8	0.3	9.4	0.0	12.5	0.4	9.2	0.0	12.2	0.3	8.1	-0.1	12.7	0.4	7.3	-0.19
S59	4.7	-6.73	4.4	-6.76	4.8	-6.72	2.4	-6.98	5.5	-6.64	2.2	-7	5.2	-6.67	1.1	-7.12	5.7	-6.62	0.3	-7.21
S60	11.9	0.5	11.7	0.5	12.0	0.5	9.6	0.3	12.8	0.6	9.4	0.2	12.4	0.6	8.3	0.1	12.9	0.6	7.5	0.0

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	-0.6	-10.8	-2.17	-11	-1.31	-10.9	-2.9	-11.1	-1.7	-10.9	-3.31	-11.1	-2.04	-11	-3.78	-11.1	-1.93	-10.9	-3.93	-11.2
S2	10.1	-0.06	8.6	-0.23	9.4	-0.14	7.8	-0.31	9.0	-0.18	7.4	-0.36	8.7	-0.22	7.0	-0.41	8.8	-0.21	6.8	-0.42
S3	1.2	-9.01	-0.37	-9.17	0.5	-9.08	-1.1	-9.25	0.1	-9.12	-1.51	-9.3	-0.24	-9.16	-1.98	-9.35	-0.13	-9.15	-2.13	-9.36
S4	10.3	0.1	8.8	-0.04	9.6	0.1	8.0	-0.12	9.2	0.0	7.6	-0.16	8.9	-0.03	7.2	-0.21	9.0	-0.01	7.0	-0.23
S5	-0.63	-10.8	-2.2	-11	-1.34	-10.9	-2.93	-11.1	-1.73	-11	-3.34	-11.1	-2.07	-11	-3.81	-11.2	-1.96	-11	-3.96	-11.2
S6	10.1	-0.07	8.6	-0.24	9.4	-0.14	7.8	-0.31	9.0	-0.19	7.4	-0.36	8.7	-0.22	7.0	-0.41	8.8	-0.21	6.8	-0.42
S7	1.7	-8.55	0.1	-8.71	0.9	-8.62	-0.64	-8.79	0.6	-8.66	-1.05	-8.84	0.2	-8.7	-1.52	-8.89	0.3	-8.69	-1.67	-8.9
S8	10.4	0.2	8.8	0.0	9.7	0.1	8.1	-0.07	9.3	0.1	7.7	-0.11	8.9	0.0	7.2	-0.16	9.1	0.0	7.1	-0.18
S9	-1.16	-11.4	-2.72	-11.5	-1.87	-11.4	-3.46	-11.6	-2.26	-11.5	-3.86	-11.7	-2.59	-11.5	-4.33	-11.7	-2.48	-11.5	-4.48	-11.7
S10	10.1	-0.12	8.5	-0.29	9.4	-0.2	7.8	-0.37	9.0	-0.24	7.4	-0.41	8.6	-0.28	6.9	-0.47	8.8	-0.27	6.8	-0.48
S11	1.7	-8.55	0.1	-8.71	0.9	-8.62	-0.64	-8.79	0.6	-8.66	-1.05	-8.84	0.2	-8.7	-1.52	-8.89	0.3	-8.69	-1.67	-8.9
S12	10.4	0.2	8.8	0.0	9.7	0.1	8.1	-0.07	9.3	0.1	7.7	-0.11	8.9	0.0	7.2	-0.16	9.1	0.0	7.1	-0.18
S13	-0.85	-11.1	-2.42	-11.2	-1.56	-11.1	-3.15	-11.3	-1.95	-11.2	-3.55	-11.3	-2.29	-11.2	-4.03	-11.4	-2.18	-11.2	-4.17	-11.4
S14	10.1	-0.09	8.5	-0.26	9.4	-0.17	7.8	-0.34	9.0	-0.21	7.4	-0.38	8.7	-0.25	6.9	-0.43	8.8	-0.23	6.8	-0.45
S15	2.5	-7.73	0.9	-7.9	1.8	-7.8	0.2	-7.97	1.4	-7.85	-0.23	-8.02	1.0	-7.88	-0.7	-8.07	1.1	-7.87	-0.85	-8.08
S16	10.5	0.3	8.9	0.1	9.8	0.2	8.2	0.0	9.4	0.1	7.8	-0.02	9.0	0.1	7.3	-0.08	9.1	0.1	7.1	-0.09
S17	-0.89	-11.1	-2.45	-11.3	-1.6	-11.2	-3.19	-11.3	-1.99	-11.2	-3.59	-11.4	-2.32	-11.2	-4.06	-11.4	-2.21	-11.2	-4.21	-11.4
S18	10.1	-0.1	8.5	-0.26	9.4	-0.17	7.8	-0.34	9.0	-0.21	7.4	-0.39	8.7	-0.25	6.9	-0.44	8.8	-0.24	6.8	-0.45
S19	3.0	-7.21	1.4	-7.38	2.3	-7.28	0.7	-7.45	1.9	-7.33	0.3	-7.5	1.6	-7.36	-0.18	-7.55	1.7	-7.35	-0.33	-7.56
S20	10.5	0.3	9.0	0.2	9.8	0.2	8.2	0.1	9.4	0.2	7.8	0.0	9.1	0.2	7.3	-0.02	9.2	0.2	7.2	-0.04
S21	-1.39	-11.6	-2.95	-11.8	-2.1	-11.7	-3.69	-11.8	-2.49	-11.7	-4.09	-11.9	-2.82	-11.7	-4.56	-11.9	-2.71	-11.7	-4.71	-11.9
S22	10.1	-0.15	8.5	-0.32	9.3	-0.22	7.8	-0.4	9.0	-0.27	7.3	-0.44	8.6	-0.3	6.9	-0.49	8.7	-0.29	6.7	-0.51
S23	-1.12	-11.3	-2.69	-11.5	-1.83	-11.4	-3.42	-11.6	-2.22	-11.4	-3.82	-11.6	-2.56	-11.5	-4.3	-11.7	-2.45	-11.5	-4.44	-11.7
S24	10.1	-0.12	8.5	-0.29	9.4	-0.2	7.8	-0.37	9.0	-0.24	7.4	-0.41	8.6	-0.27	6.9	-0.46	8.8	-0.26	6.8	-0.48
S25	-1.45	-11.7	-3.02	-11.8	-2.16	-11.7	-3.75	-11.9	-2.55	-11.8	-4.15	-11.9	-2.88	-11.8	-4.62	-12	-2.77	-11.8	-4.77	-12
S26	10.0	-0.16	8.5	-0.32	9.3	-0.23	7.7	-0.4	8.9	-0.27	7.3	-0.45	8.6	-0.31	6.9	-0.5	8.7	-0.3	6.7	-0.51
S27	0.9	-9.27	-0.63	-9.43	0.2	-9.34	-1.36	-9.51	-0.17	-9.38	-1.77	-9.56	-0.5	-9.42	-2.24	-9.61	-0.39	-9.41	-2.39	-9.62
S28	10.3	0.1	8.7	-0.07	9.6	0.0	8.0	-0.15	9.2	-0.02	7.6	-0.19	8.9	-0.05	7.1	-0.24	9.0	-0.04	7.0	-0.26
S29	-2.2	-12.4	-3.76	-12.6	-2.9	-12.5	-4.49	-12.6	-3.3	-12.5	-4.9	-12.7	-3.63	-12.6	-5.37	-12.7	-3.52	-12.5	-5.52	-12.8
S30	10.0	-0.24	8.4	-0.4	9.3	-0.31	7.7	-0.48	8.9	-0.35	7.3	-0.53	8.5	-0.39	6.8	-0.58	8.6	-0.38	6.6	-0.59
S31	1.1	-9.06	-0.42	-9.22	0.4	-9.13	-1.15	-9.3	0.0	-9.17	-1.56	-9.35	-0.29	-9.21	-2.03	-9.4	-0.18	-9.2	-2.18	-9.41
S32	10.3	0.1	8.8	-0.05	9.6	0.0	8.0	-0.12	9.2	0.0	7.6	-0.17	8.9	-0.03	7.1	-0.22	9.0	-0.02	7.0	-0.23
S33	-1.89	-12.1	-3.45	-12.3	-2.6	-12.2	-4.19	-12.3	-2.99	-12.2	-4.59	-12.4	-3.32	-12.2	-5.06	-12.4	-3.21	-12.2	-5.21	-12.4
S34	10.0	-0.2	8.4	-0.37	9.3	-0.28	7.7	-0.45	8.9	-0.32	7.3	-0.49	8.6	-0.36	6.8	-0.54	8.7	-0.35	6.7	-0.56
S35	2.2	-7.98	0.7	-8.15	1.5	-8.05	-0.07	-8.22	1.1	-8.1	-0.48	-8.27	0.8	-8.13	-0.95	-8.32	0.9	-8.12	-1.1	-8.34
S36	10.4	0.2	8.9	0.1	9.7	0.2	8.1	-0.01	9.3	0.1	7.7	-0.05	9.0	0.1	7.3	-0.1	9.1	0.1	7.1	-0.12
S37	-2.38	-12.6	-3.95	-12.7	-3.09	-12.7	-4.68	-12.8	-3.48	-12.7	-5.08	-12.9	-3.81	-12.7	-5.55	-12.9	-3.7	-12.7	-5.7	-12.9
S38	9.9	-0.26	8.4	-0.42	9.2	-0.33	7.6	-0.5	8.8	-0.37	7.2	-0.55	8.5	-0.41	6.8	-0.6	8.6	-0.4	6.6	-0.61
S39	3.1	-7.15	1.5	-7.31	2.3	-7.22	0.8	-7.39	2.0	-7.26	0.4	-7.44	1.6	-7.3	-0.12	-7.49	1.7	-7.29	-0.27	-7.5
S40	10.5	0.3	9.0	0.2	9.8	0.3	8.2	0.1	9.4	0.2	7.8	0.0	9.1	0.2	7.4	-0.01	9.2	0.2	7.2	-0.03
S41		-10.2	-1.56	-10.4	-0.71	-10.3	-2.3	-10.4	-1.1	-10.3	-2.7	-10.5	-1.43	-10.4	-3.17	-10.5	-1.32	-10.3	-3.32	-10.6
S42	10.2		8.6	-0.17	9.5	-0.08	7.9	-0.25	9.1	-0.12	7.5	-0.29	8.8	-0.15	7.0	-0.34	8.9	-0.14	6.9	-0.36
S43	1.6	-8.64		-8.8	0.9	-8.71	-0.73	-8.88	0.5	-8.75	-1.14	-8.93	0.1	-8.79	-1.61	-8.98	0.2	-8.78	-1.76	-8.99
S44	10.4	0.2	8.8		9.7	0.1	8.1	-0.08	9.3	0.0	7.7	-0.12	8.9	0.0	7.2	-0.17	9.0	0.0	7.0	-0.19
S45	0.7	-9.49	-0.86	-9.66		-9.57	-1.59	-9.74	-0.39	-9.61	-2	-9.78	-0.73	-9.65	-2.47	-9.84	-0.62	-9.64	-2.62	-9.85
S46	10.3	0.1	8.7	-0.09	9.6		8.0	-0.17	9.2	-0.04	7.6	-0.21	8.8	-0.08	7.1	-0.26	9.0	-0.07	7.0	-0.28
S47	2.3	-7.9	0.7	-8.07	1.6	-7.98		-8.15	1.2	-8.02	-0.41	-8.2	0.9	-8.06	-0.88	-8.25	1.0	-8.05	-1.03	-8.26
S48	10.4	0.2	8.9	0.1	9.7	0.2	8.2		9.3	0.1	7.7	-0.04	9.0	0.1	7.3	-0.09	9.1	0.1	7.1	-0.11
S49	1.1	-9.1	-0.47	-9.27	0.4	-9.18	-1.2	-9.35		-9.22	-1.6	-9.39	-0.33	-9.25	-2.07	-9.44	-0.22	-9.24	-2.22	-9.46
S50	10.3	0.1	8.8	-0.05	9.6	0.0	8.0	-0.13	9.2		7.6	-0.17	8.9	-0.04	7.1	-0.22	9.0	-0.02	7.0	-0.24
S51	2.7	-7.5	1.1	-7.67	2.0	-7.57	0.4	-7.74	1.6	-7.62		-7.79	1.3	-7.65	-0.47	-7.84	1.4	-7.64	-0.62	-7.85
S52	10.5	0.3	8.9	0.1	9.8	0.2	8.2	0.0	9.4	0.2	7.8		9.1	0.1	7.3	-0.05	9.2	0.1	7.2	-0.07
S53	1.4	-8.77	-0.13	-8.93	0.7	-8.84	-0.86	-9.01	0.3	-8.88	-1.27	-9.06		-8.92	-1.74	-9.11	0.1	-8.91	-1.89	-9.12
S54	10.4	0.2	8.8	-0.01	9.6	0.1	8.1	-0.09	9.3	0.0	7.7	-0.14	8.9		7.2	-0.19	9.0	0.0	7.0	-0.2
S55	3.2	-7.03	1.6	-7.19	2.5	-7.1	0.9	-7.27	2.1	-7.14	0.5	-7.32	1.7	-7.18		-7.37	1.8	-7.17	-0.15	-7.38
S56	10.5	0.3	9.0	0.2	9.8	0.3	8.2	0.1	9.4	0.2	7.8	0.1	9.1	0.2	7.4		9.2	0.2	7.2	-0.02
S57	1.3	-8.88	-0.24	-9.04	0.6	-8.95	-0.97	-9.12	0.2	-8.99	-1.38	-9.17	-0.11	-9.03	-1.85	-9.22		-9.02	-2	-9.23
S58	10.3	0.1	8.8	-0.03	9.6	0.1	8.0	-0.1	9.2	0.0	7.6	-0.15	8.9	-0.01	7.2	-0.2	9.0		7.0	-0.21
S59	3.3	-6.88	1.8	-7.05	2.6	-6.95	1.0	-7.12	2.2	-7	0.6	-7.17	1.9	-7.03	0.1	-7.22	2.0	-7.02		-7.23
S60	10.6	0.4	9.0	0.2	9.9	0.3	8.3	0.1	9.5	0.2	7.9	0.1	9.1	0.2	7.4	0.0	9.2	0.2	7.2	

Table D-3 Excerpt of Watershed Level TN Load Reduction Index (TNRI) for Each Scenario

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1																				
S2	0.89		0.89		0.88		0.87		0.86		0.85		0.83		0.82		0.81		0.79	
S3	0.03																			
S4	0.9	0.03	0.89		0.88		0.88		0.86		0.85		0.83		0.82		0.81		0.8	
S5	0.14		0.11																	
S6	0.907	0.14	0.904	0.11	0.89		0.89		0.88		0.87		0.85		0.84		0.83		0.82	
S7	0.16		0.14		0.03															
S8	0.910	0.16	0.907	0.14	0.9	0.03	0.89		0.88		0.87		0.86		0.85		0.84		0.82	
S9	0.26		0.23		0.14		0.11													
S10	0.920	0.26	0.918	0.23	0.908	0.14	0.905	0.11	0.89		0.89		0.87		0.86		0.86		0.84	
S11	0.28		0.26		0.17		0.15		0.04											
S12	0.923	0.28	0.921	0.26	0.911	0.17	0.908	0.15	0.9	0.04	0.89		0.88		0.87		0.86		0.85	
S13	0.37		0.35		0.28		0.25		0.16		0.12									
S14	0.933	0.37	0.931	0.35	0.922	0.28	0.920	0.25	0.910	0.16	0.906	0.12	0.89		0.89		0.88		0.87	
S15	0.41		0.39		0.32		0.29		0.21		0.17		0.06							
S16	0.937	0.41	0.935	0.39	0.927	0.32	0.924	0.29	0.915	0.21	0.911	0.17	0.9	0.06	0.89		0.89		0.88	
S17	0.45		0.43		0.36		0.34		0.26		0.23		0.12		0.06					
S18	0.941	0.45	0.939	0.43	0.931	0.36	0.929	0.34	0.920	0.26	0.917	0.23	0.905	0.12	0.9	0.06	0.89		0.88	
S19	0.49		0.47		0.41		0.39		0.31		0.28		0.18		0.13		0.07			
S20	0.945	0.49	0.943	0.47	0.936	0.41	0.934	0.39	0.926	0.31	0.923	0.28	0.912	0.18	0.907	0.13	0.901	0.07	0.89	
S21																				
S22	0.87		0.87		0.85		0.85		0.83		0.82		0.8		0.79		0.77		0.75	
S23																				
S24	0.86		0.85		0.84		0.83		0.81		0.8		0.77		0.76		0.74		0.72	
S25																				
S26	0.88		0.88		0.87		0.86		0.84		0.84		0.82		0.8		0.79		0.77	
S27																				
S28	0.89		0.89		0.87		0.87		0.85		0.85		0.82		0.81		0.8		0.79	
S29	0.02																			
S30	0.89	0.02	0.89		0.88		0.87		0.86		0.85		0.83		0.82		0.81		0.79	
S31	0.07		0.05																	
S32	0.900	0.07	0.9	0.05	0.88		0.88		0.87		0.86		0.84		0.83		0.82		0.81	
S33	0.11		0.08																	
S34	0.904	0.11	0.901	0.08	0.89		0.89		0.87		0.87		0.85		0.84		0.83		0.81	
S35	0.17		0.15		0.04		0.01													
S36	0.911	0.17	0.908	0.15	0.9	0.04	0.89	0.01	0.88		0.88		0.86		0.85		0.84		0.83	
S37	0.2		0.17		0.07		0.04													
S38	0.914	0.2	0.911	0.17	0.900	0.07	0.9	0.04	0.88		0.88		0.86		0.85		0.84		0.83	
S39	0.27		0.25		0.15		0.13		0.02											
S40	0.922	0.27	0.919	0.25	0.909	0.15	0.906	0.13	0.89	0.02	0.89		0.87		0.87		0.86		0.85	
S41	0.07		0.04																	
S42	0.9	0.07	0.9	0.04	0.88		0.88		0.87		0.86		0.84		0.83		0.82		0.8	
S43	0.08		0.05																	
S44	0.901	0.08	0.9	0.05	0.89		0.88		0.87		0.86		0.84		0.83		0.82		0.81	
S45	0.23		0.21		0.11		0.08													
S46	0.917	0.23	0.915	0.21	0.904	0.11	0.901	0.08	0.89		0.88		0.87		0.86		0.85		0.84	
S47	0.24		0.22		0.12		0.09													
S48	0.919	0.24	0.916	0.22	0.906	0.12	0.903	0.09	0.89		0.89		0.87		0.86		0.85		0.84	
S49	0.37		0.35		0.27		0.25		0.16		0.12									
S50	0.933	0.37	0.931	0.35	0.922	0.27	0.919	0.25	0.909	0.16	0.906	0.12	0.89		0.89		0.88		0.87	
S51	0.39		0.37		0.29		0.27		0.17		0.14		0.02							
S52	0.934	0.39	0.932	0.37	0.924	0.29	0.921	0.27	0.911	0.17	0.908	0.14	0.89	0.02	0.89		0.88		0.87	
S53	0.46		0.44		0.37		0.35		0.27		0.24		0.13		0.08		0.02			
S54	0.942	0.46	0.940	0.44	0.933	0.37	0.930	0.35	0.922	0.27	0.918	0.24	0.907	0.13	0.901	0.08	0.89	0.02	0.89	
S55	0.47		0.46		0.39		0.37		0.29		0.26		0.16		0.1		0.04			
S56	0.943	0.47	0.941	0.46	0.934	0.39	0.932	0.37	0.924	0.29	0.921	0.26	0.909	0.16	0.904	0.1	0.9	0.04	0.89	
S57	0.55		0.54		0.48		0.46		0.39		0.37		0.28		0.24		0.19		0.12	
S58	0.952	0.55	0.950	0.54	0.944	0.48	0.942	0.46	0.935	0.39	0.932	0.37	0.923	0.28	0.918	0.24	0.913	0.19	0.906	0.12
S59	0.56		0.55		0.49		0.48		0.41		0.39		0.3		0.26		0.21		0.15	
S60	0.953	0.56	0.952	0.55	0.946	0.49	0.944	0.48	0.937	0.41	0.934	0.39	0.925	0.3	0.921	0.26	0.915	0.21	0.908	0.15

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	0.15		0.24		0.07		0.02													
S2	0.909	0.15	0.919	0.24	0.900	0.07	0.9	0.02	0.89		0.88		0.88		0.87		0.87		0.85	
S3	0.18		0.27		0.1		0.05		0.01											
S4	0.912	0.18	0.921	0.27	0.903	0.1	0.9	0.05	0.89	0.01	0.89		0.88		0.87		0.87		0.86	
S5	0.27		0.35		0.2		0.16		0.12		0.07		0.03							
S6	0.922	0.27	0.930	0.35	0.914	0.2	0.909	0.16	0.905	0.12	0.9	0.07	0.9	0.03	0.89		0.88		0.87	
S7	0.29		0.37		0.22		0.18		0.15		0.1		0.06							
S8	0.924	0.29	0.932	0.37	0.916	0.22	0.912	0.18	0.908	0.15	0.903	0.1	0.9	0.06	0.89		0.89		0.88	
S9	0.37		0.44		0.31		0.27		0.24		0.2		0.17		0.1		0.07			
S10	0.932	0.37	0.940	0.44	0.926	0.31	0.922	0.27	0.919	0.24	0.914	0.2	0.911	0.17	0.904	0.1	0.9	0.07	0.89	
S11	0.4		0.46		0.34		0.3		0.27		0.23		0.2		0.14		0.11		0.02	
S12	0.935	0.4	0.942	0.46	0.929	0.34	0.925	0.3	0.922	0.27	0.917	0.23	0.914	0.2	0.907	0.14	0.9	0.11	0.89	0.02
S13	0.47		0.53		0.42		0.39		0.36		0.32		0.3		0.24		0.22		0.14	
S14	0.943	0.47	0.949	0.53	0.938	0.42	0.934	0.39	0.931	0.36	0.927	0.32	0.925	0.3	0.919	0.24	0.92	0.22	0.91	0.14
S15	0.5		0.55		0.45		0.42		0.4		0.36		0.34		0.29		0.27		0.19	
S16	0.946	0.5	0.952	0.55	0.941	0.45	0.938	0.42	0.935	0.4	0.932	0.36	0.929	0.34	0.924	0.29	0.92	0.27	0.91	0.19
S17	0.53		0.58		0.49		0.46		0.44		0.4		0.38		0.33		0.31		0.24	
S18	0.950	0.53	0.955	0.58	0.945	0.49	0.942	0.46	0.939	0.44	0.936	0.4	0.933	0.38	0.928	0.33	0.93	0.31	0.92	0.24
S19	0.57		0.61		0.52		0.5		0.48		0.45		0.43		0.38		0.36		0.3	
S20	0.953	0.57	0.958	0.61	0.949	0.52	0.946	0.5	0.944	0.48	0.941	0.45	0.938	0.43	0.934	0.38	0.93	0.36	0.92	0.3
S21			0.11																	
S22	0.89		0.904	0.11	0.88		0.88		0.87		0.86		0.86		0.85		0.84		0.83	
S23																				
S24	0.88		0.89		0.87		0.86		0.86		0.85		0.84		0.83		0.82		0.81	
S25	0.09		0.19																	
S26	0.902	0.09	0.913	0.19	0.89		0.89		0.88		0.88		0.87		0.86		0.86		0.84	
S27	0.13		0.23		0.05															
S28	0.907	0.13	0.917	0.23	0.9	0.05	0.89		0.89		0.88		0.88		0.87		0.86		0.85	
S29	0.17		0.26		0.09		0.04													
S30	0.911	0.17	0.920	0.26	0.902	0.09	0.9	0.04	0.89		0.89		0.88		0.87		0.87		0.86	
S31	0.22		0.3		0.14		0.09		0.06											
S32	0.916	0.22	0.925	0.3	0.908	0.14	0.903	0.09	0.9	0.06	0.89		0.89		0.88		0.88		0.86	
S33	0.24		0.32		0.17		0.13		0.09		0.04									
S34	0.919	0.24	0.928	0.32	0.911	0.17	0.906	0.13	0.902	0.09	0.9	0.04	0.89		0.88		0.88		0.87	
S35	0.3		0.37		0.23		0.19		0.15		0.11		0.07							
S36	0.925	0.3	0.933	0.37	0.917	0.23	0.913	0.19	0.909	0.15	0.904	0.11	0.900	0.07	0.89		0.89		0.88	
S37	0.32		0.39		0.25		0.21		0.18		0.13		0.1		0.03					
S38	0.927	0.32	0.935	0.39	0.920	0.25	0.916	0.21	0.912	0.18	0.907	0.13	0.903	0.1	0.9	0.03	0.89		0.88	
S39	0.38		0.45		0.32		0.29		0.26		0.21		0.18		0.12		0.09			
S40	0.934	0.38	0.941	0.45	0.927	0.32	0.923	0.29	0.920	0.26	0.915	0.21	0.912	0.18	0.905	0.12	0.902	0.09	0.89	
S41	0.21		0.3		0.13		0.09		0.05											
S42	0.915	0.21	0.924	0.3	0.907	0.13	0.902	0.09	0.9	0.05	0.89		0.89		0.88		0.88		0.86	
S43	0.22		0.31		0.15		0.1		0.06		0.01									
S44	0.917	0.22	0.925	0.31	0.908	0.15	0.904	0.1	0.9	0.06	0.89	0.01	0.89		0.88		0.88		0.86	
S45	0.35		0.42		0.28		0.25		0.22		0.17		0.14		0.07		0.04			
S46	0.930	0.35	0.938	0.42	0.923	0.28	0.919	0.25	0.916	0.22	0.911	0.17	0.907	0.14	0.900	0.07	0.9	0.04	0.89	
S47	0.36		0.43		0.3		0.26		0.23		0.18		0.15		0.09		0.06			
S48	0.931	0.36	0.938	0.43	0.924	0.3	0.920	0.26	0.917	0.23	0.912	0.18	0.909	0.15	0.902	0.09	0.9	0.06	0.89	
S49	0.47		0.52		0.42		0.39		0.36		0.32		0.3		0.24		0.22		0.14	
S50	0.943	0.47	0.949	0.52	0.937	0.42	0.934	0.39	0.931	0.36	0.927	0.32	0.924	0.3	0.919	0.24	0.916	0.22	0.908	0.14
S51	0.48		0.54		0.43		0.4		0.37		0.34		0.31		0.26		0.24		0.16	
S52	0.944	0.48	0.950	0.54	0.939	0.43	0.936	0.4	0.933	0.37	0.929	0.34	0.926	0.31	0.920	0.26	0.918	0.24	0.910	0.16
S53	0.54		0.59		0.5		0.47		0.45		0.41		0.39		0.35		0.32		0.26	
S54	0.951	0.54	0.956	0.59	0.946	0.5	0.943	0.47	0.941	0.45	0.937	0.41	0.935	0.39	0.930	0.35	0.927	0.32	0.920	0.26
S55	0.55		0.6		0.51		0.48		0.46		0.43		0.41		0.36		0.34		0.28	
S56	0.952	0.55	0.957	0.6	0.947	0.51	0.944	0.48	0.942	0.46	0.939	0.43	0.936	0.41	0.932	0.36	0.929	0.34	0.922	0.28
S57	0.62		0.66		0.58		0.56		0.54		0.51		0.5		0.46		0.44		0.38	
S58	0.959	0.62	0.963	0.66	0.955	0.58	0.953	0.56	0.951	0.54	0.948	0.51	0.946	0.5	0.942	0.46	0.940	0.44	0.934	0.38
S59	0.63		0.67		0.59		0.57		0.55		0.53		0.51		0.47		0.46		0.4	
S60	0.960	0.63	0.965	0.67	0.956	0.59	0.954	0.57	0.952	0.55	0.949	0.53	0.947	0.51	0.943	0.47	0.942	0.46	0.936	0.4

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1																				
S2	0.88		0.88		0.86		0.86		0.83		0.83		0.8		0.8		0.76		0.75	
S3																				
S4	0.89		0.89		0.86		0.86		0.83		0.83		0.81		0.8		0.77		0.76	
S5	0.07		0.06																	
S6	0.900	0.07	0.9	0.06	0.88		0.88		0.85		0.85		0.83		0.82		0.79		0.79	
S7	0.1		0.09																	
S8	0.904	0.1	0.902	0.09	0.88		0.88		0.86		0.85		0.83		0.83		0.8		0.79	
S9	0.2		0.19		0.03		0.02													
S10	0.914	0.2	0.913	0.19	0.9	0.03	0.89	0.02	0.87		0.87		0.85		0.85		0.82		0.82	
S11	0.23		0.22		0.07		0.06													
S12	0.918	0.23	0.916	0.22	0.900	0.07	0.9	0.06	0.88		0.88		0.86		0.85		0.83		0.82	
S13	0.33		0.32		0.19		0.17		0											
S14	0.928	0.33	0.927	0.32	0.913	0.19	0.911	0.17	0.89	0	0.89		0.88		0.87		0.85		0.85	
S15	0.37		0.36		0.23		0.22		0.06		0.04									
S16	0.932	0.37	0.931	0.36	0.918	0.23	0.916	0.22	0.9	0.06	0.9	0.04	0.88		0.88		0.86		0.85	
S17	0.41		0.4		0.28		0.27		0.12		0.1									
S18	0.936	0.41	0.935	0.4	0.923	0.28	0.922	0.27	0.905	0.12	0.903	0.1	0.89		0.89		0.87		0.86	
S19	0.45		0.44		0.33		0.32		0.18		0.17		0.06		0.03					
S20	0.941	0.45	0.940	0.44	0.929	0.33	0.927	0.32	0.912	0.18	0.910	0.17	0.9	0.06	0.9	0.03	0.88		0.87	
S21																				
S22	0.86		0.86		0.84		0.83		0.8		0.79		0.77		0.76		0.72		0.71	
S23																				
S24	0.85		0.85		0.82		0.81		0.77		0.77		0.74		0.73		0.69		0.68	
S25																				
S26	0.88		0.87		0.85		0.85		0.82		0.81		0.79		0.78		0.74		0.74	
S27																				
S28	0.88		0.88		0.86		0.86		0.83		0.82		0.8		0.79		0.76		0.75	
S29																				
S30	0.89		0.89		0.86		0.86		0.83		0.83		0.81		0.8		0.77		0.76	
S31	0																			
S32	0.89	0	0.89		0.87		0.87		0.84		0.84		0.82		0.81		0.78		0.77	
S33	0.04		0.03																	
S34	0.9	0.04	0.9	0.03	0.88		0.87		0.85		0.84		0.82		0.82		0.79		0.78	
S35	0.11		0.1																	
S36	0.904	0.11	0.903	0.1	0.88		0.88		0.86		0.86		0.84		0.83		0.8		0.8	
S37	0.14		0.13																	
S38	0.907	0.14	0.906	0.13	0.89		0.89		0.86		0.86		0.84		0.84		0.81		0.8	
S39	0.22		0.2		0.05		0.04													
S40	0.916	0.22	0.915	0.2	0.9	0.05	0.9	0.04	0.88		0.87		0.86		0.85		0.83		0.82	
S41																				
S42	0.89		0.89		0.87		0.87		0.84		0.84		0.82		0.81		0.78		0.77	
S43	0.01																			
S44	0.89	0.01	0.89		0.87		0.87		0.84		0.84		0.82		0.81		0.78		0.77	
S45	0.17		0.16																	
S46	0.911	0.17	0.910	0.16	0.89		0.89		0.87		0.87		0.85		0.84		0.82		0.81	
S47	0.19		0.17		0.02															
S48	0.913	0.19	0.911	0.17	0.89	0.02	0.89		0.87		0.87		0.85		0.85		0.82		0.81	
S49	0.33		0.32		0.18		0.17													
S50	0.928	0.33	0.927	0.32	0.912	0.18	0.911	0.17	0.89		0.89		0.88		0.87		0.85		0.85	
S51	0.34		0.33		0.2		0.19		0.02											
S52	0.929	0.34	0.928	0.33	0.914	0.2	0.913	0.19	0.89	0.02	0.89		0.88		0.88		0.85		0.85	
S53	0.42		0.41		0.29		0.28		0.14		0.12									
S54	0.937	0.42	0.937	0.41	0.924	0.29	0.923	0.28	0.907	0.14	0.905	0.12	0.89		0.89		0.87		0.87	
S55	0.43		0.42		0.31		0.3		0.16		0.14		0.03							
S56	0.939	0.43	0.938	0.42	0.926	0.31	0.925	0.3	0.910	0.16	0.908	0.14	0.9	0.03	0.89		0.87		0.87	
S57	0.52		0.51		0.41		0.4		0.28		0.27		0.17		0.15					
S58	0.948	0.52	0.947	0.51	0.937	0.41	0.936	0.4	0.923	0.28	0.921	0.27	0.911	0.17	0.909	0.15	0.89		0.89	
S59	0.53		0.52		0.43		0.42		0.3		0.29		0.2		0.17		0.03			
S60	0.950	0.53	0.949	0.52	0.939	0.43	0.938	0.42	0.925	0.3	0.924	0.29	0.914	0.2	0.911	0.17	0.9	0.03	0.89	

Table D-4 Excerpt of Watershed Level TP Load Reduction Index (TPRI) for Each Scenario

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1					0				0.04				0.02				0.02			
S2	0.89		0.87		0.89	0	0.87		0.9	0.04	0.87		0.89	0.02	0.86		0.9	0.02	0.85	
S3	0.15				0.15				0.19				0.17				0.17			
S4	0.909	0.15	0.89		0.909	0.15	0.89		0.913	0.19	0.89		0.910	0.17	0.88		0.911	0.17	0.87	
S5									0.04				0.02				0.02			
S6	0.89		0.87		0.89		0.87		0.9	0.04	0.87		0.89	0.02	0.86		0.89	0.02	0.85	
S7	0.19		0.04		0.19				0.22		0		0.2				0.21			
S8	0.913	0.19	0.9	0.04	0.913	0.19	0.89		0.917	0.22	0.89	0	0.914	0.2	0.88		0.915	0.21	0.88	
S9																				
S10	0.89		0.87		0.89		0.86		0.89		0.86		0.89		0.85		0.89		0.84	
S11	0.19		0.04		0.19				0.22				0.2				0.21			
S12	0.913	0.19	0.9	0.04	0.913	0.19	0.89		0.917	0.22	0.89		0.914	0.2	0.88		0.915	0.21	0.88	
S13									0.02											
S14	0.89		0.87		0.89		0.87		0.9	0.02	0.87		0.89		0.85		0.89	0	0.84	
S15	0.26		0.12		0.26		0.08		0.29		0.08		0.27				0.27			
S16	0.920	0.26	0.906	0.12	0.920	0.26	0.902	0.08	0.924	0.29	0.902	0.08	0.922	0.27	0.89		0.922	0.27	0.89	
S17									0.02											
S18	0.89		0.87		0.89		0.86		0.89	0.02	0.86		0.89		0.85		0.89		0.84	
S19	0.3		0.18		0.3		0.14		0.33		0.14		0.31		0.06		0.32			
S20	0.925	0.3	0.911	0.18	0.925	0.3	0.907	0.14	0.928	0.33	0.907	0.14	0.926	0.31	0.9	0.06	0.926	0.31	0.89	
S21																				
S22	0.89		0.87		0.89		0.86		0.89		0.86		0.89		0.85		0.89		0.84	
S23									0											
S24	0.89		0.87		0.89		0.86		0.89	0	0.86		0.89		0.85		0.89		0.84	
S25																				
S26	0.89		0.86		0.89		0.86		0.89		0.86		0.89		0.85		0.89		0.84	
S27	0.13				0.13				0.17				0.15				0.15			
S28	0.906	0.13	0.89		0.907	0.13	0.88		0.910	0.17	0.88		0.908	0.15	0.87		0.908	0.15	0.87	
S29																				
S30	0.88		0.86		0.88		0.85		0.88		0.85		0.88		0.84		0.88		0.83	
S31	0.15				0.15				0.18				0.16				0.17			
S32	0.908	0.15	0.89		0.908	0.15	0.89		0.912	0.18	0.89		0.910	0.16	0.88		0.910	0.16	0.87	
S33																				
S34	0.88		0.86		0.88		0.85		0.89		0.85		0.88		0.84		0.88		0.83	
S35	0.23		0.1		0.24		0.06		0.27		0.06		0.25				0.25			
S36	0.918	0.23	0.903	0.1	0.918	0.24	0.9	0.06	0.921	0.27	0.9	0.06	0.919	0.25	0.89		0.920	0.25	0.88	
S37																				
S38	0.88		0.86		0.88		0.85		0.88		0.85		0.88		0.83		0.88		0.82	
S39	0.3		0.18		0.31		0.14		0.33		0.14		0.32		0.07		0.32		0.01	
S40	0.925	0.3	0.912	0.18	0.925	0.31	0.908	0.14	0.929	0.33	0.908	0.14	0.927	0.32	0.9	0.06	0.927	0.32	0.89	0.01
S41	0.05				0.05				0.09				0.07				0.07			
S42	0.9	0.05	0.88		0.9	0.05	0.87		0.902	0.09	0.87		0.900	0.07	0.86		0.900	0.07	0.85	
S43	0.18		0.04		0.18				0.22				0.2				0.2			
S44	0.912	0.18	0.9	0.04	0.912	0.18	0.89		0.916	0.22	0.89		0.914	0.2	0.88		0.914	0.2	0.87	
S45	0.11				0.11				0.15				0.13				0.13			
S46	0.904	0.11	0.89		0.904	0.11	0.88		0.908	0.15	0.88		0.906	0.13	0.87		0.906	0.13	0.86	
S47	0.24		0.11		0.24		0.07		0.27		0.07		0.26				0.26			
S48	0.918	0.24	0.904	0.11	0.919	0.24	0.9	0.07	0.922	0.27	0.9	0.07	0.920	0.26	0.89		0.920	0.26	0.88	
S49	0.14				0.14				0.18				0.16				0.16			
S50	0.908	0.14	0.89		0.908	0.14	0.89		0.912	0.18	0.89		0.910	0.16	0.88		0.910	0.16	0.87	
S51	0.27		0.15		0.28		0.11		0.31		0.11		0.29		0.03		0.29			
S52	0.922	0.27	0.908	0.15	0.922	0.28	0.904	0.11	0.926	0.31	0.904	0.11	0.924	0.29	0.9	0.03	0.924	0.29	0.89	
S53	0.17		0.02		0.17				0.21				0.19				0.19			
S54	0.911	0.17	0.9	0.02	0.911	0.17	0.89		0.915	0.21	0.89		0.913	0.19	0.88		0.913	0.19	0.87	
S55	0.31		0.19		0.32		0.16		0.34		0.16		0.33		0.08		0.33		0.02	
S56	0.926	0.31	0.913	0.19	0.926	0.32	0.909	0.16	0.930	0.34	0.909	0.16	0.928	0.33	0.901	0.08	0.928	0.33	0.89	0.02
S57	0.16		0.01		0.16				0.2				0.18				0.18			
S58	0.910	0.16	0.89	0.01	0.910	0.16	0.89		0.914	0.2	0.89		0.912	0.18	0.88		0.912	0.18	0.87	
S59	0.33		0.21		0.33		0.17		0.36		0.17		0.34		0.09		0.34		0.04	
S60	0.928	0.33	0.915	0.21	0.928	0.33	0.911	0.17	0.931	0.36	0.911	0.17	0.929	0.34	0.903	0.09	0.929	0.34	0.9	0.04

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	0.06		0.04		0.07				0.12				0.1				0.13			
S2	0.9	0.06	0.9	0.04	0.9	0.07	0.88		0.905	0.12	0.87		0.903	0.1	0.86		0.91	0.13	0.85	
S3	0.2		0.18		0.21		0.02		0.25		0		0.23				0.26			
S4	0.914	0.2	0.912	0.18	0.915	0.21	0.9	0.02	0.919	0.25	0.89	0	0.917	0.23	0.88		0.92	0.26	0.87	
S5	0.06		0.04		0.06				0.11				0.09				0.13			
S6	0.9	0.06	0.9	0.04	0.9	0.06	0.88		0.905	0.11	0.87		0.903	0.09	0.86		0.91	0.13	0.85	
S7	0.24		0.22		0.24		0.07		0.28		0.05		0.27				0.29			
S8	0.918	0.24	0.916	0.22	0.918	0.24	0.9	0.07	0.923	0.28	0.9	0.05	0.921	0.27	0.89		0.92	0.29	0.87	
S9	0.02				0.02				0.08				0.05				0.09			
S10	0.89	0.02	0.89		0.89	0.02	0.87		0.901	0.08	0.87		0.9	0.05	0.85		0.9	0.09	0.84	
S11	0.24		0.22		0.24		0.07		0.28		0.05		0.27				0.29			
S12	0.918	0.24	0.916	0.22	0.918	0.24	0.9	0.07	0.923	0.28	0.9	0.05	0.921	0.27	0.89		0.92	0.29	0.87	
S13	0.04		0.02		0.05				0.1				0.08				0.11			
S14	0.9	0.04	0.89	0.02	0.9	0.05	0.87		0.903	0.1	0.87		0.901	0.08	0.86		0.9	0.11	0.84	
S15	0.3		0.29		0.3		0.15		0.34		0.13		0.33		0.03		0.35			
S16	0.925	0.3	0.923	0.29	0.925	0.3	0.908	0.15	0.929	0.34	0.906	0.13	0.928	0.33	0.9	0.03	0.93	0.35	0.89	
S17	0.04		0.02		0.04				0.1				0.08				0.11			
S18	0.9	0.04	0.89	0.02	0.9	0.04	0.87		0.903	0.1	0.87		0.901	0.08	0.86		0.9	0.11	0.84	
S19	0.34		0.33		0.34		0.2		0.38		0.18		0.37		0.08		0.39			
S20	0.929	0.34	0.928	0.33	0.930	0.34	0.914	0.2	0.933	0.38	0.912	0.18	0.932	0.37	0.902	0.08	0.93	0.39	0.89	
S21					0				0.06				0.04				0.07			
S22	0.89		0.89		0.89	0	0.87		0.9	0.06	0.87		0.9	0.04	0.85		0.9	0.07	0.84	
S23	0.02				0.03				0.08				0.06				0.09			
S24	0.89	0.02	0.89		0.9	0.03	0.87		0.901	0.08	0.87		0.9	0.06	0.85		0.902	0.09	0.84	
S25									0.05				0.03				0.07			
S26	0.89		0.89		0.89		0.87		0.9	0.05	0.87		0.9	0.03	0.85		0.9	0.07	0.83	
S27	0.18		0.16		0.19				0.23				0.21				0.24			
S28	0.912	0.18	0.910	0.16	0.912	0.18	0.89		0.917	0.23	0.89		0.915	0.21	0.88		0.918	0.24	0.87	
S29																	0.01			
S30	0.89		0.88		0.89		0.86		0.89		0.86		0.89		0.84		0.89	0.01	0.83	
S31	0.2		0.18		0.2		0.02		0.25				0.23				0.26			
S32	0.914	0.2	0.912	0.18	0.914	0.2	0.89	0.02	0.919	0.25	0.89		0.917	0.23	0.88		0.920	0.26	0.87	
S33									0.02								0.04			
S34	0.89		0.89		0.89		0.86		0.9	0.02	0.86		0.89		0.84		0.9	0.04	0.83	
S35	0.28		0.27		0.29		0.12		0.32		0.1		0.31				0.33			
S36	0.923	0.28	0.921	0.27	0.923	0.28	0.906	0.12	0.927	0.32	0.904	0.1	0.926	0.31	0.89		0.928	0.33	0.88	
S37																				
S38	0.88		0.88		0.88		0.86		0.89		0.86		0.89		0.84		0.89		0.82	
S39	0.35		0.33		0.35		0.2		0.39		0.19		0.37		0.09		0.39			
S40	0.930	0.35	0.928	0.33	0.930	0.35	0.914	0.2	0.934	0.39	0.913	0.19	0.932	0.37	0.902	0.09	0.935	0.39	0.89	
S41	0.11		0.09		0.11				0.16				0.14				0.17			
S42	0.904	0.11	0.902	0.09	0.905	0.11	0.88		0.910	0.16	0.88		0.908	0.14	0.87		0.911	0.17	0.85	
S43	0.23		0.21		0.23		0.06		0.28		0.04		0.26				0.29			
S44	0.917	0.23	0.916	0.21	0.918	0.23	0.9	0.06	0.922	0.28	0.9	0.04	0.920	0.26	0.88		0.923	0.29	0.87	
S45	0.16		0.15		0.17				0.21				0.19				0.22			
S46	0.910	0.16	0.908	0.15	0.911	0.17	0.89		0.915	0.21	0.89		0.913	0.19	0.87		0.917	0.22	0.86	
S47	0.29		0.27		0.29		0.13		0.33		0.11		0.31		0.01		0.34			
S48	0.923	0.29	0.922	0.27	0.924	0.29	0.906	0.13	0.928	0.33	0.905	0.11	0.926	0.31	0.89	0.01	0.929	0.34	0.88	
S49	0.19		0.18		0.2		0.02		0.24				0.22				0.25			
S50	0.913	0.19	0.912	0.18	0.914	0.2	0.89	0.02	0.919	0.24	0.89		0.917	0.22	0.88		0.920	0.25	0.87	
S51	0.32		0.3		0.32		0.17		0.36		0.15		0.34		0.05		0.37			
S52	0.927	0.32	0.925	0.3	0.927	0.32	0.911	0.17	0.931	0.36	0.909	0.15	0.930	0.34	0.9	0.05	0.932	0.37	0.89	
S53	0.22		0.2		0.22		0.05		0.27		0.03		0.25				0.28			
S54	0.916	0.22	0.914	0.2	0.917	0.22	0.9	0.05	0.921	0.27	0.9	0.03	0.919	0.25	0.88		0.922	0.28	0.87	
S55	0.36		0.34		0.36		0.21		0.39		0.2		0.38		0.1		0.4		0.01	
S56	0.931	0.36	0.929	0.34	0.931	0.36	0.915	0.21	0.935	0.39	0.914	0.2	0.933	0.38	0.904	0.1	0.936	0.4	0.89	0.01
S57	0.21		0.19		0.22		0.04		0.26		0.02		0.24				0.27			
S58	0.915	0.21	0.913	0.19	0.916	0.22	0.9	0.04	0.920	0.26	0.89	0.02	0.918	0.24	0.88		0.921	0.27	0.87	
S59	0.37		0.35		0.37		0.23		0.41		0.21		0.39		0.12		0.41		0.03	
S60	0.932	0.37	0.931	0.35	0.932	0.37	0.917	0.23	0.936	0.4	0.915	0.21	0.935	0.39	0.905	0.12	0.937	0.41	0.9	0.03

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1																				
S2	0.89		0.87		0.88		0.86		0.87		0.85		0.87		0.84		0.87		0.84	
S3	0.1				0.05				0.01											
S4	0.904	0.1	0.89		0.9	0.05	0.88		0.89	0.01	0.87		0.89		0.87		0.89		0.86	
S5																				
S6	0.89		0.87		0.88		0.86		0.87		0.85		0.87		0.84		0.87		0.84	
S7	0.14		0.01		0.09				0.05				0.02				0.03			
S8	0.908	0.14	0.89	0.01	0.902	0.09	0.88		0.9	0.05	0.88		0.89	0.02	0.87		0.9	0.03	0.87	
S9																				
S10	0.88		0.86		0.87		0.85		0.87		0.85		0.86		0.84		0.87		0.83	
S11	0.14		0.01		0.09				0.05				0.02				0.03			
S12	0.908	0.14	0.89	0.01	0.902	0.09	0.88		0.9	0.05	0.88		0.89	0.02	0.87		0.9	0.03	0.87	
S13																				
S14	0.88		0.87		0.88		0.86		0.87		0.85		0.87		0.84		0.87		0.84	
S15	0.22		0.09		0.16		0.02		0.13				0.1				0.11			
S16	0.916	0.22	0.902	0.09	0.910	0.16	0.89	0.02	0.907	0.13	0.89		0.904	0.1	0.88		0.905	0.11	0.88	
S17																				
S18	0.88		0.87		0.88		0.86		0.87		0.85		0.87		0.84		0.87		0.84	
S19	0.26		0.14		0.21		0.08		0.18		0.03		0.16				0.17			
S20	0.921	0.26	0.908	0.14	0.915	0.21	0.901	0.08	0.912	0.18	0.9	0.03	0.909	0.16	0.89		0.910	0.17	0.89	
S21																				
S22	0.88		0.86		0.87		0.85		0.87		0.84		0.86		0.83		0.86		0.83	
S23																				
S24	0.88		0.86		0.87		0.85		0.87		0.85		0.87		0.84		0.87		0.83	
S25																				
S26	0.88		0.86		0.87		0.85		0.87		0.84		0.86		0.83		0.86		0.83	
S27	0.08				0.02															
S28	0.901	0.08	0.89		0.89	0.02	0.88		0.89		0.87		0.89		0.86		0.89		0.86	
S29																				
S30	0.87		0.85		0.86		0.84		0.86		0.83		0.85		0.82		0.86		0.82	
S31	0.1				0.04				0											
S32	0.903	0.1	0.89		0.9	0.04	0.88		0.89	0	0.87		0.89		0.87		0.89		0.86	
S33																				
S34	0.87		0.85		0.87		0.84		0.86		0.84		0.86		0.83		0.86		0.82	
S35	0.19		0.07		0.14				0.11				0.08				0.09			
S36	0.913	0.19	0.9	0.07	0.908	0.14	0.89		0.904	0.11	0.89		0.901	0.08	0.88		0.902	0.09	0.88	
S37																				
S38	0.87		0.85		0.86		0.84		0.86		0.83		0.85		0.82		0.85		0.82	
S39	0.27		0.15		0.22		0.08		0.19		0.04		0.16				0.17			
S40	0.921	0.27	0.909	0.15	0.916	0.22	0.901	0.08	0.913	0.19	0.9	0.04	0.910	0.16	0.89		0.911	0.17	0.89	
S41																				
S42	0.89		0.88		0.89		0.87		0.88		0.86		0.88		0.85		0.88		0.85	
S43	0.14				0.08				0.05				0.01				0.02			
S44	0.907	0.14	0.89		0.901	0.08	0.88		0.9	0.04	0.88		0.89	0.01	0.87		0.9	0.02	0.87	
S45	0.06																			
S46	0.9	0.06	0.88		0.89		0.87		0.89		0.87		0.88		0.86		0.89		0.86	
S47	0.2		0.07		0.15				0.12				0.09				0.1			
S48	0.914	0.2	0.900	0.07	0.908	0.15	0.89		0.905	0.12	0.89		0.902	0.09	0.88		0.903	0.1	0.88	
S49	0.1				0.04															
S50	0.903	0.1	0.89		0.9	0.04	0.88		0.89		0.87		0.89		0.87		0.89		0.86	
S51	0.24		0.12		0.19		0.04		0.16				0.13				0.14			
S52	0.918	0.24	0.905	0.12	0.913	0.19	0.9	0.04	0.909	0.16	0.89		0.906	0.13	0.89		0.907	0.14	0.88	
S53	0.13				0.07				0.03								0.01			
S54	0.906	0.13	0.89		0.9	0.07	0.88		0.9	0.03	0.88		0.89		0.87		0.89	0.01	0.87	
S55	0.28		0.16		0.23		0.1		0.2		0.05		0.17				0.18			
S56	0.922	0.28	0.910	0.16	0.917	0.23	0.903	0.1	0.914	0.2	0.9	0.05	0.911	0.17	0.89		0.912	0.18	0.89	
S57	0.12				0.06				0.02											
S58	0.905	0.12	0.89		0.9	0.06	0.88		0.89	0.02	0.88		0.89		0.87		0.89		0.87	
S59	0.29		0.18		0.24		0.11		0.22		0.07		0.19		0.02		0.2			
S60	0.924	0.29	0.912	0.18	0.919	0.24	0.905	0.11	0.916	0.22	0.900	0.07	0.913	0.19	0.89	0.02	0.914	0.2	0.89	

Table D-5 Excerpt of TN Load Reduction Uncertainty Ratio at 95% CL with UP Analysis

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S2	0.011	1	0.011	1	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S3	0.465	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S4	0.011	0.465	0.011	1	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S5	0.091	1	0.114	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S6	0.011	0.091	0.011	0.114	0.010	1	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.01	1	0.010	1
S7	0.075	1	0.090	1	0.400	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S8	0.011	0.075	0.011	0.090	0.010	0.400	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.01	1	0.010	1
S9	0.045	1	0.050	1	0.084	1	0.107	1	1	1	1	1	1	1	1	1	1	1	1	1
S10	0.010	0.045	0.011	0.050	0.01	0.084	0.010	0.107	0.01	1	0.010	1	0.010	1	0.011	1	0.009	1	0.01	1
S11	0.040	1	0.044	1	0.067	1	0.081	1	0.321	1	1	1	1	1	1	1	1	1	1	1
S12	0.010	0.040	0.011	0.044	0.01	0.067	0.010	0.081	0.01	0.321	0.010	1	0.010	1	0.011	1	0.009	1	0.01	1
S13	0.030	1	0.032	1	0.040	1	0.045	1	0.074	1	0.096	1	1	1	1	1	1	1	1	1
S14	0.010	0.030	0.010	0.032	0.01	0.040	0.01	0.045	0.01	0.074	0.01	0.096	0.010	1	0.011	1	0.009	1	0.01	1
S15	0.027	1	0.029	1	0.035	1	0.038	1	0.056	1	0.069	1	0.221	1	1	1	1	1	1	1
S16	0.010	0.027	0.010	0.029	0.01	0.035	0.01	0.038	0.01	0.056	0.01	0.069	0.010	0.221	0.011	1	0.009	1	0.01	1
S17	0.024	1	0.025	1	0.029	1	0.031	1	0.042	1	0.048	1	0.098	1	0.194	1	1	1	1	1
S18	0.010	0.024	0.010	0.025	0.01	0.029	0.01	0.031	0.01	0.042	0.01	0.048	0.01	0.098	0.011	0.194	0.009	1	0.009	1
S19	0.022	1	0.022	1	0.025	1	0.027	1	0.034	1	0.038	1	0.062	1	0.091	1	0.150	1	1	1
S20	0.010	0.022	0.010	0.022	0.01	0.025	0.01	0.027	0.01	0.034	0.01	0.038	0.01	0.062	0.011	0.091	0.009	0.150	0.009	1
S21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S22	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.011	1	0.012	1
S23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S24	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.013	1	0.011	1	0.012	1
S25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S26	0.011	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S28	0.011	1	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S29	0.725	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S30	0.011	0.724	0.011	1	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S31	0.182	1	0.299	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S32	0.011	0.182	0.011	0.299	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.012	1	0.01	1	0.011	1
S33	0.117	1	0.159	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S34	0.011	0.117	0.011	0.159	0.010	1	0.010	1	0.010	1	0.010	1	0.011	1	0.012	1	0.01	1	0.010	1
S35	0.072	1	0.086	1	0.315	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S36	0.011	0.072	0.011	0.086	0.010	0.315	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.01	1	0.010	1
S37	0.061	1	0.071	1	0.174	1	0.312	1	1	1	1	1	1	1	1	1	1	1	1	1
S38	0.011	0.061	0.011	0.071	0.01	0.174	0.010	0.312	0.010	1	0.010	1	0.011	1	0.011	1	0.01	1	0.010	1
S39	0.043	1	0.048	1	0.076	1	0.095	1	0.708	1	1	1	1	1	1	1	1	1	1	1
S40	0.010	0.043	0.011	0.048	0.01	0.076	0.010	0.095	0.01	0.708	0.010	1	0.010	1	0.011	1	0.009	1	0.01	1
S41	0.193	1	0.330	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S42	0.011	0.193	0.011	0.330	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.012	1	0.01	1	0.011	1
S43	0.161	1	0.246	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S44	0.011	0.161	0.011	0.246	0.010	1	0.010	1	0.010	1	0.011	1	0.011	1	0.012	1	0.01	1	0.011	1
S45	0.051	1	0.058	1	0.110	1	0.152	1	1	1	1	1	1	1	1	1	1	1	1	1
S46	0.010	0.051	0.011	0.058	0.01	0.110	0.010	0.152	0.01	1	0.010	1	0.010	1	0.011	1	0.01	1	0.010	1
S47	0.049	1	0.055	1	0.097	1	0.129	1	1	1	1	1	1	1	1	1	1	1	1	1
S48	0.010	0.049	0.011	0.055	0.01	0.097	0.010	0.129	0.01	1	0.010	1	0.010	1	0.011	1	0.009	1	0.010	1
S49	0.030	1	0.032	1	0.041	1	0.045	1	0.075	1	0.099	1	1	1	1	1	1	1	1	1
S50	0.010	0.030	0.010	0.032	0.01	0.041	0.01	0.045	0.01	0.075	0.01	0.099	0.010	1	0.011	1	0.009	1	0.01	1
S51	0.029	1	0.031	1	0.038	1	0.042	1	0.067	1	0.085	1	0.666	1	1	1	1	1	1	1
S52	0.010	0.029	0.010	0.031	0.01	0.038	0.01	0.042	0.01	0.067	0.01	0.085	0.010	0.666	0.011	1	0.009	1	0.01	1
S53	0.023	1	0.025	1	0.028	1	0.030	1	0.040	1	0.046	1	0.088	1	0.155	1	0.621	1	1	1
S54	0.010	0.023	0.010	0.025	0.01	0.028	0.01	0.030	0.01	0.040	0.01	0.046	0.01	0.088	0.011	0.155	0.009	0.621	0.009	1
S55	0.023	1	0.024	1	0.027	1	0.029	1	0.037	1	0.042	1	0.075	1	0.118	1	0.262	1	1	1
S56	0.010	0.023	0.010	0.024	0.01	0.027	0.01	0.029	0.01	0.037	0.01	0.042	0.01	0.075	0.011	0.118	0.009	0.262	0.009	1
S57	0.019	1	0.019	1	0.021	1	0.022	1	0.026	1	0.028	1	0.039	1	0.048	1	0.056	1	0.092	1
S58	0.010	0.019	0.010	0.019	0.009	0.021	0.01	0.022	0.009	0.026	0.01	0.028	0.01	0.039	0.010	0.048	0.009	0.056	0.009	0.092
S59	0.018	1	0.019	1	0.020	1	0.021	1	0.024	1	0.027	1	0.035	1	0.044	1	0.049	1	0.075	1
S60	0.010	0.018	0.010	0.019	0.009	0.020	0.01	0.021	0.009	0.024	0.01	0.027	0.01	0.035	0.010	0.044	0.009	0.049	0.009	0.075

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	0.085	1	0.049	1	0.186	1	0.591	1	1	1	1	1	1	1	1	1	1	1	1	1
S2	0.011	0.085	0.010	0.049	0.011	0.186	0.011	0.591	0.011	1	0.011	1	0.01	1	0.011	1	0.01	1	0.011	1
S3	0.073	1	0.045	1	0.134	1	0.263	1	1	1	1	1	1	1	1	1	1	1	1	1
S4	0.011	0.073	0.010	0.045	0.011	0.134	0.011	0.263	0.011	1	0.011	1	0.01	1	0.011	1	0.01	1	0.011	1
S5	0.045	1	0.032	1	0.061	1	0.080	1	0.104	1	0.189	1	0.386	1	1	1	1	1	1	1
S6	0.011	0.045	0.010	0.032	0.011	0.061	0.011	0.080	0.011	0.104	0.011	0.189	0.01	0.386	0.01	1	0.01	1	0.011	1
S7	0.042	1	0.030	1	0.054	1	0.068	1	0.084	1	0.132	1	0.198	1	1	1	1	1	1	1
S8	0.011	0.042	0.010	0.030	0.011	0.054	0.011	0.068	0.011	0.084	0.011	0.132	0.01	0.198	0.01	1	0.01	1	0.011	1
S9	0.032	1	0.024	1	0.037	1	0.043	1	0.049	1	0.061	1	0.069	1	0.117	1	0.162	1	1	1
S10	0.011	0.032	0.010	0.024	0.011	0.037	0.011	0.043	0.011	0.049	0.011	0.061	0.01	0.069	0.01	0.117	0.01	0.162	0.01	1
S11	0.029	1	0.023	1	0.034	1	0.039	1	0.043	1	0.053	1	0.058	1	0.087	1	0.109	1	0.603	1
S12	0.011	0.029	0.010	0.023	0.010	0.034	0.011	0.039	0.011	0.043	0.011	0.053	0.01	0.058	0.01	0.087	0.01	0.109	0.01	0.603
S13	0.024	1	0.020	1	0.026	1	0.029	1	0.031	1	0.036	1	0.037	1	0.047	1	0.051	1	0.084	1
S14	0.011	0.024	0.010	0.020	0.010	0.026	0.011	0.029	0.010	0.031	0.011	0.036	0.01	0.037	0.01	0.047	0.01	0.051	0.01	0.084
S15	0.023	1	0.019	1	0.024	1	0.027	1	0.028	1	0.032	1	0.032	1	0.04	1	0.043	1	0.062	1
S16	0.011	0.023	0.01	0.019	0.010	0.024	0.011	0.027	0.010	0.028	0.011	0.032	0.01	0.032	0.01	0.04	0.01	0.043	0.01	0.062
S17	0.021	1	0.017	1	0.022	1	0.023	1	0.024	1	0.027	1	0.027	1	0.032	1	0.034	1	0.045	1
S18	0.011	0.021	0.01	0.017	0.010	0.022	0.010	0.023	0.010	0.024	0.011	0.027	0.01	0.027	0.01	0.032	0.01	0.034	0.01	0.045
S19	0.019	1	0.016	1	0.020	1	0.021	1	0.022	1	0.024	1	0.024	1	0.028	1	0.029	1	0.036	1
S20	0.011	0.019	0.01	0.016	0.010	0.020	0.010	0.021	0.010	0.022	0.010	0.024	0.01	0.024	0.01	0.028	0.01	0.029	0.01	0.036
S21	1	1	0.125	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S22	0.012	1	0.011	0.125	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.011	1
S23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S24	0.012	1	0.011	1	0.011	1	0.012	1	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.012	1
S25	0.151	1	0.066	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S26	0.011	0.151	0.010	0.066	0.011	1	0.011	1	0.011	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1
S27	0.100	1	0.054	1	0.275	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S28	0.011	0.100	0.010	0.054	0.011	0.275	0.011	1	0.011	1	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1
S29	0.077	1	0.046	1	0.149	1	0.328	1	1	1	1	1	1	1	1	1	1	1	1	1
S30	0.011	0.077	0.010	0.046	0.011	0.149	0.011	0.328	0.011	1	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1
S31	0.060	1	0.039	1	0.093	1	0.141	1	0.244	1	1	1	1	1	1	1	1	1	1	1
S32	0.011	0.060	0.010	0.039	0.011	0.093	0.011	0.141	0.011	0.244	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1
S33	0.051	1	0.035	1	0.072	1	0.099	1	0.141	1	0.356	1	1	1	1	1	1	1	1	1
S34	0.011	0.051	0.010	0.035	0.011	0.072	0.011	0.099	0.011	0.141	0.011	0.356	0.010	1	0.011	1	0.010	1	0.011	1
S35	0.041	1	0.030	1	0.053	1	0.065	1	0.080	1	0.122	1	0.175	1	1	1	1	1	1	1
S36	0.011	0.041	0.010	0.030	0.011	0.053	0.011	0.065	0.011	0.080	0.011	0.122	0.010	0.175	0.010	1	0.010	1	0.011	1
S37	0.037	1	0.028	1	0.046	1	0.056	1	0.067	1	0.094	1	0.121	1	0.404	1	1	1	1	1
S38	0.011	0.037	0.010	0.028	0.011	0.046	0.011	0.056	0.011	0.067	0.011	0.094	0.010	0.121	0.010	0.404	0.010	1	0.010	1
S39	0.031	1	0.024	1	0.036	1	0.041	1	0.046	1	0.057	1	0.064	1	0.102	1	0.134	1	1	1
S40	0.011	0.031	0.010	0.024	0.010	0.036	0.011	0.041	0.011	0.046	0.011	0.057	0.01	0.064	0.010	0.102	0.01	0.134	0.010	1
S41	0.061	1	0.040	1	0.096	1	0.147	1	0.263	1	1	1	1	1	1	1	1	1	1	1
S42	0.011	0.061	0.010	0.040	0.011	0.096	0.011	0.147	0.011	0.263	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1
S43	0.057	1	0.038	1	0.087	1	0.128	1	0.207	1	1	1	1	1	1	1	1	1	1	1
S44	0.011	0.057	0.010	0.038	0.011	0.087	0.011	0.128	0.011	0.207	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1
S45	0.034	1	0.026	1	0.041	1	0.048	1	0.056	1	0.073	1	0.086	1	0.172	1	0.293	1	1	1
S46	0.011	0.034	0.010	0.026	0.011	0.041	0.011	0.048	0.011	0.056	0.011	0.073	0.01	0.086	0.010	0.172	0.01	0.293	0.010	1
S47	0.033	1	0.025	1	0.039	1	0.046	1	0.053	1	0.068	1	0.078	1	0.144	1	0.217	1	1	1
S48	0.011	0.033	0.010	0.025	0.011	0.039	0.011	0.046	0.011	0.053	0.011	0.068	0.01	0.078	0.010	0.144	0.01	0.217	0.010	1
S49	0.024	1	0.020	1	0.027	1	0.029	1	0.031	1	0.036	1	0.037	1	0.047	1	0.052	1	0.086	1
S50	0.011	0.024	0.010	0.020	0.010	0.027	0.011	0.029	0.010	0.031	0.011	0.036	0.01	0.037	0.010	0.047	0.01	0.052	0.010	0.086
S51	0.024	1	0.019	1	0.026	1	0.028	1	0.030	1	0.034	1	0.035	1	0.044	1	0.048	1	0.075	1
S52	0.011	0.024	0.01	0.019	0.010	0.026	0.011	0.028	0.010	0.030	0.011	0.034	0.01	0.035	0.010	0.044	0.01	0.048	0.010	0.075
S53	0.020	1	0.017	1	0.021	1	0.023	1	0.024	1	0.027	1	0.027	1	0.031	1	0.033	1	0.044	1
S54	0.011	0.020	0.01	0.017	0.010	0.021	0.010	0.023	0.010	0.024	0.011	0.027	0.01	0.027	0.01	0.031	0.01	0.033	0.01	0.044
S55	0.020	1	0.017	1	0.021	1	0.022	1	0.023	1	0.026	1	0.025	1	0.030	1	0.031	1	0.040	1
S56	0.011	0.020	0.01	0.017	0.010	0.021	0.010	0.022	0.010	0.023	0.011	0.026	0.01	0.025	0.01	0.030	0.01	0.031	0.01	0.040
S57	0.017	1	0.015	1	0.018	1	0.019	1	0.019	1	0.021	1	0.020	1	0.023	1	0.023	1	0.027	1
S58	0.011	0.017	0.01	0.015	0.010	0.018	0.010	0.019	0.010	0.019	0.010	0.021	0.01	0.020	0.01	0.023	0.01	0.023	0.01	0.027
S59	0.017	1	0.015	1	0.017	1	0.018	1	0.019	1	0.020	1	0.019	1	0.022	1	0.022	1	0.026	1
S60	0.011	0.017	0.01	0.015	0.010	0.017	0.010	0.018	0.010	0.019	0.010	0.020	0.01	0.019	0.01	0.022	0.009	0.022	0.01	0.026

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S2	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S4	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S5	0.177	1	0.217	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S6	0.011	0.177	0.011	0.217	0.010	1	0.010	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S7	0.125	1	0.144	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S8	0.011	0.125	0.011	0.144	0.010	1	0.010	1	0.011	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1
S9	0.060	1	0.063	1	0.370	1	0.667	1	1	1	1	1	1	1	1	1	1	1	1	1
S10	0.011	0.060	0.011	0.063	0.010	0.370	0.010	0.667	0.010	1	0.011	1	0.010	1	0.01	1	0.01	1	0.01	1
S11	0.051	1	0.054	1	0.174	1	0.220	1	1	1	1	1	1	1	1	1	1	1	1	1
S12	0.011	0.051	0.011	0.054	0.010	0.174	0.010	0.220	0.010	1	0.010	1	0.010	1	0.01	1	0.01	1	0.01	1
S13	0.035	1	0.036	1	0.063	1	0.068	1	1	1	1	1	1	1	1	1	1	1	1	1
S14	0.011	0.035	0.011	0.036	0.01	0.063	0.010	0.068	0.010	1	0.010	1	0.01	1	0.01	1	0.01	1	0.01	1
S15	0.031	1	0.032	1	0.050	1	0.053	1	0.212	1	0.330	1	1	1	1	1	1	1	1	1
S16	0.010	0.031	0.010	0.032	0.01	0.050	0.01	0.053	0.010	0.212	0.010	0.329	0.01	1	0.01	1	0.01	1	0.01	1
S17	0.027	1	0.027	1	0.038	1	0.040	1	0.097	1	0.117	1	1	1	1	1	1	1	1	1
S18	0.010	0.027	0.010	0.027	0.01	0.038	0.01	0.040	0.010	0.097	0.010	0.117	0.01	1	0.01	1	0.01	1	0.01	1
S19	0.024	1	0.024	1	0.032	1	0.033	1	0.062	1	0.069	1	0.206	1	0.374	1	1	1	1	1
S20	0.010	0.024	0.010	0.024	0.01	0.032	0.01	0.033	0.01	0.062	0.010	0.069	0.01	0.206	0.01	0.374	0.01	1	0.01	1
S21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S22	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.012	1	0.012	1	0.012	1
S23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S24	0.012	1	0.012	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.012	1	0.013	1	0.013	1
S25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S26	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1
S27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S28	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1
S29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S30	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S32	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S33	0.316	1	0.473	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S34	0.011	0.316	0.011	0.473	0.010	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S35	0.117	1	0.132	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S36	0.011	0.117	0.011	0.132	0.010	1	0.010	1	0.011	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1
S37	0.091	1	0.100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S38	0.011	0.091	0.011	0.100	0.010	1	0.010	1	0.011	1	0.011	1	0.010	1	0.010	1	0.010	1	0.011	1
S39	0.056	1	0.059	1	0.247	1	0.349	1	1	1	1	1	1	1	1	1	1	1	1	1
S40	0.011	0.056	0.011	0.059	0.010	0.247	0.010	0.349	0.010	1	0.011	1	0.010	1	0.010	1	0.010	1	0.010	1
S41	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S42	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S43	0.983	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S44	0.011	0.983	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S45	0.071	1	0.076	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S46	0.011	0.071	0.011	0.076	0.010	1	0.010	1	0.011	1	0.011	1	0.010	1	0.010	1	0.010	1	0.011	1
S47	0.066	1	0.070	1	0.844	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S48	0.011	0.066	0.011	0.070	0.010	0.844	0.010	1	0.011	1	0.011	1	0.010	1	0.010	1	0.010	1	0.010	1
S49	0.035	1	0.037	1	0.064	1	0.069	1	1	1	1	1	1	1	1	1	1	1	1	1
S50	0.011	0.035	0.011	0.036	0.01	0.064	0.010	0.069	0.010	1	0.010	1	0.01	1	0.01	1	0.01	1	0.010	1
S51	0.034	1	0.035	1	0.058	1	0.062	1	0.585	1	1	1	1	1	1	1	1	1	1	1
S52	0.011	0.034	0.010	0.035	0.01	0.058	0.010	0.062	0.010	0.585	0.010	1	0.01	1	0.01	1	0.01	1	0.01	1
S53	0.026	1	0.027	1	0.037	1	0.039	1	0.087	1	0.102	1	1	1	1	1	1	1	1	1
S54	0.010	0.026	0.010	0.027	0.01	0.037	0.01	0.039	0.010	0.087	0.010	0.102	0.01	1	0.01	1	0.01	1	0.01	1
S55	0.025	1	0.026	1	0.035	1	0.036	1	0.074	1	0.085	1	0.469	1	1	1	1	1	1	1
S56	0.010	0.025	0.010	0.026	0.01	0.035	0.01	0.036	0.010	0.074	0.010	0.085	0.01	0.469	0.01	1	0.01	1	0.01	1
S57	0.020	1	0.021	1	0.025	1	0.026	1	0.038	1	0.041	1	0.065	1	0.075	1	1	1	1	1
S58	0.010	0.020	0.010	0.021	0.01	0.025	0.01	0.026	0.01	0.038	0.01	0.041	0.009	0.065	0.01	0.075	0.009	1	0.009	1
S59	0.020	1	0.020	1	0.024	1	0.024	1	0.035	1	0.038	1	0.056	1	0.064	1	0.377	1	1	1
S60	0.010	0.020	0.010	0.020	0.01	0.024	0.01	0.024	0.01	0.035	0.01	0.038	0.009	0.056	0.01	0.064	0.009	0.377	0.009	1

Table D-6 Excerpt of TP Load Reduction Uncertainty Ratio at 95% CL with UP Analysis

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1	1	1	1	1	1	1	1	1	0.294	1	1	1	0.673	1	1	1	0.561	1	1	1
S2	0.011	1	0.011	1	0.010	1	0.011	1	0.010	0.294	0.011	1	0.011	0.675	0.011	1	0.010	0.563	0.010	1
S3	0.085	1	1	1	0.082	1	1	1	0.065	1	1	1	0.076	1	1	1	0.072	1	1	1
S4	0.011	0.085	0.011	1	0.010	0.082	0.011	1	0.010	0.065	0.010	1	0.011	0.077	0.011	1	0.01	0.072	0.01	1
S5	1	1	1	1	1	1	1	1	0.304	1	1	1	0.748	1	1	1	0.611	1	1	1
S6	0.011	1	0.011	1	0.010	1	0.011	1	0.010	0.304	0.011	1	0.011	0.749	0.011	1	0.010	0.613	0.010	1
S7	0.065	1	0.296	1	0.063	1	1	1	0.052	1	1	1	0.060	1	1	1	0.056	1	1	1
S8	0.011	0.065	0.011	0.296	0.010	0.063	0.011	1	0.010	0.052	0.010	1	0.011	0.060	0.011	1	0.01	0.056	0.01	1
S9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S10	0.011	1	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1	0.010	1	0.010	1
S11	0.065	1	0.294	1	0.062	1	1	1	0.052	1	1	1	0.060	1	1	1	0.056	1	1	1
S12	0.011	0.065	0.011	0.293	0.010	0.062	0.011	1	0.010	0.052	0.010	1	0.011	0.060	0.011	1	0.01	0.056	0.01	1
S13	1	1	1	1	1	1	1	1	0.540	1	1	1	1	1	1	1	1	1	1	1
S14	0.011	1	0.011	1	0.010	1	0.011	1	0.010	0.540	0.011	1	0.011	1	0.011	1	0.010	1	0.010	1
S15	0.047	1	0.104	1	0.045	1	0.153	1	0.040	1	0.151	1	0.044	1	1	1	0.042	1	1	1
S16	0.010	0.047	0.011	0.103	0.010	0.045	0.010	0.153	0.01	0.040	0.010	0.151	0.011	0.044	0.011	1	0.01	0.042	0.01	1
S17	1	1	1	1	1	1	1	1	0.592	1	1	1	1	1	1	1	1	1	1	1
S18	0.011	1	0.011	1	0.010	1	0.011	1	0.010	0.590	0.011	1	0.011	1	0.011	1	0.010	1	0.010	1
S19	0.038	1	0.069	1	0.037	1	0.087	1	0.033	1	0.086	1	0.036	1	0.216	1	0.034	1	1	1
S20	0.010	0.038	0.011	0.069	0.01	0.037	0.010	0.087	0.01	0.033	0.010	0.086	0.011	0.036	0.011	0.216	0.01	0.034	0.01	1
S21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S22	0.011	1	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1	0.010	1	0.010	1
S23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S24	0.011	1	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1	0.010	1	0.010	1
S25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S26	0.011	1	0.011	1	0.010	1	0.011	1	0.010	1	0.011	1	0.011	1	0.011	1	0.010	1	0.010	1
S27	0.101	1	1	1	0.097	1	1	1	0.074	1	1	1	0.089	1	1	1	0.083	1	1	1
S28	0.011	0.101	0.011	1	0.010	0.097	0.011	1	0.010	0.074	0.010	1	0.011	0.089	0.011	1	0.01	0.083	0.010	1
S29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S30	0.011	1	0.012	1	0.011	1	0.011	1	0.010	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S31	0.088	1	1	1	0.084	1	1	1	0.067	1	1	1	0.078	1	1	1	0.074	1	1	1
S32	0.011	0.088	0.011	1	0.010	0.084	0.011	1	0.010	0.067	0.010	1	0.011	0.078	0.011	1	0.01	0.074	0.01	1
S33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S34	0.011	1	0.012	1	0.011	1	0.011	1	0.010	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S35	0.051	1	0.129	1	0.049	1	0.220	1	0.042	1	0.218	1	0.048	1	1	1	0.045	1	1	1
S36	0.011	0.051	0.011	0.128	0.010	0.049	0.010	0.220	0.01	0.042	0.010	0.217	0.011	0.048	0.011	1	0.01	0.045	0.01	1
S37	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S38	0.011	1	0.012	1	0.011	1	0.011	1	0.010	1	0.011	1	0.011	1	0.012	1	0.010	1	0.011	1
S39	0.038	1	0.068	1	0.037	1	0.086	1	0.033	1	0.085	1	0.037	1	0.199	1	0.034	1	1	1
S40	0.010	0.038	0.011	0.068	0.01	0.037	0.010	0.085	0.01	0.033	0.010	0.084	0.011	0.037	0.011	0.198	0.01	0.034	0.01	1
S41	0.264	1	1	1	0.246	1	1	1	0.137	1	1	1	0.191	1	1	1	0.175	1	1	1
S42	0.011	0.264	0.011	1	0.010	0.246	0.011	1	0.010	0.137	0.011	1	0.011	0.191	0.011	1	0.010	0.175	0.010	1
S43	0.069	1	0.377	1	0.067	1	1	1	0.055	1	1	1	0.064	1	1	1	0.060	1	1	1
S44	0.011	0.069	0.011	0.377	0.010	0.067	0.011	1	0.010	0.055	0.010	1	0.011	0.064	0.011	1	0.01	0.060	0.01	1
S45	0.118	1	1	1	0.112	1	1	1	0.082	1	1	1	0.101	1	1	1	0.094	1	1	1
S46	0.011	0.117	0.011	1	0.010	0.112	0.011	1	0.010	0.082	0.010	1	0.011	0.101	0.011	1	0.01	0.094	0.010	1
S47	0.050	1	0.121	1	0.048	1	0.196	1	0.042	1	0.194	1	0.047	1	1	1	0.044	1	1	1
S48	0.010	0.050	0.011	0.120	0.010	0.048	0.010	0.196	0.01	0.042	0.010	0.194	0.011	0.047	0.011	1	0.01	0.044	0.01	1
S49	0.092	1	1	1	0.089	1	1	1	0.069	1	1	1	0.082	1	1	1	0.077	1	1	1
S50	0.011	0.092	0.011	1	0.010	0.088	0.011	1	0.010	0.069	0.010	1	0.011	0.082	0.011	1	0.01	0.077	0.010	1
S51	0.043	1	0.087	1	0.042	1	0.119	1	0.037	1	0.118	1	0.041	1	0.525	1	0.039	1	1	1
S52	0.010	0.043	0.011	0.087	0.010	0.042	0.010	0.119	0.01	0.037	0.010	0.118	0.011	0.041	0.011	0.526	0.01	0.039	0.01	1
S53	0.075	1	0.590	1	0.072	1	1	1	0.059	1	1	1	0.068	1	1	1	0.064	1	1	1
S54	0.011	0.075	0.011	0.588	0.010	0.072	0.011	1	0.010	0.059	0.010	1	0.011	0.068	0.011	1	0.01	0.064	0.01	1
S55	0.037	1	0.064	1	0.035	1	0.078	1	0.032	1	0.077	1	0.035	1	0.163	1	0.033	1	0.579	1
S56	0.010	0.037	0.011	0.064	0.01	0.035	0.010	0.078	0.01	0.032	0.010	0.077	0.011	0.035	0.011	0.163	0.01	0.033	0.01	0.580
S57	0.080	1	1	1	0.077	1	1	1	0.062	1	1	1	0.073	1	1	1	0.068	1	1	1
S58	0.011	0.080	0.011	1	0.010	0.077	0.011	1	0.010	0.062	0.010	1	0.011	0.073	0.011	1	0.01	0.068	0.01	1
S59	0.035	1	0.059	1	0.034	1	0.070	1	0.031	1	0.069	1	0.034	1	0.133	1	0.031	1	0.313	1
S60	0.010	0.035	0.011	0.059	0.01	0.034	0.010	0.070	0.01	0.031	0.010	0.069	0.011	0.034	0.011	0.133	0.01	0.031	0.01	0.313

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	0.221	1	0.318	1	0.201	1	1	1	0.110	1	1	1	0.131	1	1	1	0.096	1	1	1
S2	0.011	0.221	0.010	0.318	0.011	0.201	0.011	1	0.011	0.110	0.011	1	0.01	0.131	0.011	1	0.01	0.097	0.011	1
S3	0.063	1	0.067	1	0.061	1	0.552	1	0.049	1	1	1	0.051	1	1	1	0.045	1	1	1
S4	0.011	0.063	0.010	0.067	0.011	0.061	0.011	0.553	0.010	0.049	0.011	1	0.01	0.051	0.011	1	0.01	0.045	0.011	1
S5	0.225	1	0.330	1	0.204	1	1	1	0.110	1	1	1	0.131	1	1	1	0.096	1	1	1
S6	0.011	0.225	0.010	0.330	0.011	0.204	0.011	1	0.011	0.110	0.011	1	0.01	0.131	0.011	1	0.01	0.096	0.011	1
S7	0.052	1	0.053	1	0.050	1	0.191	1	0.041	1	0.266	1	0.043	1	1	1	0.039	1	1	1
S8	0.011	0.052	0.010	0.053	0.011	0.050	0.011	0.191	0.010	0.041	0.011	0.267	0.01	0.043	0.011	1	0.01	0.039	0.011	1
S9	0.754	1	1	1	0.585	1	1	1	0.168	1	1	1	0.23	1	1	1	0.14	1	1	1
S10	0.011	0.753	0.011	1	0.011	0.585	0.011	1	0.011	0.168	0.011	1	0.01	0.23	0.011	1	0.01	0.14	0.011	1
S11	0.052	1	0.053	1	0.049	1	0.190	1	0.041	1	0.264	1	0.043	1	1	1	0.038	1	1	1
S12	0.011	0.052	0.010	0.053	0.011	0.049	0.011	0.190	0.010	0.041	0.011	0.264	0.01	0.043	0.011	1	0.01	0.038	0.011	1
S13	0.328	1	0.622	1	0.289	1	1	1	0.132	1	1	1	0.165	1	1	1	0.114	1	1	1
S14	0.011	0.327	0.010	0.620	0.011	0.289	0.011	1	0.011	0.132	0.011	1	0.01	0.165	0.011	1	0.01	0.114	0.011	1
S15	0.040	1	0.040	1	0.039	1	0.087	1	0.034	1	0.100	1	0.034	1	0.483	1	0.031	1	1	1
S16	0.011	0.040	0.010	0.040	0.010	0.039	0.011	0.087	0.010	0.034	0.011	0.100	0.01	0.034	0.01	0.483	0.01	0.031	0.011	1
S17	0.340	1	0.695	1	0.297	1	1	1	0.131	1	1	1	0.165	1	1	1	0.113	1	1	1
S18	0.011	0.340	0.010	0.692	0.011	0.297	0.011	1	0.011	0.131	0.011	1	0.010	0.164	0.011	1	0.010	0.113	0.011	1
S19	0.034	1	0.033	1	0.032	1	0.061	1	0.029	1	0.067	1	0.029	1	0.145	1	0.027	1	1	1
S20	0.011	0.034	0.010	0.033	0.010	0.032	0.011	0.061	0.010	0.029	0.011	0.067	0.01	0.029	0.010	0.145	0.01	0.027	0.010	1
S21	1	1	1	1	1	1	1	1	0.228	1	1	1	0.355	1	1	1	0.183	1	1	1
S22	0.011	1	0.011	1	0.011	1	0.011	1	0.011	0.228	0.011	1	0.010	0.356	0.011	1	0.010	0.183	0.011	1
S23	0.650	1	1	1	0.520	1	1	1	0.163	1	1	1	0.220	1	1	1	0.137	1	1	1
S24	0.011	0.650	0.011	1	0.011	0.520	0.011	1	0.011	0.163	0.011	1	0.010	0.220	0.011	1	0.010	0.137	0.011	1
S25	1	1	1	1	1	1	1	1	0.242	1	1	1	0.396	1	1	1	0.191	1	1	1
S26	0.011	1	0.011	1	0.011	1	0.011	1	0.011	0.242	0.011	1	0.010	0.397	0.011	1	0.010	0.191	0.011	1
S27	0.071	1	0.076	1	0.068	1	1	1	0.053	1	1	1	0.057	1	1	1	0.049	1	1	1
S28	0.011	0.071	0.010	0.076	0.011	0.068	0.011	1	0.011	0.053	0.011	1	0.010	0.057	0.011	1	0.010	0.049	0.011	1
S29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.994	1	1	1
S30	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1	0.012	1	0.010	1	0.011	1	0.010	0.998	0.011	1
S31	0.065	1	0.068	1	0.062	1	0.687	1	0.049	1	1	1	0.052	1	1	1	0.046	1	1	1
S32	0.011	0.065	0.010	0.068	0.011	0.062	0.011	0.686	0.011	0.049	0.011	1	0.010	0.052	0.011	1	0.01	0.046	0.011	1
S33	1	1	1	1	1	1	1	1	0.582	1	1	1	1	1	1	1	0.358	1	1	1
S34	0.011	1	0.011	1	0.011	1	0.011	1	0.011	0.581	0.011	1	0.010	1	0.011	1	0.010	0.358	0.011	1
S35	0.043	1	0.043	1	0.041	1	0.104	1	0.035	1	0.122	1	0.036	1	1	1	0.033	1	1	1
S36	0.011	0.043	0.010	0.043	0.011	0.041	0.011	0.104	0.010	0.035	0.011	0.122	0.01	0.036	0.010	1	0.01	0.033	0.011	1
S37	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S38	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1	0.012	1	0.010	1	0.011	1	0.010	1	0.011	1
S39	0.034	1	0.034	1	0.033	1	0.061	1	0.029	1	0.067	1	0.029	1	0.139	1	0.027	1	1	1
S40	0.011	0.034	0.010	0.034	0.010	0.033	0.011	0.061	0.010	0.029	0.011	0.067	0.01	0.029	0.010	0.138	0.01	0.027	0.010	1
S41	0.122	1	0.143	1	0.114	1	1	1	0.078	1	1	1	0.087	1	1	1	0.070	1	1	1
S42	0.011	0.122	0.010	0.143	0.011	0.115	0.011	1	0.011	0.078	0.011	1	0.010	0.087	0.011	1	0.010	0.070	0.011	1
S43	0.055	1	0.056	1	0.052	1	0.224	1	0.043	1	0.331	1	0.045	1	1	1	0.040	1	1	1
S44	0.011	0.055	0.010	0.056	0.011	0.052	0.011	0.224	0.010	0.043	0.011	0.331	0.01	0.045	0.011	1	0.01	0.040	0.011	1
S45	0.078	1	0.085	1	0.075	1	1	1	0.057	1	1	1	0.061	1	1	1	0.053	1	1	1
S46	0.011	0.078	0.010	0.085	0.011	0.075	0.011	1	0.011	0.057	0.011	1	0.010	0.061	0.011	1	0.010	0.053	0.011	1
S47	0.042	1	0.043	1	0.040	1	0.099	1	0.035	1	0.115	1	0.036	1	1	1	0.033	1	1	1
S48	0.011	0.042	0.010	0.043	0.010	0.040	0.011	0.099	0.010	0.035	0.011	0.115	0.01	0.036	0.010	1	0.01	0.033	0.011	1
S49	0.067	1	0.071	1	0.064	1	0.891	1	0.051	1	1	1	0.054	1	1	1	0.047	1	1	1
S50	0.011	0.067	0.010	0.071	0.011	0.064	0.011	0.890	0.011	0.051	0.011	1	0.010	0.054	0.011	1	0.01	0.047	0.011	1
S51	0.038	1	0.038	1	0.036	1	0.076	1	0.032	1	0.085	1	0.032	1	0.251	1	0.030	1	1	1
S52	0.011	0.038	0.010	0.038	0.010	0.036	0.011	0.076	0.010	0.032	0.011	0.085	0.01	0.032	0.010	0.251	0.01	0.030	0.011	1
S53	0.058	1	0.060	1	0.055	1	0.286	1	0.045	1	0.486	1	0.047	1	1	1	0.042	1	1	1
S54	0.011	0.058	0.010	0.060	0.011	0.055	0.011	0.285	0.010	0.045	0.011	0.486	0.01	0.047	0.011	1	0.01	0.042	0.011	1
S55	0.033	1	0.032	1	0.031	1	0.057	1	0.028	1	0.062	1	0.028	1	0.120	1	0.027	1	0.908	1
S56	0.011	0.033	0.010	0.032	0.010	0.031	0.011	0.057	0.010	0.028	0.011	0.062	0.01	0.028	0.010	0.120	0.01	0.027	0.010	0.912
S57	0.061	1	0.064	1	0.058	1	0.374	1	0.047	1	0.801	1	0.050	1	1	1	0.044	1	1	1
S58	0.011	0.061	0.010	0.064	0.011	0.058	0.011	0.374	0.010	0.047	0.011	0.798	0.010	0.050	0.011	1	0.01	0.044	0.011	1
S59	0.032	1	0.031	1	0.030	1	0.053	1	0.027	1	0.057	1	0.027	1	0.102	1	0.026	1	0.398	1
S60	0.011	0.032	0.010	0.031	0.010	0.030	0.011	0.053	0.010	0.027	0.011	0.057	0.01	0.027	0.010	0.102	0.01	0.026	0.010	0.398

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S2	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.011	1	0.011	1	0.012	1	0.011	1
S3	0.125	1	1	1	0.293	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S4	0.011	0.125	0.011	1	0.011	0.293	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1
S5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S6	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.011	1	0.011	1	0.012	1	0.011	1
S7	0.086	1	1	1	0.144	1	1	1	0.252	1	1	1	0.611	1	1	1	0.418	1	1	1
S8	0.011	0.086	0.011	1	0.011	0.144	0.011	1	0.011	0.253	0.011	1	0.011	0.613	0.011	1	0.011	0.419	0.011	1
S9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S10	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.011	1	0.012	1	0.011	1
S11	0.086	1	1	1	0.143	1	1	1	0.250	1	1	1	0.607	1	1	1	0.414	1	1	1
S12	0.011	0.086	0.011	1	0.011	0.143	0.011	1	0.011	0.251	0.011	1	0.011	0.608	0.011	1	0.011	0.415	0.011	1
S13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S14	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.011	1	0.011	1	0.012	1	0.011	1
S15	0.056	1	0.142	1	0.075	1	0.687	1	0.099	1	1	1	0.126	1	1	1	0.117	1	1	1
S16	0.011	0.056	0.011	0.142	0.010	0.075	0.011	0.685	0.011	0.099	0.011	1	0.011	0.126	0.010	1	0.011	0.117	0.010	1
S17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S18	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.011	1	0.011	1	0.012	1	0.011	1
S19	0.044	1	0.084	1	0.055	1	0.162	1	0.068	1	0.385	1	0.079	1	1	1	0.076	1	1	1
S20	0.010	0.044	0.011	0.084	0.010	0.055	0.011	0.161	0.011	0.068	0.011	0.384	0.011	0.079	0.010	1	0.011	0.076	0.010	1
S21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S22	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.011	1	0.012	1	0.011	1
S23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S24	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.011	1	0.012	1	0.011	1
S25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S26	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.011	1	0.012	1	0.011	1
S27	0.162	1	1	1	0.636	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S28	0.011	0.161	0.011	1	0.011	0.637	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1
S29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S30	0.011	1	0.012	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.011	1	0.012	1	0.011	1
S31	0.130	1	1	1	0.327	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S32	0.011	0.130	0.011	1	0.011	0.327	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1
S33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S34	0.011	1	0.012	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.011	1	0.012	1	0.011	1
S35	0.063	1	0.196	1	0.088	1	1	1	0.121	1	1	1	0.166	1	1	1	0.149	1	1	1
S36	0.011	0.063	0.011	0.196	0.010	0.088	0.011	1	0.011	0.121	0.011	1	0.011	0.166	0.010	1	0.011	0.149	0.010	1
S37	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S38	0.011	1	0.012	1	0.011	1	0.011	1	0.012	1	0.012	1	0.012	1	0.011	1	0.012	1	0.011	1
S39	0.044	1	0.083	1	0.054	1	0.153	1	0.067	1	0.327	1	0.078	1	1	1	0.075	1	1	1
S40	0.010	0.044	0.011	0.083	0.010	0.054	0.011	0.153	0.011	0.067	0.011	0.326	0.011	0.077	0.010	1	0.011	0.075	0.010	1
S41	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S42	0.011	1	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1
S43	0.093	1	1	1	0.163	1	1	1	0.308	1	1	1	1	1	1	1	0.586	1	1	1
S44	0.011	0.093	0.011	1	0.011	0.163	0.011	1	0.011	0.308	0.011	1	0.011	1	0.011	1	0.011	0.589	0.011	1
S45	0.212	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S46	0.011	0.212	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1
S47	0.061	1	0.177	1	0.084	1	1	1	0.114	1	1	1	0.152	1	1	1	0.139	1	1	1
S48	0.011	0.061	0.011	0.177	0.010	0.084	0.011	1	0.011	0.114	0.011	1	0.011	0.152	0.010	1	0.011	0.139	0.010	1
S49	0.139	1	1	1	0.373	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S50	0.011	0.139	0.011	1	0.011	0.373	0.011	1	0.012	1	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1
S51	0.051	1	0.113	1	0.066	1	0.298	1	0.085	1	1	1	0.103	1	1	1	0.097	1	1	1
S52	0.011	0.051	0.011	0.113	0.010	0.066	0.011	0.298	0.011	0.085	0.011	1	0.011	0.103	0.010	1	0.011	0.097	0.010	1
S53	0.103	1	1	1	0.195	1	1	1	0.434	1	1	1	1	1	1	1	1	1	1	1
S54	0.011	0.103	0.011	1	0.011	0.195	0.011	1	0.012	0.433	0.011	1	0.011	1	0.011	1	0.011	1	0.011	1
S55	0.042	1	0.076	1	0.051	1	0.131	1	0.063	1	0.241	1	0.071	1	1	1	0.069	1	1	1
S56	0.010	0.042	0.011	0.076	0.010	0.051	0.011	0.130	0.011	0.063	0.011	0.241	0.011	0.071	0.010	1	0.011	0.069	0.010	1
S57	0.114	1	1	1	0.234	1	1	1	0.660	1	1	1	1	1	1	1	1	1	1	1
S58	0.011	0.114	0.011	1	0.011	0.234	0.011	1	0.012	0.659	0.011	1	0.011	1	0.011	1	0.012	1	0.011	1
S59	0.040	1	0.069	1	0.048	1	0.110	1	0.058	1	0.181	1	0.065	1	0.705	1	0.063	1	1	1
S60	0.010	0.040	0.011	0.069	0.010	0.048	0.010	0.110	0.011	0.058	0.011	0.181	0.011	0.065	0.010	0.704	0.011	0.063	0.010	1

Table D-7 Excerpt of TN Load Reduction TR at 95% CL with UP Analysis

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S3	1.868	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	1.011	1.868	1.011	0	1.010	0	1.011	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S5	1.100	0	1.128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	1.011	1.100	1.011	1.128	1.010	0	1.010	0	1.010	0	1.011	0	1.011	0	1.012	0	1.01	0	1.010	0
S7	1.081	0	1.099	0	1.666	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S8	1.011	1.081	1.011	1.099	1.010	1.666	1.010	0	1.010	0	1.010	0	1.011	0	1.011	0	1.01	0	1.010	0
S9	1.047	0	1.053	0	1.092	0	1.120	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	1.011	1.047	1.011	1.053	1.01	1.092	1.010	1.120	1.010	0	1.010	0	1.011	0	1.011	0	1.01	0	1.010	0
S11	1.042	0	1.046	0	1.072	0	1.089	0	1.472	0	0	0	0	0	0	0	0	0	0	0
S12	1.011	1.042	1.011	1.046	1.01	1.072	1.010	1.089	1.01	1.472	1.010	0	1.010	0	1.011	0	1.009	0	1.010	0
S13	1.031	0	1.033	0	1.042	0	1.047	0	1.080	0	1.107	0	0	0	0	0	0	0	0	0
S14	1.010	1.031	1.011	1.033	1.01	1.042	1.01	1.047	1.01	1.080	1.010	1.107	1.010	0	1.011	0	1.009	0	1.01	0
S15	1.028	0	1.030	0	1.036	0	1.040	0	1.060	0	1.074	0	1.284	0	0	0	0	0	0	0
S16	1.010	1.028	1.010	1.030	1.01	1.036	1.01	1.040	1.01	1.060	1.01	1.074	1.010	1.284	1.011	0	1.009	0	1.01	0
S17	1.024	0	1.025	0	1.029	0	1.032	0	1.043	0	1.051	0	1.109	0	1.240	0	0	0	0	0
S18	1.010	1.024	1.010	1.025	1.01	1.029	1.01	1.032	1.01	1.043	1.01	1.051	1.010	1.109	1.011	1.240	1.009	0	1.01	0
S19	1.022	0	1.023	0	1.026	0	1.028	0	1.035	0	1.040	0	1.066	0	1.100	0	1.176	0	0	0
S20	1.010	1.022	1.010	1.023	1.01	1.026	1.01	1.028	1.01	1.035	1.01	1.040	1.01	1.066	1.011	1.100	1.009	1.176	1.009	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.013	0	1.011	0	1.012	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.012	0	1.012	0	1.013	0	1.011	0	1.012	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0	1.011	0
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S29	3.630	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	1.011	3.629	1.011	0	1.010	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S31	1.223	0	1.427	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	1.011	1.223	1.011	1.427	1.010	0	1.010	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S33	1.133	0	1.189	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	1.011	1.133	1.011	1.189	1.010	0	1.010	0	1.010	0	1.011	0	1.011	0	1.012	0	1.01	0	1.011	0
S35	1.078	0	1.094	0	1.459	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S36	1.011	1.078	1.011	1.094	1.010	1.459	1.010	0	1.010	0	1.010	0	1.011	0	1.011	0	1.01	0	1.010	0
S37	1.065	0	1.076	0	1.211	0	1.453	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	1.011	1.065	1.011	1.076	1.010	1.210	1.010	1.452	1.010	0	1.010	0	1.011	0	1.011	0	1.01	0	1.010	0
S39	1.045	0	1.050	0	1.083	0	1.105	0	3.424	0	0	0	0	0	0	0	0	0	0	0
S40	1.011	1.045	1.011	1.050	1.01	1.083	1.010	1.105	1.010	3.419	1.010	0	1.010	0	1.011	0	1.01	0	1.010	0
S41	1.239	0	1.492	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	1.011	1.239	1.011	1.492	1.010	0	1.010	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S43	1.192	0	1.327	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S44	1.011	1.192	1.011	1.327	1.010	0	1.010	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S45	1.054	0	1.062	0	1.123	0	1.180	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	1.011	1.054	1.011	1.062	1.010	1.123	1.010	1.180	1.010	0	1.010	0	1.011	0	1.011	0	1.01	0	1.010	0
S47	1.051	0	1.058	0	1.108	0	1.149	0	0	0	0	0	0	0	0	0	0	0	0	0
S48	1.011	1.051	1.011	1.058	1.01	1.108	1.010	1.149	1.010	0	1.010	0	1.011	0	1.011	0	1.01	0	1.010	0
S49	1.031	0	1.033	0	1.042	0	1.048	0	1.081	0	1.110	0	0	0	0	0	0	0	0	0
S50	1.010	1.031	1.011	1.033	1.01	1.042	1.01	1.048	1.01	1.081	1.010	1.110	1.010	0	1.011	0	1.009	0	1.01	0
S51	1.030	0	1.032	0	1.040	0	1.044	0	1.072	0	1.093	0	2.994	0	0	0	0	0	0	0
S52	1.010	1.030	1.011	1.032	1.01	1.040	1.01	1.044	1.01	1.072	1.010	1.093	1.010	2.996	1.011	0	1.009	0	1.01	0
S53	1.024	0	1.025	0	1.029	0	1.031	0	1.042	0	1.048	0	1.096	0	1.183	0	2.639	0	0	0
S54	1.010	1.024	1.010	1.025	1.01	1.029	1.01	1.031	1.01	1.042	1.01	1.048	1.010	1.096	1.011	1.183	1.009	2.640	1.01	0
S55	1.023	0	1.024	0	1.027	0	1.030	0	1.039	0	1.044	0	1.081	0	1.134	0	1.354	0	0	0
S56	1.010	1.023	1.010	1.024	1.01	1.027	1.01	1.030	1.01	1.039	1.01	1.044	1.010	1.081	1.011	1.134	1.009	1.354	1.01	0
S57	1.019	0	1.020	0	1.021	0	1.022	0	1.026	0	1.029	0	1.040	0	1.051	0	1.060	0	1.102	0
S58	1.010	1.019	1.010	1.020	1.01	1.021	1.01	1.022	1.01	1.026	1.01	1.029	1.01	1.040	1.011	1.051	1.009	1.060	1.009	1.102
S59	1.019	0	1.019	0	1.020	0	1.021	0	1.025	0	1.027	0	1.037	0	1.046	0	1.052	0	1.081	0
S60	1.010	1.019	1.010	1.019	1.01	1.020	1.01	1.021	1.01	1.025	1.01	1.027	1.01	1.037	1.010	1.046	1.009	1.052	1.009	1.081

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	1.093	0	1.051	0	1.228	0	2.447	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	1.012	1.093	1.010	1.051	1.011	1.228	1.011	2.447	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.011	0
S3	1.079	0	1.047	0	1.154	0	1.356	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	1.011	1.079	1.010	1.047	1.011	1.154	1.011	1.356	1.011	0	1.011	0	1.010	0	1.011	0	1.010	0	1.011	0
S5	1.047	0	1.033	0	1.065	0	1.086	0	1.117	0	1.234	0	1.629	0	0	0	0	0	0	0
S6	1.011	1.047	1.010	1.033	1.011	1.065	1.011	1.086	1.011	1.117	1.011	1.234	1.010	1.629	1.011	0	1.010	0	1.011	0
S7	1.043	0	1.031	0	1.057	0	1.073	0	1.092	0	1.152	0	1.247	0	0	0	0	0	0	0
S8	1.011	1.043	1.010	1.031	1.011	1.057	1.011	1.073	1.011	1.092	1.011	1.152	1.010	1.247	1.011	0	1.010	0	1.011	0
S9	1.033	0	1.025	0	1.038	0	1.045	0	1.051	0	1.065	0	1.075	0	1.133	0	1.193	0	0	0
S10	1.011	1.033	1.010	1.025	1.011	1.038	1.011	1.045	1.011	1.051	1.011	1.065	1.010	1.075	1.010	1.133	1.010	1.193	1.010	0
S11	1.030	0	1.024	0	1.035	0	1.040	0	1.045	0	1.055	0	1.061	0	1.096	0	1.122	0	2.516	0
S12	1.011	1.030	1.010	1.024	1.011	1.035	1.011	1.040	1.011	1.045	1.011	1.055	1.010	1.061	1.010	1.096	1.010	1.122	1.010	2.518
S13	1.025	0	1.020	0	1.027	0	1.030	0	1.032	0	1.037	0	1.038	0	1.049	0	1.054	0	1.092	0
S14	1.011	1.025	1.010	1.020	1.010	1.027	1.011	1.030	1.011	1.032	1.011	1.037	1.01	1.038	1.010	1.049	1.01	1.054	1.010	1.092
S15	1.023	0	1.019	0	1.025	0	1.027	0	1.029	0	1.033	0	1.034	0	1.041	0	1.045	0	1.067	0
S16	1.011	1.023	1.010	1.019	1.010	1.025	1.011	1.027	1.010	1.029	1.011	1.033	1.01	1.034	1.010	1.041	1.01	1.045	1.010	1.067
S17	1.021	0	1.018	0	1.022	0	1.024	0	1.025	0	1.028	0	1.028	0	1.033	0	1.035	0	1.047	0
S18	1.011	1.021	1.010	1.018	1.010	1.022	1.011	1.024	1.010	1.025	1.011	1.028	1.01	1.028	1.010	1.033	1.01	1.035	1.010	1.047
S19	1.020	0	1.017	0	1.020	0	1.022	0	1.023	0	1.025	0	1.025	0	1.028	0	1.029	0	1.038	0
S20	1.011	1.020	1.010	1.017	1.010	1.020	1.011	1.022	1.010	1.023	1.011	1.025	1.01	1.025	1.010	1.028	1.01	1.029	1.010	1.038
S21	0	0	1.142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	1.012	0	1.011	1.142	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.011	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.011	0	1.011	0	1.012	0
S25	1.178	0	1.071	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	1.012	1.178	1.011	1.071	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S27	1.111	0	1.057	0	1.378	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	1.012	1.110	1.010	1.057	1.011	1.378	1.011	0	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.011	0
S29	1.083	0	1.048	0	1.175	0	1.489	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	1.011	1.083	1.010	1.048	1.011	1.175	1.011	1.489	1.011	0	1.011	0	1.010	0	1.011	0	1.010	0	1.011	0
S31	1.063	0	1.041	0	1.103	0	1.165	0	1.322	0	0	0	0	0	0	0	0	0	0	0
S32	1.011	1.063	1.010	1.041	1.011	1.103	1.011	1.165	1.011	1.322	1.011	0	1.010	0	1.011	0	1.010	0	1.011	0
S33	1.053	0	1.036	0	1.078	0	1.110	0	1.164	0	1.553	0	0	0	0	0	0	0	0	0
S34	1.011	1.053	1.010	1.036	1.011	1.078	1.011	1.110	1.011	1.164	1.011	1.553	1.010	0	1.011	0	1.010	0	1.011	0
S35	1.043	0	1.031	0	1.055	0	1.070	0	1.087	0	1.139	0	1.213	0	0	0	0	0	0	0
S36	1.011	1.043	1.010	1.031	1.011	1.055	1.011	1.070	1.011	1.087	1.011	1.139	1.010	1.213	1.011	0	1.010	0	1.011	0
S37	1.039	0	1.029	0	1.049	0	1.060	0	1.072	0	1.104	0	1.137	0	1.678	0	0	0	0	0
S38	1.011	1.039	1.010	1.029	1.011	1.049	1.011	1.060	1.011	1.072	1.011	1.104	1.010	1.137	1.010	1.677	1.010	0	1.011	0
S39	1.032	0	1.025	0	1.037	0	1.043	0	1.049	0	1.061	0	1.069	0	1.114	0	1.154	0	0	0
S40	1.011	1.032	1.010	1.025	1.011	1.037	1.011	1.043	1.011	1.049	1.011	1.061	1.010	1.069	1.010	1.114	1.010	1.154	1.010	0
S41	1.064	0	1.041	0	1.106	0	1.173	0	1.357	0	0	0	0	0	0	0	0	0	0	0
S42	1.011	1.064	1.010	1.041	1.011	1.106	1.011	1.173	1.011	1.357	1.011	0	1.010	0	1.011	0	1.010	0	1.011	0
S43	1.061	0	1.040	0	1.095	0	1.147	0	1.262	0	0	0	0	0	0	0	0	0	0	0
S44	1.011	1.061	1.010	1.040	1.011	1.095	1.011	1.147	1.011	1.262	1.011	0	1.010	0	1.011	0	1.010	0	1.011	0
S45	1.035	0	1.027	0	1.043	0	1.051	0	1.059	0	1.079	0	1.094	0	1.208	0	1.414	0	0	0
S46	1.011	1.035	1.010	1.027	1.011	1.043	1.011	1.051	1.011	1.059	1.011	1.079	1.010	1.094	1.010	1.208	1.010	1.415	1.010	0
S47	1.034	0	1.026	0	1.041	0	1.048	0	1.055	0	1.072	0	1.085	0	1.168	0	1.278	0	0	0
S48	1.011	1.034	1.010	1.026	1.011	1.041	1.011	1.048	1.011	1.055	1.011	1.072	1.010	1.085	1.010	1.168	1.010	1.278	1.010	0
S49	1.025	0	1.020	0	1.027	0	1.030	0	1.032	0	1.037	0	1.039	0	1.050	0	1.055	0	1.094	0
S50	1.011	1.025	1.010	1.020	1.010	1.027	1.011	1.030	1.011	1.032	1.011	1.037	1.01	1.039	1.010	1.050	1.01	1.055	1.010	1.094
S51	1.024	0	1.020	0	1.026	0	1.029	0	1.031	0	1.035	0	1.037	0	1.046	0	1.051	0	1.081	0
S52	1.011	1.024	1.010	1.020	1.010	1.026	1.011	1.029	1.010	1.031	1.011	1.035	1.01	1.037	1.010	1.046	1.01	1.051	1.010	1.081
S53	1.021	0	1.017	0	1.022	0	1.024	0	1.025	0	1.027	0	1.027	0	1.032	0	1.034	0	1.046	0
S54	1.011	1.021	1.010	1.017	1.010	1.022	1.011	1.024	1.010	1.025	1.011	1.027	1.01	1.027	1.010	1.032	1.01	1.034	1.010	1.046
S55	1.020	0	1.017	0	1.021	0	1.023	0	1.024	0	1.026	0	1.026	0	1.031	0	1.032	0	1.042	0
S56	1.011	1.020	1.010	1.017	1.010	1.021	1.011	1.023	1.010	1.024	1.011	1.026	1.01	1.026	1.010	1.031	1.01	1.032	1.010	1.042
S57	1.018	0	1.015	0	1.018	0	1.019	0	1.020	0	1.021	0	1.020	0	1.023	0	1.023	0	1.028	0
S58	1.011	1.018	1.01	1.015	1.010	1.018	1.010	1.019	1.010	1.020	1.011	1.021	1.01	1.020	1.01	1.023	1.01	1.023	1.01	1.028
S59	1.017	0	1.015	0	1.018	0	1.019	0	1.019	0	1.020	0	1.020	0	1.022	0	1.022	0	1.027	0
S60	1.011	1.017	1.01	1.015	1.010	1.018	1.010	1.019	1.010	1.019	1.010	1.020	1.01	1.020	1.01	1.022	1.01	1.022	1.01	1.027

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0
S3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0
S5	1.215	0	1.277	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	1.011	1.215	1.011	1.277	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S7	1.143	0	1.168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S8	1.011	1.143	1.011	1.168	1.010	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S9	1.063	0	1.068	0	1.586	0	3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	1.011	1.063	1.011	1.068	1.010	1.586	1.010	3.000	1.011	0	1.011	0	1.010	0	1.010	0	1.010	0	1.011	0
S11	1.054	0	1.057	0	1.211	0	1.282	0	0	0	0	0	0	0	0	0	0	0	0	0
S12	1.011	1.054	1.011	1.057	1.010	1.211	1.010	1.282	1.011	0	1.011	0	1.010	0	1.010	0	1.010	0	1.010	0
S13	1.036	0	1.038	0	1.067	0	1.073	0	0	0	0	0	0	0	0	0	0	0	0	0
S14	1.011	1.036	1.011	1.038	1.010	1.067	1.010	1.073	1.010	0	1.010	0	1.01	0	1.010	0	1.01	0	1.010	0
S15	1.032	0	1.033	0	1.053	0	1.056	0	1.269	0	1.491	0	0	0	0	0	0	0	0	0
S16	1.011	1.032	1.011	1.033	1.010	1.053	1.010	1.056	1.010	1.269	1.010	1.491	1.01	0	1.010	0	1.01	0	1.01	0
S17	1.027	0	1.028	0	1.040	0	1.042	0	1.107	0	1.132	0	0	0	0	0	0	0	0	0
S18	1.011	1.027	1.011	1.028	1.01	1.040	1.010	1.042	1.010	1.107	1.010	1.132	1.01	0	1.01	0	1.01	0	1.01	0
S19	1.025	0	1.025	0	1.033	0	1.034	0	1.066	0	1.074	0	1.260	0	1.597	0	0	0	0	0
S20	1.010	1.025	1.010	1.025	1.01	1.033	1.01	1.034	1.010	1.066	1.010	1.074	1.01	1.260	1.01	1.597	1.01	0	1.01	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	1.012	0	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.012	0	1.012	0	1.013	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	1.012	0	1.012	0	1.011	0	1.012	0	1.012	0	1.012	0	1.012	0	1.012	0	1.013	0	1.013	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0	1.012	0	1.012	0	1.012	0
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.012	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0
S31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S33	1.463	0	1.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	1.011	1.463	1.011	1.898	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S35	1.132	0	1.153	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S36	1.011	1.132	1.011	1.153	1.010	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S37	1.100	0	1.111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	1.011	1.100	1.011	1.111	1.010	0	1.010	0	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.011	0
S39	1.059	0	1.063	0	1.328	0	1.537	0	0	0	0	0	0	0	0	0	0	0	0	0
S40	1.011	1.059	1.011	1.063	1.010	1.328	1.010	1.537	1.011	0	1.011	0	1.010	0	1.010	0	1.010	0	1.010	0
S41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S43	58.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S44	1.011	58.77	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0
S45	1.076	0	1.082	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	1.011	1.076	1.011	1.082	1.010	0	1.010	0	1.011	0	1.011	0	1.010	0	1.010	0	1.010	0	1.011	0
S47	1.070	0	1.076	0	6.406	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S48	1.011	1.070	1.011	1.076	1.010	6.404	1.010	0	1.011	0	1.011	0	1.010	0	1.010	0	1.010	0	1.011	0
S49	1.037	0	1.038	0	1.068	0	1.074	0	0	0	0	0	0	0	0	0	0	0	0	0
S50	1.011	1.037	1.011	1.038	1.010	1.068	1.010	1.074	1.010	0	1.010	0	1.010	0	1.010	0	1.01	0	1.010	0
S51	1.035	0	1.036	0	1.061	0	1.066	0	2.412	0	0	0	0	0	0	0	0	0	0	0
S52	1.011	1.035	1.011	1.036	1.010	1.061	1.010	1.066	1.010	2.412	1.010	0	1.01	0	1.010	0	1.01	0	1.010	0
S53	1.027	0	1.028	0	1.039	0	1.040	0	1.095	0	1.114	0	0	0	0	0	0	0	0	0
S54	1.011	1.027	1.011	1.028	1.01	1.039	1.01	1.040	1.010	1.095	1.010	1.114	1.01	0	1.01	0	1.01	0	1.01	0
S55	1.026	0	1.026	0	1.036	0	1.038	0	1.080	0	1.093	0	1.882	0	0	0	0	0	0	0
S56	1.011	1.026	1.010	1.026	1.01	1.036	1.01	1.038	1.010	1.080	1.010	1.093	1.01	1.882	1.01	0	1.01	0	1.01	0
S57	1.021	0	1.021	0	1.025	0	1.026	0	1.040	0	1.043	0	1.069	0	1.082	0	0	0	0	0
S58	1.010	1.021	1.010	1.021	1.01	1.025	1.01	1.026	1.01	1.040	1.010	1.043	1.01	1.069	1.01	1.082	1.009	0	1.01	0
S59	1.020	0	1.020	0	1.024	0	1.025	0	1.037	0	1.039	0	1.059	0	1.068	0	1.606	0	0	0
S60	1.010	1.020	1.010	1.020	1.01	1.024	1.01	1.025	1.01	1.037	1.01	1.039	1.01	1.059	1.01	1.068	1.009	1.606	1.009	0

Table D-8 Excerpt of TP Load Reduction TR at 95% CL with UP Analysis

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1	0	0	0	0	0	0	0	0	1.417	0	0	0	3.063	0	0	0	2.276	0	0	0
S2	1.011	0	1.011	0	1.010	0	1.011	0	1.010	1.417	1.011	0	1.011	3.078	1.011	0	1.010	2.286	1.010	0
S3	1.093	0	0	0	1.089	0	0	0	1.070	0	0	0	1.083	0	0	0	1.077	0	0	0
S4	1.011	1.093	1.011	0	1.010	1.089	1.011	0	1.010	1.070	1.010	0	1.011	1.083	1.011	0	1.01	1.077	1.010	0
S5	0	0	0	0	0	0	0	0	1.437	0	0	0	3.966	0	0	0	2.568	0	0	0
S6	1.011	0	1.011	0	1.010	0	1.011	0	1.010	1.437	1.011	0	1.011	3.988	1.011	0	1.010	2.581	1.010	0
S7	1.070	0	1.421	0	1.067	0	0	0	1.055	0	0	0	1.064	0	0	0	1.060	0	0	0
S8	1.011	1.070	1.011	1.420	1.010	1.067	1.011	0	1.010	1.055	1.010	0	1.011	1.064	1.011	0	1.01	1.060	1.010	0
S9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	1.011	0	1.012	0	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.010	0
S11	1.069	0	1.416	0	1.066	0	0	0	1.055	0	0	0	1.063	0	0	0	1.059	0	0	0
S12	1.011	1.069	1.011	1.415	1.010	1.066	1.011	0	1.010	1.055	1.010	0	1.011	1.063	1.011	0	1.01	1.059	1.01	0
S13	0	0	0	0	0	0	0	0	2.175	0	0	0	0	0	0	0	0	0	0	0
S14	1.011	0	1.012	0	1.010	0	1.011	0	1.010	2.172	1.011	0	1.011	0	1.011	0	1.010	0	1.010	0
S15	1.049	0	1.116	0	1.047	0	1.181	0	1.041	0	1.178	0	1.046	0	0	0	1.043	0	0	0
S16	1.011	1.049	1.011	1.115	1.010	1.047	1.011	1.180	1.010	1.041	1.010	1.178	1.011	1.046	1.011	0	1.01	1.043	1.01	0
S17	0	0	0	0	0	0	0	0	2.449	0	0	0	0	0	0	0	0	0	0	0
S18	1.011	0	1.012	0	1.010	0	1.011	0	1.010	2.440	1.011	0	1.011	0	1.011	0	1.010	0	1.010	0
S19	1.039	0	1.074	0	1.038	0	1.095	0	1.034	0	1.094	0	1.038	0	1.275	0	1.035	0	0	0
S20	1.011	1.039	1.011	1.074	1.010	1.038	1.010	1.095	1.010	1.034	1.010	1.094	1.011	1.038	1.011	1.275	1.01	1.035	1.01	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	1.011	0	1.012	0	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	1.011	0	1.012	0	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.010	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	1.011	0	1.012	0	1.011	0	1.011	0	1.010	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S27	1.112	0	0	0	1.107	0	0	0	1.080	0	0	0	1.097	0	0	0	1.090	0	0	0
S28	1.011	1.112	1.011	0	1.010	1.107	1.011	0	1.010	1.080	1.011	0	1.011	1.097	1.011	0	1.010	1.091	1.010	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S31	1.096	0	0	0	1.092	0	0	0	1.071	0	0	0	1.085	0	0	0	1.079	0	0	0
S32	1.011	1.096	1.011	0	1.010	1.092	1.011	0	1.010	1.071	1.011	0	1.011	1.085	1.011	0	1.01	1.079	1.010	0
S33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S35	1.054	0	1.148	0	1.052	0	1.282	0	1.044	0	1.278	0	1.050	0	0	0	1.047	0	0	0
S36	1.011	1.054	1.011	1.147	1.010	1.052	1.011	1.282	1.010	1.044	1.010	1.278	1.011	1.050	1.011	0	1.01	1.047	1.01	0
S37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.010	0	1.011	0
S39	1.040	0	1.073	0	1.038	0	1.093	0	1.034	0	1.092	0	1.038	0	1.248	0	1.035	0	0	0
S40	1.011	1.040	1.011	1.073	1.010	1.038	1.010	1.093	1.010	1.034	1.010	1.092	1.011	1.038	1.011	1.248	1.01	1.035	1.01	0
S41	1.359	0	0	0	1.327	0	0	0	1.159	0	0	0	1.236	0	0	0	1.212	0	0	0
S42	1.011	1.358	1.011	0	1.010	1.327	1.011	0	1.010	1.159	1.011	0	1.011	1.236	1.011	0	1.010	1.213	1.010	0
S43	1.075	0	1.604	0	1.072	0	0	0	1.058	0	0	0	1.068	0	0	0	1.064	0	0	0
S44	1.011	1.075	1.011	1.604	1.010	1.072	1.011	0	1.010	1.058	1.010	0	1.011	1.068	1.011	0	1.01	1.064	1.010	0
S45	1.133	0	0	0	1.126	0	0	0	1.090	0	0	0	1.112	0	0	0	1.104	0	0	0
S46	1.011	1.133	1.011	0	1.010	1.126	1.011	0	1.010	1.090	1.011	0	1.011	1.112	1.011	0	1.010	1.104	1.010	0
S47	1.052	0	1.137	0	1.050	0	1.243	0	1.044	0	1.240	0	1.049	0	0	0	1.046	0	0	0
S48	1.011	1.052	1.011	1.137	1.010	1.050	1.011	1.243	1.010	1.044	1.010	1.240	1.011	1.049	1.011	0	1.01	1.046	1.01	0
S49	1.101	0	0	0	1.097	0	0	0	1.075	0	0	0	1.089	0	0	0	1.083	0	0	0
S50	1.011	1.101	1.011	0	1.010	1.097	1.011	0	1.010	1.075	1.011	0	1.011	1.089	1.011	0	1.010	1.083	1.010	0
S51	1.045	0	1.096	0	1.044	0	1.135	0	1.039	0	1.133	0	1.043	0	2.107	0	1.040	0	0	0
S52	1.011	1.045	1.011	1.096	1.010	1.044	1.010	1.135	1.010	1.039	1.010	1.133	1.011	1.043	1.011	2.110	1.01	1.040	1.01	0
S53	1.081	0	2.441	0	1.077	0	0	0	1.062	0	0	0	1.073	0	0	0	1.068	0	0	0
S54	1.011	1.081	1.011	2.428	1.010	1.077	1.011	0	1.010	1.062	1.010	0	1.011	1.073	1.011	0	1.01	1.068	1.010	0
S55	1.038	0	1.068	0	1.037	0	1.085	0	1.033	0	1.083	0	1.036	0	1.195	0	1.034	0	2.373	0
S56	1.011	1.038	1.011	1.068	1.010	1.037	1.010	1.084	1.01	1.033	1.010	1.083	1.011	1.036	1.011	1.195	1.01	1.034	1.01	2.381
S57	1.087	0	0	0	1.084	0	0	0	1.067	0	0	0	1.078	0	0	0	1.073	0	0	0
S58	1.011	1.087	1.011	0	1.010	1.084	1.011	0	1.010	1.066	1.010	0	1.011	1.078	1.011	0	1.01	1.073	1.010	0
S59	1.036	0	1.062	0	1.035	0	1.075	0	1.031	0	1.075	0	1.035	0	1.153	0	1.033	0	1.455	0
S60	1.010	1.036	1.011	1.062	1.010	1.035	1.010	1.075	1.01	1.031	1.010	1.074	1.011	1.035	1.011	1.153	1.01	1.033	1.01	1.455

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	1.284	0	1.467	0	1.251	0	0	0	1.123	0	0	0	1.150	0	0	0	1.107	0	0	0
S2	1.011	1.284	1.011	1.467	1.011	1.252	1.011	0	1.011	1.123	1.011	0	1.010	1.151	1.011	0	1.010	1.107	1.011	0
S3	1.068	0	1.071	0	1.064	0	2.235	0	1.051	0	0	0	1.054	0	0	0	1.047	0	0	0
S4	1.011	1.068	1.010	1.071	1.011	1.064	1.011	2.237	1.011	1.051	1.011	0	1.010	1.054	1.011	0	1.010	1.047	1.011	0
S5	1.291	0	1.494	0	1.256	0	0	0	1.123	0	0	0	1.151	0	0	0	1.106	0	0	0
S6	1.011	1.291	1.011	1.493	1.011	1.256	1.011	0	1.011	1.123	1.011	0	1.010	1.151	1.011	0	1.010	1.107	1.011	0
S7	1.055	0	1.057	0	1.052	0	1.237	0	1.043	0	1.363	0	1.045	0	0	0	1.040	0	0	0
S8	1.011	1.055	1.010	1.056	1.011	1.052	1.011	1.237	1.011	1.043	1.011	1.363	1.010	1.045	1.011	0	1.010	1.040	1.011	0
S9	4.071	0	0	0	2.410	0	0	0	1.202	0	0	0	1.299	0	0	0	1.163	0	0	0
S10	1.011	4.048	1.011	0	1.011	2.408	1.012	0	1.011	1.202	1.011	0	1.010	1.299	1.011	0	1.010	1.163	1.011	0
S11	1.054	0	1.056	0	1.052	0	1.234	0	1.043	0	1.359	0	1.045	0	0	0	1.040	0	0	0
S12	1.011	1.054	1.010	1.056	1.011	1.052	1.011	1.234	1.011	1.043	1.011	1.359	1.010	1.045	1.011	0	1.010	1.040	1.011	0
S13	1.488	0	2.643	0	1.406	0	0	0	1.152	0	0	0	1.197	0	0	0	1.129	0	0	0
S14	1.011	1.487	1.011	2.634	1.011	1.406	1.011	0	1.011	1.152	1.011	0	1.010	1.197	1.011	0	1.010	1.129	1.011	0
S15	1.042	0	1.042	0	1.040	0	1.096	0	1.035	0	1.111	0	1.035	0	1.935	0	1.032	0	0	0
S16	1.011	1.042	1.010	1.042	1.011	1.040	1.011	1.096	1.010	1.035	1.011	1.111	1.01	1.035	1.011	1.935	1.01	1.032	1.011	0
S17	1.516	0	3.281	0	1.423	0	0	0	1.151	0	0	0	1.197	0	0	0	1.127	0	0	0
S18	1.011	1.514	1.011	3.250	1.011	1.422	1.011	0	1.011	1.151	1.011	0	1.010	1.197	1.011	0	1.010	1.127	1.011	0
S19	1.035	0	1.035	0	1.034	0	1.065	0	1.030	0	1.072	0	1.030	0	1.170	0	1.028	0	0	0
S20	1.011	1.035	1.010	1.035	1.011	1.034	1.011	1.065	1.010	1.030	1.011	1.072	1.01	1.030	1.010	1.170	1.01	1.028	1.011	0
S21	0	0	0	0	0	0	0	0	1.295	0	0	0	1.551	0	0	0	1.223	0	0	0
S22	1.012	0	1.011	0	1.011	0	1.012	0	1.011	1.295	1.012	0	1.010	1.553	1.011	0	1.010	1.224	1.011	0
S23	2.857	0	0	0	2.082	0	0	0	1.195	0	0	0	1.282	0	0	0	1.158	0	0	0
S24	1.011	2.854	1.011	0	1.011	2.083	1.012	0	1.011	1.195	1.011	0	1.010	1.282	1.011	0	1.010	1.159	1.011	0
S25	0	0	0	0	0	0	0	0	1.319	0	0	0	1.656	0	0	0	1.236	0	0	0
S26	1.012	0	1.011	0	1.011	0	1.012	0	1.011	1.319	1.012	0	1.010	1.658	1.011	0	1.010	1.236	1.011	0
S27	1.077	0	1.082	0	1.073	0	0	0	1.056	0	0	0	1.060	0	0	0	1.052	0	0	0
S28	1.011	1.077	1.010	1.082	1.011	1.073	1.011	0	1.011	1.056	1.011	0	1.010	1.060	1.011	0	1.010	1.052	1.011	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	167.7	0	0	0
S30	1.012	0	1.011	0	1.011	0	1.012	0	1.011	0	1.012	0	1.010	0	1.011	0	1.010	618.9	1.012	0
S31	1.069	0	1.073	0	1.066	0	3.195	0	1.052	0	0	0	1.055	0	0	0	1.048	0	0	0
S32	1.011	1.069	1.010	1.073	1.011	1.066	1.011	3.188	1.011	1.052	1.011	0	1.010	1.055	1.011	0	1.010	1.048	1.011	0
S33	0	0	0	0	0	0	0	0	2.393	0	0	0	0	0	0	0	1.558	0	0	0
S34	1.012	0	1.011	0	1.011	0	1.012	0	1.011	2.389	1.012	0	1.010	0	1.011	0	1.010	1.558	1.011	0
S35	1.045	0	1.045	0	1.043	0	1.116	0	1.037	0	1.140	0	1.038	0	0	0	1.034	0	0	0
S36	1.011	1.045	1.010	1.045	1.011	1.043	1.011	1.116	1.011	1.037	1.011	1.140	1.010	1.038	1.011	0	1.01	1.034	1.011	0
S37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	1.012	0	1.011	0	1.011	0	1.012	0	1.011	0	1.012	0	1.010	0	1.011	0	1.010	0	1.012	0
S39	1.035	0	1.035	0	1.034	0	1.065	0	1.030	0	1.071	0	1.030	0	1.161	0	1.028	0	0	0
S40	1.011	1.035	1.010	1.035	1.011	1.034	1.011	1.065	1.010	1.030	1.011	1.071	1.01	1.030	1.010	1.161	1.01	1.028	1.011	0
S41	1.139	0	1.167	0	1.129	0	0	0	1.084	0	0	0	1.095	0	0	0	1.076	0	0	0
S42	1.011	1.139	1.011	1.167	1.011	1.129	1.011	0	1.011	1.084	1.011	0	1.010	1.095	1.011	0	1.010	1.076	1.011	0
S43	1.058	0	1.060	0	1.055	0	1.288	0	1.045	0	1.495	0	1.047	0	0	0	1.042	0	0	0
S44	1.011	1.058	1.010	1.060	1.011	1.055	1.011	1.289	1.011	1.045	1.011	1.496	1.010	1.047	1.011	0	1.010	1.042	1.011	0
S45	1.085	0	1.093	0	1.081	0	0	0	1.061	0	0	0	1.065	0	0	0	1.055	0	0	0
S46	1.011	1.085	1.010	1.093	1.011	1.081	1.011	0	1.011	1.061	1.011	0	1.010	1.065	1.011	0	1.010	1.055	1.011	0
S47	1.044	0	1.044	0	1.042	0	1.110	0	1.036	0	1.130	0	1.037	0	0	0	1.034	0	0	0
S48	1.011	1.044	1.010	1.044	1.011	1.042	1.011	1.110	1.010	1.036	1.011	1.130	1.010	1.037	1.011	0	1.01	1.034	1.011	0
S49	1.072	0	1.077	0	1.069	0	9.208	0	1.054	0	0	0	1.057	0	0	0	1.050	0	0	0
S50	1.011	1.072	1.010	1.077	1.011	1.069	1.011	9.063	1.011	1.054	1.011	0	1.010	1.057	1.011	0	1.010	1.050	1.011	0
S51	1.039	0	1.039	0	1.038	0	1.082	0	1.033	0	1.092	0	1.033	0	1.335	0	1.031	0	0	0
S52	1.011	1.039	1.010	1.039	1.011	1.038	1.011	1.082	1.010	1.033	1.011	1.092	1.01	1.033	1.010	1.335	1.01	1.031	1.011	0
S53	1.061	0	1.064	0	1.058	0	1.400	0	1.047	0	1.947	0	1.050	0	0	0	1.044	0	0	0
S54	1.011	1.061	1.010	1.064	1.011	1.058	1.011	1.400	1.011	1.047	1.011	1.945	1.010	1.050	1.011	0	1.010	1.044	1.011	0
S55	1.034	0	1.034	0	1.033	0	1.061	0	1.029	0	1.066	0	1.029	0	1.136	0	1.027	0	10.88	0
S56	1.011	1.034	1.010	1.034	1.011	1.033	1.011	1.061	1.010	1.029	1.011	1.066	1.01	1.029	1.010	1.136	1.01	1.027	1.011	11.32
S57	1.065	0	1.068	0	1.062	0	1.598	0	1.050	0	5.025	0	1.052	0	0	0	1.046	0	0	0
S58	1.011	1.065	1.010	1.068	1.011	1.062	1.011	1.596	1.011	1.050	1.011	4.952	1.010	1.052	1.011	0	1.010	1.046	1.011	0
S59	1.033	0	1.032	0	1.031	0	1.056	0	1.028	0	1.061	0	1.028	0	1.114	0	1.026	0	1.661	0
S60	1.011	1.033	1.010	1.032	1.010	1.031	1.011	1.056	1.010	1.028	1.011	1.061	1.01	1.028	1.010	1.114	1.01	1.026	1.011	1.661

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S3	1.142	0	0	0	1.414	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	1.011	1.143	1.011	0	1.011	1.414	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0
S5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S7	1.094	0	0	0	1.168	0	0	0	1.338	0	0	0	2.573	0	0	0	1.717	0	0	0
S8	1.011	1.094	1.011	0	1.011	1.168	1.011	0	1.012	1.338	1.011	0	1.011	2.582	1.011	0	1.012	1.72	1.011	0
S9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	1.011	0	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S11	1.094	0	0	0	1.167	0	0	0	1.334	0	0	0	2.542	0	0	0	1.708	0	0	0
S12	1.011	1.094	1.011	0	1.011	1.167	1.011	0	1.012	1.334	1.011	0	1.011	2.548	1.011	0	1.012	1.71	1.011	0
S13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S14	1.011	0	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S15	1.060	0	1.166	0	1.081	0	3.199	0	1.110	0	0	0	1.144	0	0	0	1.132	0	0	0
S16	1.011	1.060	1.011	1.166	1.011	1.081	1.011	3.177	1.011	1.11	1.011	0	1.011	1.144	1.011	0	1.011	1.132	1.01	0
S17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S18	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S19	1.046	0	1.092	0	1.058	0	1.193	0	1.073	0	1.626	0	1.085	0	0	0	1.082	0	0	0
S20	1.011	1.046	1.011	1.092	1.010	1.058	1.011	1.192	1.011	1.073	1.011	1.623	1.011	1.085	1.01	0	1.011	1.082	1.01	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	1.011	0	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	1.011	0	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	1.011	0	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S27	1.193	0	0	0	2.750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	1.011	1.193	1.011	0	1.011	2.753	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	1.011	0	1.012	0	1.011	0	1.012	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S31	1.150	0	0	0	1.486	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	1.011	1.150	1.011	0	1.011	1.486	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0
S33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	1.011	0	1.012	0	1.011	0	1.011	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S35	1.067	0	1.244	0	1.096	0	0	0	1.138	0	0	0	1.199	0	0	0	1.175	0	0	0
S36	1.011	1.067	1.011	1.243	1.011	1.096	1.011	0	1.012	1.138	1.011	0	1.011	1.199	1.011	0	1.012	1.175	1.011	0
S37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	1.011	0	1.012	0	1.011	0	1.012	0	1.012	0	1.012	0	1.012	0	1.011	0	1.012	0	1.011	0
S39	1.046	0	1.091	0	1.058	0	1.180	0	1.072	0	1.486	0	1.084	0	0	0	1.081	0	0	0
S40	1.011	1.046	1.011	1.090	1.010	1.058	1.011	1.180	1.011	1.072	1.011	1.484	1.011	1.084	1.010	0	1.011	1.081	1.010	0
S41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	1.011	0	1.011	0	1.011	0	1.011	0	1.012	0	1.012	0	1.011	0	1.011	0	1.012	0	1.011	0
S43	1.103	0	0	0	1.195	0	0	0	1.445	0	0	0	0	0	0	0	2.417	0	0	0
S44	1.011	1.103	1.011	0	1.011	1.195	1.011	0	1.012	1.446	1.011	0	1.011	0	1.011	0	1.012	2.432	1.011	0
S45	1.269	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	1.011	1.269	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0
S47	1.065	0	1.215	0	1.092	0	0	0	1.129	0	0	0	1.180	0	0	0	1.161	0	0	0
S48	1.011	1.065	1.011	1.215	1.011	1.092	1.011	0	1.012	1.129	1.011	0	1.011	1.180	1.011	0	1.011	1.161	1.011	0
S49	1.161	0	0	0	1.595	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S50	1.011	1.161	1.011	0	1.011	1.594	1.011	0	1.012	0	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0
S51	1.054	0	1.127	0	1.071	0	1.424	0	1.093	0	0	0	1.115	0	0	0	1.108	0	0	0
S52	1.011	1.054	1.011	1.127	1.011	1.071	1.011	1.424	1.011	1.093	1.011	0	1.011	1.115	1.011	0	1.011	1.108	1.010	0
S53	1.115	0	0	0	1.242	0	0	0	1.766	0	0	0	0	0	0	0	0	0	0	0
S54	1.011	1.115	1.011	0	1.011	1.242	1.011	0	1.012	1.765	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0
S55	1.044	0	1.082	0	1.054	0	1.150	0	1.067	0	1.318	0	1.077	0	0	0	1.074	0	0	0
S56	1.011	1.044	1.011	1.082	1.010	1.054	1.011	1.150	1.011	1.067	1.011	1.318	1.011	1.077	1.010	0	1.011	1.074	1.010	0
S57	1.129	0	0	0	1.306	0	0	0	2.944	0	0	0	0	0	0	0	0	0	0	0
S58	1.011	1.128	1.011	0	1.011	1.306	1.011	0	1.012	2.930	1.011	0	1.011	0	1.011	0	1.012	0	1.011	0
S59	1.041	0	1.074	0	1.050	0	1.124	0	1.062	0	1.221	0	1.070	0	3.395	0	1.068	0	0	0
S60	1.011	1.041	1.011	1.074	1.010	1.050	1.011	1.124	1.011	1.062	1.011	1.221	1.011	1.070	1.010	3.378	1.011	1.068	1.010	0

D.2 Monthly Load Reduction Matrices

Table D-9 and Table D-10 list monthly nutrient load reduction for selected scenarios. In these tables, the top row presents current scenarios and the first column contains potential alternative scenarios. Both current scenario columns and alternative scenario rows ranged from S1 to S65 to represent scenarios #1 to #65 as described in Table A-21. The intersection cell value is the potential nutrient load reduction if the management practice changed from the selected current scenario to the alternative one.

Table D-9 Monthly TN Load Reduction Matrix

SCEN	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35
1		-0.14	-0.67	-0.81	-1.27	-1.42	-1.86	-2.04	-2.22	-2.42	0.91	0.64	0.38	0.12	-0.09	-0.36	-0.53	-0.85
3	0.14		-0.53	-0.67	-1.13	-1.27	-1.71	-1.89	-2.08	-2.28	1.05	0.78	0.52	0.26	0.05	-0.22	-0.39	-0.70
5	0.67	0.53		-0.13	-0.60	-0.74	-1.18	-1.36	-1.54	-1.75	1.58	1.32	1.05	0.79	0.58	0.31	0.14	-0.17
7	0.81	0.67	0.13		-0.46	-0.61	-1.05	-1.23	-1.41	-1.61	1.72	1.45	1.19	0.93	0.72	0.45	0.28	-0.04
9	1.27	1.13	0.60	0.46		-0.14	-0.58	-0.76	-0.95	-1.15	2.18	1.91	1.65	1.39	1.18	0.91	0.74	0.43
11	1.42	1.27	0.74	0.61	0.14		-0.44	-0.62	-0.80	-1.01	2.32	2.06	1.80	1.53	1.32	1.06	0.89	0.57
13	1.86	1.71	1.18	1.05	0.58	0.44		-0.18	-0.36	-0.57	2.76	2.50	2.24	1.97	1.76	1.50	1.33	1.01
15	2.04	1.89	1.36	1.23	0.76	0.62	0.18		-0.18	-0.39	2.94	2.68	2.42	2.15	1.94	1.67	1.50	1.19
17	2.22	2.08	1.54	1.41	0.95	0.80	0.36	0.18		-0.20	3.13	2.86	2.60	2.34	2.13	1.86	1.69	1.37
19	2.42	2.28	1.75	1.61	1.15	1.01	0.57	0.39	0.20		3.33	3.06	2.80	2.54	2.33	2.06	1.89	1.58
21	-0.91	-1.05	-1.58	-1.72	-2.18	-2.32	-2.76	-2.94	-3.13	-3.33		-0.27	-0.53	-0.79	-1.00	-1.27	-1.44	-1.75
23	-0.64	-0.78	-1.32	-1.45	-1.91	-2.06	-2.50	-2.68	-2.86	-3.06	0.27		-0.26	-0.52	-0.73	-1.00	-1.17	-1.49
25	-0.38	-0.52	-1.05	-1.19	-1.65	-1.80	-2.24	-2.42	-2.60	-2.80	0.53	0.26		-0.26	-0.47	-0.74	-0.91	-1.23
27	-0.12	-0.26	-0.79	-0.93	-1.39	-1.53	-1.97	-2.15	-2.34	-2.54	0.79	0.52	0.26		-0.21	-0.48	-0.65	-0.96
29	0.09	-0.05	-0.58	-0.72	-1.18	-1.32	-1.76	-1.94	-2.13	-2.33	1.00	0.73	0.47	0.21		-0.27	-0.44	-0.75
31	0.36	0.22	-0.31	-0.45	-0.91	-1.06	-1.50	-1.67	-1.86	-2.06	1.27	1.00	0.74	0.48	0.27		-0.17	-0.49
33	0.53	0.39	-0.14	-0.28	-0.74	-0.89	-1.33	-1.50	-1.69	-1.89	1.44	1.17	0.91	0.65	0.44	0.17		-0.32
35	0.85	0.70	0.17	0.04	-0.43	-0.57	-1.01	-1.19	-1.37	-1.58	1.75	1.49	1.23	0.96	0.75	0.49	0.32	
37	0.98	0.83	0.30	0.17	-0.30	-0.44	-0.88	-1.06	-1.24	-1.45	1.88	1.62	1.36	1.09	0.88	0.61	0.44	0.13
39	1.34	1.20	0.67	0.53	0.07	-0.08	-0.52	-0.70	-0.88	-1.08	2.25	1.98	1.72	1.46	1.25	0.98	0.81	0.49
41	0.34	0.20	-0.33	-0.47	-0.93	-1.08	-1.52	-1.70	-1.88	-2.08	1.25	0.98	0.72	0.46	0.25	-0.02	-0.19	-0.51
43	0.40	0.26	-0.27	-0.40	-0.87	-1.01	-1.45	-1.63	-1.81	-2.02	1.31	1.05	0.78	0.52	0.31	0.04	-0.13	-0.44
45	1.15	1.00	0.47	0.34	-0.13	-0.27	-0.71	-0.89	-1.07	-1.28	2.05	1.79	1.52	1.26	1.05	0.78	0.61	0.30
47	1.20	1.06	0.53	0.39	-0.07	-0.21	-0.65	-0.83	-1.02	-1.22	2.11	1.84	1.58	1.32	1.11	0.84	0.67	0.36
49	1.85	1.70	1.17	1.04	0.57	0.43	-0.01	-0.19	-0.37	-0.58	2.75	2.49	2.23	1.96	1.76	1.49	1.32	1.00
51	1.92	1.77	1.24	1.11	0.64	0.50	0.06	-0.12	-0.30	-0.51	2.82	2.56	2.30	2.03	1.82	1.55	1.38	1.07
53	2.27	2.13	1.60	1.46	1.00	0.85	0.41	0.24	0.05	-0.15	3.18	2.91	2.65	2.39	2.18	1.91	1.74	1.42
55	2.34	2.20	1.67	1.53	1.07	0.92	0.48	0.30	0.12	-0.08	3.25	2.98	2.72	2.46	2.25	1.98	1.81	1.49
57	2.73	2.59	2.05	1.92	1.45	1.31	0.87	0.69	0.51	0.31	3.64	3.37	3.11	2.85	2.64	2.37	2.20	1.88
59	2.80	2.65	2.12	1.99	1.52	1.38	0.94	0.76	0.58	0.37	3.70	3.44	3.18	2.91	2.71	2.44	2.27	1.95
61	4.79	4.65	4.12	3.99	3.52	3.38	2.94	2.76	2.57	2.37	5.70	5.43	5.17	4.91	4.70	4.43	4.26	3.95
62	4.84	4.70	4.16	4.03	3.57	3.42	2.98	2.80	2.62	2.42	5.75	5.48	5.22	4.96	4.75	4.48	4.31	3.99
63	4.78	4.63	4.10	3.97	3.50	3.36	2.92	2.74	2.56	2.35	5.68	5.42	5.16	4.89	4.68	4.42	4.25	3.93
64	3.93	3.79	3.25	3.12	2.66	2.51	2.07	1.89	1.71	1.51	4.84	4.57	4.31	4.05	3.84	3.57	3.40	3.08
65	3.09	2.94	2.41	2.28	1.81	1.67	1.23	1.05	0.87	0.66	3.99	3.73	3.47	3.20	2.99	2.73	2.56	2.24

SCEN	37	39	41	43	45	47	49	51	53	55	57	59	61	62	63	64	65
1	-0.98	-1.34	-0.34	-0.40	-1.15	-1.20	-1.85	-1.92	-2.27	-2.34	-2.73	-2.80	-4.79	-4.84	-4.78	-3.93	-3.09
3	-0.83	-1.20	-0.20	-0.26	-1.00	-1.06	-1.70	-1.77	-2.13	-2.20	-2.59	-2.65	-4.65	-4.70	-4.63	-3.79	-2.94
5	-0.30	-0.67	0.33	0.27	-0.47	-0.53	-1.17	-1.24	-1.60	-1.67	-2.05	-2.12	-4.12	-4.16	-4.10	-3.25	-2.41
7	-0.17	-0.53	0.47	0.40	-0.34	-0.39	-1.04	-1.11	-1.46	-1.53	-1.92	-1.99	-3.99	-4.03	-3.97	-3.12	-2.28
9	0.30	-0.07	0.93	0.87	0.13	0.07	-0.57	-0.64	-1.00	-1.07	-1.45	-1.52	-3.52	-3.57	-3.50	-2.66	-1.81
11	0.44	0.08	1.08	1.01	0.27	0.21	-0.43	-0.50	-0.85	-0.92	-1.31	-1.38	-3.38	-3.42	-3.36	-2.51	-1.67
13	0.88	0.52	1.52	1.45	0.71	0.65	0.01	-0.06	-0.41	-0.48	-0.87	-0.94	-2.94	-2.98	-2.92	-2.07	-1.23
15	1.06	0.70	1.70	1.63	0.89	0.83	0.19	0.12	-0.24	-0.30	-0.69	-0.76	-2.76	-2.80	-2.74	-1.89	-1.05
17	1.24	0.88	1.88	1.81	1.07	1.02	0.37	0.30	-0.05	-0.12	-0.51	-0.58	-2.57	-2.62	-2.56	-1.71	-0.87
19	1.45	1.08	2.08	2.02	1.28	1.22	0.58	0.51	0.15	0.08	-0.31	-0.37	-2.37	-2.42	-2.35	-1.51	-0.66
21	-1.88	-2.25	-1.25	-1.31	-2.05	-2.11	-2.75	-2.82	-3.18	-3.25	-3.64	-3.70	-5.70	-5.75	-5.68	-4.84	-3.99
23	-1.62	-1.98	-0.98	-1.05	-1.79	-1.84	-2.49	-2.56	-2.91	-2.98	-3.37	-3.44	-5.43	-5.48	-5.42	-4.57	-3.73
25	-1.36	-1.72	-0.72	-0.78	-1.52	-1.58	-2.23	-2.30	-2.65	-2.72	-3.11	-3.18	-5.17	-5.22	-5.16	-4.31	-3.47
27	-1.09	-1.46	-0.46	-0.52	-1.26	-1.32	-1.96	-2.03	-2.39	-2.46	-2.85	-2.91	-4.91	-4.96	-4.89	-4.05	-3.20
29	-0.88	-1.25	-0.25	-0.31	-1.05	-1.11	-1.76	-1.82	-2.18	-2.25	-2.64	-2.71	-4.70	-4.75	-4.68	-3.84	-2.99
31	-0.61	-0.98	0.02	-0.04	-0.78	-0.84	-1.49	-1.55	-1.91	-1.98	-2.37	-2.44	-4.43	-4.48	-4.42	-3.57	-2.73
33	-0.44	-0.81	0.19	0.13	-0.61	-0.67	-1.32	-1.38	-1.74	-1.81	-2.20	-2.27	-4.26	-4.31	-4.25	-3.40	-2.56
35	-0.13	-0.49	0.51	0.44	-0.30	-0.36	-1.00	-1.07	-1.42	-1.49	-1.88	-1.95	-3.95	-3.99	-3.93	-3.08	-2.24
37		-0.36	0.64	0.57	-0.17	-0.23	-0.87	-0.94	-1.30	-1.36	-1.75	-1.82	-3.82	-3.86	-3.80	-2.95	-2.11
39	0.36		1.00	0.94	0.19	0.14	-0.51	-0.58	-0.93	-1.00	-1.39	-1.46	-3.45	-3.50	-3.44	-2.59	-1.75
41	-0.64	-1.00		-0.06	-0.80	-0.86	-1.51	-1.58	-1.93	-2.00	-2.39	-2.46	-4.45	-4.50	-4.44	-3.59	-2.75
43	-0.57	-0.94	0.06		-0.74	-0.80	-1.44	-1.51	-1.87	-1.94	-2.32	-2.39	-4.39	-4.43	-4.37	-3.52	-2.68
45	0.17	-0.19	0.80	0.74		-0.06	-0.70	-0.77	-1.13	-1.19	-1.58	-1.65	-3.65	-3.69	-3.63	-2.78	-1.94
47	0.23	-0.14	0.86	0.80	0.06		-0.64	-0.71	-1.07	-1.14	-1.53	-1.59	-3.59	-3.64	-3.57	-2.73	-1.88
49	0.87	0.51	1.51	1.44	0.70	0.64		-0.07	-0.42	-0.49	-0.88	-0.95	-2.95	-2.99	-2.93	-2.08	-1.24
51	0.94	0.58	1.58	1.51	0.77	0.71	0.07		-0.36	-0.42	-0.81	-0.88	-2.88	-2.92	-2.86	-2.01	-1.17
53	1.30	0.93	1.93	1.87	1.13	1.07	0.42	0.36		-0.07	-0.46	-0.53	-2.52	-2.57	-2.51	-1.66	-0.82
55	1.36	1.00	2.00	1.94	1.19	1.14	0.49	0.42	0.07		-0.39	-0.46	-2.45	-2.50	-2.44	-1.59	-0.75
57	1.75	1.39	2.39	2.32	1.58	1.53	0.88	0.81	0.46	0.39		-0.07	-2.07	-2.11	-2.05	-1.20	-0.36
59	1.82	1.46	2.46	2.39	1.65	1.59	0.95	0.88	0.53	0.46	0.07		-2.00	-2.04	-1.98	-1.13	-0.29
61	3.82	3.45	4.45	4.39	3.65	3.59	2.95	2.88	2.52	2.45	2.07	2.00		-0.04	0.02	0.86	1.71
62	3.86	3.50	4.50	4.43	3.69	3.64	2.99	2.92	2.57	2.50	2.11	2.04	0.04		0.06	0.91	1.75
63	3.80	3.44	4.44	4.37	3.63	3.57	2.93	2.86	2.51	2.44	2.05	1.98	-0.02	-0.06		0.85	1.69
64	2.95	2.59	3.59	3.52	2.78	2.73	2.08	2.01	1.66	1.59	1.20	1.13	-0.86	-0.91	-0.85		0.84
65	2.11	1.75	2.75	2.68	1.94	1.88	1.24	1.17	0.82	0.75	0.36	0.29	-1.71	-1.75	-1.69	-0.84	

Table D-10 Monthly TP Load Reduction Matrix

SCEN	S1	S3	S5	S7	S9	S11	S13	S15	S17	S19	S21	S23	S25	S27	S29	S31	S33	S35
S1		-0.15	0.00	-0.19	0.05	-0.19	0.02	-0.26	0.02	-0.30	0.07	-0.07	0.07	-0.13	0.13	-0.15	0.11	-0.24
S3	0.15		0.15	-0.04	0.20	-0.04	0.17	-0.11	0.17	-0.15	0.22	0.08	0.22	0.02	0.28	0.00	0.26	-0.09
S5	0.00	-0.15		-0.19	0.04	-0.19	0.02	-0.26	0.02	-0.30	0.06	-0.07	0.07	-0.13	0.13	-0.15	0.10	-0.24
S7	0.19	0.04	0.19		0.23	0.00	0.21	-0.07	0.21	-0.11	0.25	0.12	0.26	0.06	0.32	0.04	0.30	-0.05
S9	-0.05	-0.20	-0.04	-0.23		-0.23	-0.03	-0.30	-0.02	-0.35	0.02	-0.12	0.02	-0.17	0.09	-0.19	0.06	-0.28
S11	0.19	0.04	0.19	0.00	0.23		0.21	-0.07	0.21	-0.11	0.25	0.12	0.26	0.06	0.32	0.04	0.30	-0.05
S13	-0.02	-0.17	-0.02	-0.21	0.03	-0.21		-0.28	0.00	-0.32	0.04	-0.09	0.05	-0.15	0.11	-0.17	0.09	-0.26
S15	0.26	0.11	0.26	0.07	0.30	0.07	0.28		0.28	-0.04	0.32	0.18	0.33	0.13	0.39	0.11	0.36	0.02
S17	-0.02	-0.17	-0.02	-0.21	0.02	-0.21	0.00	-0.28		-0.32	0.04	-0.10	0.05	-0.15	0.11	-0.17	0.08	-0.26
S19	0.30	0.15	0.30	0.11	0.35	0.11	0.32	0.04	0.32		0.37	0.23	0.37	0.17	0.43	0.15	0.41	0.06
S21	-0.07	-0.22	-0.06	-0.25	-0.02	-0.25	-0.04	-0.32	-0.04	-0.37		-0.14	0.01	-0.19	0.07	-0.21	0.04	-0.30
S23	0.07	-0.08	0.07	-0.12	0.12	-0.12	0.09	-0.18	0.10	-0.23	0.14		0.14	-0.06	0.20	-0.07	0.18	-0.16
S25	-0.07	-0.22	-0.07	-0.26	-0.02	-0.26	-0.05	-0.33	-0.05	-0.37	-0.01	-0.14		-0.20	0.06	-0.22	0.04	-0.31
S27	0.13	-0.02	0.13	-0.06	0.17	-0.06	0.15	-0.13	0.15	-0.17	0.19	0.06	0.20		0.26	-0.02	0.24	-0.11
S29	-0.13	-0.28	-0.13	-0.32	-0.09	-0.32	-0.11	-0.39	-0.11	-0.43	-0.07	-0.20	-0.06	-0.26		-0.28	-0.03	-0.37
S31	0.15	0.00	0.15	-0.04	0.19	-0.04	0.17	-0.11	0.17	-0.15	0.21	0.07	0.22	0.02	0.28		0.25	-0.09
S33	-0.11	-0.26	-0.10	-0.30	-0.06	-0.30	-0.09	-0.36	-0.08	-0.41	-0.04	-0.18	-0.04	-0.24	0.03	-0.25		-0.34
S35	0.24	0.09	0.24	0.05	0.28	0.05	0.26	-0.02	0.26	-0.06	0.30	0.16	0.31	0.11	0.37	0.09	0.34	
S37	-0.15	-0.30	-0.15	-0.34	-0.10	-0.34	-0.13	-0.40	-0.12	-0.45	-0.08	-0.22	-0.08	-0.28	-0.02	-0.29	-0.04	-0.38
S39	0.30	0.15	0.31	0.12	0.35	0.12	0.33	0.05	0.33	0.01	0.37	0.23	0.38	0.18	0.44	0.16	0.41	0.07
S41	0.05	-0.10	0.05	-0.14	0.10	-0.14	0.07	-0.21	0.07	-0.25	0.12	-0.02	0.12	-0.08	0.18	-0.10	0.16	-0.19
S43	0.18	0.03	0.18	-0.01	0.23	-0.01	0.20	-0.08	0.20	-0.12	0.25	0.11	0.25	0.05	0.31	0.04	0.29	-0.05
S45	0.11	-0.04	0.11	-0.08	0.16	-0.08	0.13	-0.15	0.13	-0.19	0.17	0.04	0.18	-0.02	0.24	-0.04	0.22	-0.13
S47	0.24	0.09	0.24	0.05	0.29	0.05	0.26	-0.01	0.27	-0.06	0.31	0.17	0.31	0.11	0.37	0.10	0.35	0.01
S49	0.14	-0.01	0.14	-0.05	0.19	-0.05	0.16	-0.11	0.17	-0.16	0.21	0.07	0.21	0.01	0.27	0.00	0.25	-0.09
S51	0.28	0.13	0.28	0.09	0.32	0.09	0.30	0.02	0.30	-0.02	0.34	0.20	0.35	0.15	0.41	0.13	0.38	0.04
S53	0.17	0.02	0.17	-0.02	0.22	-0.02	0.19	-0.09	0.19	-0.13	0.24	0.10	0.24	0.04	0.30	0.02	0.28	-0.07
S55	0.31	0.16	0.32	0.13	0.36	0.13	0.34	0.06	0.34	0.02	0.38	0.24	0.39	0.19	0.45	0.17	0.42	0.08
S57	0.16	0.01	0.16	-0.03	0.21	-0.03	0.18	-0.10	0.18	-0.14	0.23	0.09	0.23	0.03	0.29	0.02	0.27	-0.07
S59	0.33	0.18	0.33	0.14	0.37	0.14	0.35	0.07	0.35	0.03	0.39	0.26	0.40	0.20	0.46	0.18	0.43	0.09
S61	0.98	0.83	0.98	0.79	1.02	0.79	1.00	0.72	1.00	0.68	1.04	0.90	1.05	0.85	1.11	0.83	1.08	0.74
S62	0.97	0.82	0.98	0.79	1.02	0.79	0.99	0.72	1.00	0.67	1.04	0.90	1.04	0.85	1.11	0.83	1.08	0.74
S63	0.95	0.80	0.96	0.77	1.00	0.77	0.97	0.70	0.98	0.65	1.02	0.88	1.02	0.83	1.09	0.81	1.06	0.72
S64	0.84	0.69	0.84	0.65	0.88	0.65	0.86	0.58	0.86	0.54	0.90	0.77	0.91	0.71	0.97	0.69	0.94	0.60
S65	0.35	0.20	0.35	0.16	0.39	0.16	0.37	0.09	0.37	0.05	0.41	0.28	0.42	0.22	0.48	0.20	0.45	0.11

SCEN	S37	S39	S41	S43	S45	S47	S49	S51	S53	S55	S57	S59	S61	S62	S63	S64	S65
S1	0.15	-0.30	-0.05	-0.18	-0.11	-0.24	-0.14	-0.28	-0.17	-0.31	-0.16	-0.33	-0.98	-0.97	-0.95	-0.84	-0.35
S3	0.30	-0.15	0.10	-0.03	0.04	-0.09	0.01	-0.13	-0.02	-0.16	-0.01	-0.18	-0.83	-0.82	-0.80	-0.69	-0.20
S5	0.15	-0.31	-0.05	-0.18	-0.11	-0.24	-0.14	-0.28	-0.17	-0.32	-0.16	-0.33	-0.98	-0.98	-0.96	-0.84	-0.35
S7	0.34	-0.12	0.14	0.01	0.08	-0.05	0.05	-0.09	0.02	-0.13	0.03	-0.14	-0.79	-0.79	-0.77	-0.65	-0.16
S9	0.10	-0.35	-0.10	-0.23	-0.16	-0.29	-0.19	-0.32	-0.22	-0.36	-0.21	-0.37	-1.02	-1.02	-1.00	-0.88	-0.39
S11	0.34	-0.12	0.14	0.01	0.08	-0.05	0.05	-0.09	0.02	-0.13	0.03	-0.14	-0.79	-0.79	-0.77	-0.65	-0.16
S13	0.13	-0.33	-0.07	-0.20	-0.13	-0.26	-0.16	-0.30	-0.19	-0.34	-0.18	-0.35	-1.00	-0.99	-0.97	-0.86	-0.37
S15	0.40	-0.05	0.21	0.08	0.15	0.01	0.11	-0.02	0.09	-0.06	0.10	-0.07	-0.72	-0.72	-0.70	-0.58	-0.09
S17	0.12	-0.33	-0.07	-0.20	-0.13	-0.27	-0.17	-0.30	-0.19	-0.34	-0.18	-0.35	-1.00	-1.00	-0.98	-0.86	-0.37
S19	0.45	-0.01	0.25	0.12	0.19	0.06	0.16	0.02	0.13	-0.02	0.14	-0.03	-0.68	-0.67	-0.65	-0.54	-0.05
S21	0.08	-0.37	-0.12	-0.25	-0.17	-0.31	-0.21	-0.34	-0.24	-0.38	-0.23	-0.39	-1.04	-1.04	-1.02	-0.90	-0.41
S23	0.22	-0.23	0.02	-0.11	-0.04	-0.17	-0.07	-0.20	-0.10	-0.24	-0.09	-0.26	-0.90	-0.90	-0.88	-0.77	-0.28
S25	0.08	-0.38	-0.12	-0.25	-0.18	-0.31	-0.21	-0.35	-0.24	-0.39	-0.23	-0.40	-1.05	-1.04	-1.02	-0.91	-0.42
S27	0.28	-0.18	0.08	-0.05	0.02	-0.11	-0.01	-0.15	-0.04	-0.19	-0.03	-0.20	-0.85	-0.85	-0.83	-0.71	-0.22
S29	0.02	-0.44	-0.18	-0.31	-0.24	-0.37	-0.27	-0.41	-0.30	-0.45	-0.29	-0.46	-1.11	-1.11	-1.09	-0.97	-0.48
S31	0.29	-0.16	0.10	-0.04	0.04	-0.10	0.00	-0.13	-0.02	-0.17	-0.02	-0.18	-0.83	-0.83	-0.81	-0.69	-0.20
S33	0.04	-0.41	-0.16	-0.29	-0.22	-0.35	-0.25	-0.38	-0.28	-0.42	-0.27	-0.43	-1.08	-1.08	-1.06	-0.94	-0.45
S35	0.38	-0.07	0.19	0.05	0.13	-0.01	0.09	-0.04	0.07	-0.08	0.07	-0.09	-0.74	-0.74	-0.72	-0.60	-0.11
S37		-0.45	-0.20	-0.33	-0.26	-0.39	-0.29	-0.42	-0.32	-0.46	-0.31	-0.48	-1.12	-1.12	-1.10	-0.99	-0.50
S39	0.45		0.25	0.12	0.20	0.06	0.16	0.03	0.14	-0.01	0.14	-0.02	-0.67	-0.67	-0.65	-0.53	-0.04
S41	0.20	-0.25		-0.13	-0.06	-0.19	-0.09	-0.23	-0.12	-0.26	-0.11	-0.28	-0.93	-0.92	-0.90	-0.79	-0.30
S43	0.33	-0.12	0.13		0.07	-0.06	0.04	-0.09	0.01	-0.13	0.02	-0.15	-0.79	-0.79	-0.77	-0.66	-0.17
S45	0.26	-0.20	0.06	-0.07		-0.13	-0.03	-0.17	-0.06	-0.21	-0.05	-0.22	-0.87	-0.86	-0.84	-0.73	-0.24
S47	0.39	-0.06	0.19	0.06	0.13		0.10	-0.03	0.07	-0.07	0.08	-0.09	-0.73	-0.73	-0.71	-0.60	-0.11
S49	0.29	-0.16	0.09	-0.04	0.03	-0.10		-0.13	-0.03	-0.17	-0.02	-0.19	-0.83	-0.83	-0.81	-0.69	-0.20
S51	0.42	-0.03	0.23	0.09	0.17	0.03	0.13		0.11	-0.04	0.11	-0.05	-0.70	-0.70	-0.68	-0.56	-0.07
S53	0.32	-0.14	0.12	-0.01	0.06	-0.07	0.03	-0.11		-0.14	0.01	-0.16	-0.81	-0.80	-0.78	-0.67	-0.18
S55	0.46	0.01	0.26	0.13	0.21	0.07	0.17	0.04	0.14		0.15	-0.01	-0.66	-0.66	-0.64	-0.52	-0.03
S57	0.31	-0.14	0.11	-0.02	0.05	-0.08	0.02	-0.11	-0.01	-0.15		-0.17	-0.81	-0.81	-0.79	-0.68	-0.19
S59	0.48	0.02	0.28	0.15	0.22	0.09	0.19	0.05	0.16	0.01	0.17		-0.65	-0.65	-0.63	-0.51	-0.02
S61	1.12	0.67	0.93	0.79	0.87	0.73	0.83	0.70	0.81	0.66	0.81	0.65		0.00	0.02	0.14	0.63
S62	1.12	0.67	0.92	0.79	0.86	0.73	0.83	0.70	0.80	0.66	0.81	0.65	0.00		0.02	0.14	0.63
S63	1.10	0.65	0.90	0.77	0.84	0.71	0.81	0.68	0.78	0.64	0.79	0.63	-0.02	-0.02		0.12	0.61
S64	0.99	0.53	0.79	0.66	0.73	0.60	0.69	0.56	0.67	0.52	0.68	0.51	-0.14	-0.14	-0.12		0.49
S65	0.50	0.04	0.30	0.17	0.24	0.11	0.20	0.07	0.18	0.03	0.19	0.02	-0.63	-0.63	-0.61	-0.49	

D.3 Paired and Unpaired Analysis Comparison

The Table D-11 is the excerpt comparison of TN load reduction R_U difference for the first 60 alternative scenarios at 95% confidence level between paired analyses (PD) to unpaired (UP) analyses. Similarly, The Table D-12 tabulates TN load reduction TR difference for the first 60 alternative scenarios. As described previously, in these matrices, the first (top) row presents current scenarios and the first column contains potential alternative scenarios. Both current scenario columns and alternative scenario rows ranged from S1 to S225 to represent scenarios #1 to #225 as described in Table A-20. The cell value in each column and row intersection is the difference of potential nutrient load reduction R_U (or TR) between PD and UP analyses.

In the Table D-11, different color in the cell represents the different magnitude of the difference in R_U. For example, the black block represents a positive R_U difference of PD - UP. Similarly, greenish block represents the R_U difference is less than 0 but larger than -0.1 while lime colored block is the value less than -0.1 but larger than -0.5. For an extremely case, the blue block means the difference is between -0.5 to -1. In Table D-12, the black block represents the PD-UP difference of TR is larger than 0.01. Similarly, greenish block represents the difference is less than 0 but larger than -0.01 while lime colored block is the value less than -0.1 but larger than -0.5. For some extremely cases, the blue block means the TR difference is between -0.5 to -1.0 and red block means the value less than -1.

Table D-11 TN Load Reduction Uncertainty Ratio Difference between PD-UP Analyses at 95% CL

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	-0.444	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	0	-0.444	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	-0.070	0	-0.088	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	-0.070	0	-0.088	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S7	-0.057	0	-0.070	0	-0.378	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S8	0	-0.057	0	-0.070	0	-0.378	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S9	-0.028	0	-0.032	0	-0.070	0	-0.089	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	0	-0.028	0	-0.032	0	-0.070	0	-0.089	0	0	0	0	0	0	0	0	0	0	0	0
S11	-0.025	0	-0.028	0	-0.055	0	-0.067	0	-0.300	0	0	0	0	0	0	0	0	0	0	0
S12	0	-0.025	0	-0.028	0	-0.055	0	-0.067	0	-0.300	0	0	0	0	0	0	0	0	0	0
S13	-0.015	0	-0.017	0	-0.026	0	-0.030	0	-0.052	0	-0.069	0	0	0	0	0	0	0	0	0
S14	0	-0.015	0	-0.017	0	-0.026	0	-0.030	0	-0.052	0	-0.069	0	0	0	0	0	0	0	0
S15	-0.013	0	-0.015	0	-0.021	0	-0.024	0	-0.037	0	-0.047	0	-0.199	0	0	0	0	0	0	0
S16	0	-0.013	0	-0.015	0	-0.021	0	-0.024	0	-0.037	0	-0.047	0	-0.199	0	0	0	0	0	0
S17	0	0	-0.011	0	-0.016	0	-0.018	0	-0.028	0	-0.033	0	-0.069	0	-0.125	0	0	0	0	0
S18	0	0	0	-0.011	0	-0.016	0	-0.018	0	-0.028	0	-0.033	0	-0.069	0	-0.125	0	0	0	0
S19	0	0	0	0	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.045	0	-0.064	0	-0.129	0	0	0
S20	0	0	0	0	0	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.045	0	-0.064	0	-0.129	0	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	-0.469	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	-0.469	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S31	-0.116	0	-0.193	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	0	-0.116	0	-0.193	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S33	-0.071	0	-0.095	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	0	-0.071	0	-0.095	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S35	-0.042	0	-0.049	0	-0.225	0	-0.576	0	0	0	0	0	0	0	0	0	0	0	0	0
S36	0	-0.042	0	-0.049	0	-0.225	0	-0.576	0	0	0	0	0	0	0	0	0	0	0	0
S37	-0.035	0	-0.041	0	-0.117	0	-0.211	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	0	-0.035	0	-0.041	0	-0.117	0	-0.211	0	0	0	0	0	0	0	0	0	0	0	0
S39	-0.024	0	-0.027	0	-0.051	0	-0.065	0	-0.496	0	0	0	0	0	0	0	0	0	0	0
S40	0	-0.024	0	-0.027	0	-0.051	0	-0.065	0	-0.496	0	0	0	0	0	0	0	0	0	0
S41	-0.163	0	-0.282	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	0	-0.163	0	-0.282	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S43	-0.135	0	-0.210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S44	0	-0.135	0	-0.210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S45	-0.036	0	-0.041	0	-0.088	0	-0.125	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	0	-0.036	0	-0.041	0	-0.088	0	-0.125	0	0	0	0	0	0	0	0	0	0	0	0
S47	-0.034	0	-0.038	0	-0.078	0	-0.106	0	0	0	0	0	0	0	0	0	0	0	0	0
S48	0	-0.034	0	-0.038	0	-0.078	0	-0.106	0	0	0	0	0	0	0	0	0	0	0	0
S49	-0.016	0	-0.018	0	-0.028	0	-0.032	0	-0.057	0	-0.077	0	0	0	0	0	0	0	0	0
S50	0	-0.016	0	-0.018	0	-0.028	0	-0.032	0	-0.057	0	-0.077	0	0	0	0	0	0	0	0
S51	-0.015	0	-0.017	0	-0.026	0	-0.030	0	-0.050	0	-0.066	0	-0.529	0	0	0	0	0	0	0
S52	0	-0.015	0	-0.017	0	-0.026	0	-0.030	0	-0.050	0	-0.066	0	-0.529	0	0	0	0	0	0
S53	-0.010	0	-0.011	0	-0.016	0	-0.018	0	-0.027	0	-0.031	0	-0.052	0	-0.086	0	-0.457	0	0	0
S54	0	-0.010	0	-0.011	0	-0.016	0	-0.018	0	-0.027	0	-0.031	0	-0.052	0	-0.086	0	-0.457	0	0
S55	0	0	-0.010	0	-0.015	0	-0.016	0	-0.025	0	-0.029	0	-0.044	0	-0.065	0	-0.192	0	0	0
S56	0	0	0	-0.010	0	-0.015	0	-0.016	0	-0.025	0	-0.029	0	-0.044	0	-0.065	0	-0.192	0	0
S57	0	0	0	0	0	0	-0.010	0	-0.014	0	-0.015	0	-0.025	0	-0.030	0	-0.041	0	-0.070	0
S58	0	0	0	0	0	0	0	-0.010	0	-0.014	0	-0.015	0	-0.025	0	-0.030	0	-0.041	0	-0.070
S59	0	0	0	0	0	0	0	0	-0.013	0	-0.014	0	-0.022	0	-0.027	0	-0.035	0	-0.056	0
S60	0	0	0	0	0	0	0	0	0	-0.013	0	-0.014	0	-0.022	0	-0.027	0	-0.035	0	-0.056

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	-0.063	0	-0.034	0	-0.133	0	-0.423	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	-0.063	0	-0.034	0	-0.133	0	-0.423	0	0	0	0	0	0	0	0	0	0	0	0
S3	-0.053	0	-0.031	0	-0.096	0	-0.190	0	-0.550	0	0	0	0	0	0	0	0	0	0	0
S4	0	-0.053	0	-0.031	0	-0.096	0	-0.190	0	-0.549	0	0	0	0	0	0	0	0	0	0
S5	-0.028	0	-0.019	0	-0.042	0	-0.056	0	-0.072	0	-0.132	0	-0.279	0	0	0	0	0	0	0
S6	0	-0.028	0	-0.019	0	-0.042	0	-0.056	0	-0.072	0	-0.132	0	-0.279	0	0	0	0	0	0
S7	-0.025	0	-0.018	0	-0.037	0	-0.048	0	-0.059	0	-0.093	0	-0.140	0	0	0	0	0	0	0
S8	0	-0.025	0	-0.018	0	-0.037	0	-0.048	0	-0.059	0	-0.093	0	-0.140	0	0	0	0	0	0
S9	-0.016	0	-0.012	0	-0.022	0	-0.027	0	-0.031	0	-0.040	0	-0.051	0	-0.088	0	-0.109	0	0	0
S10	0	-0.016	0	-0.012	0	-0.022	0	-0.027	0	-0.031	0	-0.040	0	-0.051	0	-0.088	0	-0.109	0	0
S11	-0.015	0	-0.011	0	-0.020	0	-0.024	0	-0.028	0	-0.035	0	-0.041	0	-0.064	0	-0.074	0	-0.432	0
S12	0	-0.015	0	-0.011	0	-0.020	0	-0.024	0	-0.028	0	-0.035	0	-0.041	0	-0.064	0	-0.074	0	-0.432
S13	-0.011	0	0	0	-0.014	0	-0.016	0	-0.018	0	-0.021	0	-0.020	0	-0.025	0	-0.035	0	-0.060	0
S14	0	-0.011	0	0	0	-0.014	0	-0.016	0	-0.018	0	-0.021	0	-0.020	0	-0.025	0	-0.035	0	-0.060
S15	0	0	0	0	-0.013	0	-0.015	0	-0.016	0	-0.019	0	-0.016	0	-0.020	0	-0.028	0	-0.044	0
S16	0	0	0	0	0	-0.013	0	-0.015	0	-0.016	0	-0.019	0	-0.016	0	-0.020	0	-0.028	0	-0.044
S17	0	0	0	0	0	0	0	0	-0.011	0	-0.012	0	-0.014	0	-0.017	0	-0.019	0	-0.027	0
S18	0	0	0	0	0	0	0	0	0	-0.011	0	-0.012	0	-0.014	0	-0.017	0	-0.019	0	-0.027
S19	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.012	0	-0.014	0	-0.016	0	-0.022	0
S20	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.012	0	-0.014	0	-0.016	0	-0.022
S21	0	0	-0.108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	0	0	0	-0.108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S25	-0.126	0	-0.051	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	0	-0.126	0	-0.051	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S27	-0.080	0	-0.041	0	-0.259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	0	-0.080	0	-0.041	0	-0.259	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	-0.055	0	-0.031	0	-0.131	0	-0.291	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	-0.055	0	-0.031	0	-0.131	0	-0.291	0	0	0	0	0	0	0	0	0	0	0	0
S31	-0.041	0	-0.026	0	-0.079	0	-0.124	0	-0.228	0	0	0	0	0	0	0	0	0	0	0
S32	0	-0.041	0	-0.026	0	-0.079	0	-0.124	0	-0.228	0	0	0	0	0	0	0	0	0	0
S33	-0.029	0	-0.019	0	-0.048	0	-0.067	0	-0.101	0	-0.253	0	0	0	0	0	0	0	0	0
S34	0	-0.029	0	-0.019	0	-0.048	0	-0.067	0	-0.101	0	-0.253	0	0	0	0	0	0	0	0
S35	-0.022	0	-0.015	0	-0.034	0	-0.043	0	-0.055	0	-0.085	0	-0.160	0	0	0	0	0	0	0
S36	0	-0.022	0	-0.015	0	-0.034	0	-0.043	0	-0.055	0	-0.085	0	-0.160	0	0	0	0	0	0
S37	-0.021	0	-0.015	0	-0.032	0	-0.039	0	-0.050	0	-0.069	0	-0.086	0	-0.274	0	0	0	0	0
S38	0	-0.021	0	-0.015	0	-0.032	0	-0.039	0	-0.050	0	-0.069	0	-0.086	0	-0.274	0	0	0	0
S39	-0.016	0	-0.012	0	-0.023	0	-0.028	0	-0.033	0	-0.042	0	-0.045	0	-0.071	0	-0.118	0	0	0
S40	0	-0.016	0	-0.012	0	-0.023	0	-0.028	0	-0.033	0	-0.042	0	-0.045	0	-0.071	0	-0.118	0	0
S41	-0.042	0	-0.026	0	-0.064	0	-0.100	0	-0.161	0	0	0	0	0	0	0	0	0	0	0
S42	0	-0.042	0	-0.026	0	-0.064	0	-0.100	0	-0.161	0	0	0	0	0	0	0	0	0	0
S43	-0.039	0	-0.025	0	-0.059	0	-0.087	0	-0.127	0	-0.430	0	0	0	0	0	0	0	0	0
S44	0	-0.039	0	-0.025	0	-0.059	0	-0.087	0	-0.127	0	-0.430	0	0	0	0	0	0	0	0
S45	-0.019	0	-0.014	0	-0.026	0	-0.032	0	-0.036	0	-0.048	0	-0.053	0	-0.105	0	-0.198	0	0	0
S46	0	-0.019	0	-0.014	0	-0.026	0	-0.032	0	-0.036	0	-0.048	0	-0.053	0	-0.105	0	-0.198	0	0
S47	-0.018	0	-0.013	0	-0.025	0	-0.030	0	-0.034	0	-0.044	0	-0.048	0	-0.088	0	-0.147	0	0	0
S48	0	-0.018	0	-0.013	0	-0.025	0	-0.030	0	-0.034	0	-0.044	0	-0.048	0	-0.088	0	-0.147	0	0
S49	-0.011	0	0	0	-0.014	0	-0.016	0	-0.018	0	-0.022	0	-0.022	0	-0.028	0	-0.035	0	-0.060	0
S50	0	-0.011	0	0	0	-0.014	0	-0.016	0	-0.018	0	-0.022	0	-0.022	0	-0.028	0	-0.035	0	-0.060
S51	-0.010	0	0	0	-0.014	0	-0.016	0	-0.017	0	-0.020	0	-0.020	0	-0.026	0	-0.032	0	-0.052	0
S52	0	-0.010	0	0	0	-0.014	0	-0.016	0	-0.017	0	-0.020	0	-0.020	0	-0.026	0	-0.032	0	-0.052
S53	0	0	0	0	0	0	0	0	-0.010	0	-0.012	0	-0.014	0	-0.018	0	-0.017	0	-0.024	0
S54	0	0	0	0	0	0	0	0	0	-0.010	0	-0.012	0	-0.014	0	-0.018	0	-0.017	0	-0.024
S55	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.014	0	-0.017	0	-0.016	0	-0.022	0
S56	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.014	0	-0.017	0	-0.016	0	-0.022
S57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.014	0
S58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.014
S59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.010	0	-0.013	0
S60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.010	0	-0.013

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	-0.127	0	-0.157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	-0.127	0	-0.157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S7	-0.090	0	-0.104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S8	0	-0.090	0	-0.104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S9	-0.035	0	-0.037	0	-0.277	0	-0.502	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	0	-0.035	0	-0.037	0	-0.277	0	-0.502	0	0	0	0	0	0	0	0	0	0	0	0
S11	-0.030	0	-0.032	0	-0.132	0	-0.167	0	0	0	0	0	0	0	0	0	0	0	0	0
S12	0	-0.030	0	-0.032	0	-0.132	0	-0.167	0	0	0	0	0	0	0	0	0	0	0	0
S13	-0.019	0	-0.019	0	-0.045	0	-0.049	0	-0.038	0	0	0	0	0	0	0	0	0	0	0
S14	0	-0.019	0	-0.019	0	-0.045	0	-0.049	0	-0.039	0	0	0	0	0	0	0	0	0	0
S15	-0.016	0	-0.017	0	-0.034	0	-0.037	0	-0.163	0	-0.254	0	0	0	0	0	0	0	0	0
S16	0	-0.016	0	-0.017	0	-0.034	0	-0.037	0	-0.163	0	-0.254	0	0	0	0	0	0	0	0
S17	-0.011	0	-0.011	0	-0.022	0	-0.023	0	-0.066	0	-0.081	0	0	0	0	0	0	0	0	0
S18	0	-0.011	0	-0.011	0	-0.022	0	-0.023	0	-0.066	0	-0.081	0	0	0	0	0	0	0	0
S19	0	0	0	0	-0.018	0	-0.019	0	-0.043	0	-0.049	0	-0.146	0	-0.266	0	0	0	0	0
S20	0	0	0	0	0	-0.018	0	-0.019	0	-0.043	0	-0.049	0	-0.146	0	-0.266	0	0	0	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S33	-0.170	0	-0.256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	0	-0.170	0	-0.256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S35	-0.060	0	-0.069	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S36	0	-0.060	0	-0.069	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S37	-0.051	0	-0.057	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	0	-0.051	0	-0.057	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S39	-0.030	0	-0.032	0	-0.167	0	-0.238	0	0	0	0	0	0	0	0	0	0	0	0	0
S40	0	-0.030	0	-0.032	0	-0.167	0	-0.238	0	0	0	0	0	0	0	0	0	0	0	0
S41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S43	-0.964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S44	0	-0.964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S45	-0.052	0	-0.057	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	0	-0.052	0	-0.057	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S47	-0.048	0	-0.052	0	-0.823	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S48	0	-0.048	0	-0.052	0	-0.823	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S49	-0.020	0	-0.021	0	-0.051	0	-0.056	0	0	0	0	0	0	0	0	0	0	0	0	0
S50	0	-0.020	0	-0.021	0	-0.051	0	-0.056	0	0	0	0	0	0	0	0	0	0	0	0
S51	-0.019	0	-0.020	0	-0.046	0	-0.050	0	-0.564	0	0	0	0	0	0	0	0	0	0	0
S52	0	-0.019	0	-0.020	0	-0.046	0	-0.050	0	-0.564	0	0	0	0	0	0	0	0	0	0
S53	-0.011	0	-0.012	0	-0.023	0	-0.024	0	-0.063	0	-0.075	0	0	0	0	0	0	0	0	0
S54	0	-0.011	0	-0.012	0	-0.023	0	-0.024	0	-0.063	0	-0.075	0	0	0	0	0	0	0	0
S55	-0.011	0	-0.011	0	-0.021	0	-0.022	0	-0.053	0	-0.061	0	-0.449	0	0	0	0	0	0	0
S56	0	-0.011	0	-0.011	0	-0.021	0	-0.022	0	-0.053	0	-0.061	0	-0.449	0	0	0	0	0	0
S57	0	0	0	0	-0.013	0	-0.014	0	-0.026	0	-0.028	0	-0.046	0	-0.053	0	0	0	0	0
S58	0	0	0	0	0	-0.013	0	-0.014	0	-0.026	0	-0.028	0	-0.046	0	-0.053	0	0	0	0
S59	0	0	0	0	-0.012	0	-0.013	0	-0.023	0	-0.025	0	-0.039	0	-0.045	0	-0.359	0	0	0
S60	0	0	0	0	0	-0.012	0	-0.013	0	-0.023	0	-0.025	0	-0.039	0	-0.045	0	-0.359	0	0

Table D-12 TN Load Reduction TR Difference between PD-UP Analyses at 95% CL

SCEN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	-0.847	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	0	-0.847	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	-0.078	0	-0.102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	-0.078	0	-0.102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S7	-0.063	0	-0.078	0	-0.644	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S8	0	-0.063	0	-0.078	0	-0.644	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S9	-0.030	0	-0.034	0	-0.077	0	-0.101	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	0	-0.030	0	-0.034	0	-0.077	0	-0.101	0	0	0	0	0	0	0	0	0	0	0	0
S11	-0.026	0	-0.029	0	-0.059	0	-0.074	0	-0.451	0	0	0	0	0	0	0	0	0	0	0
S12	0	-0.026	0	-0.029	0	-0.059	0	-0.074	0	-0.451	0	0	0	0	0	0	0	0	0	0
S13	-0.016	0	-0.018	0	-0.028	0	-0.032	0	-0.057	0	-0.079	0	0	0	0	0	0	0	0	0
S14	0	-0.016	0	-0.018	0	-0.028	0	-0.032	0	-0.057	0	-0.079	0	0	0	0	0	0	0	0
S15	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.040	0	-0.052	0	-0.261	0	0	0	0	0	0	0
S16	0	-0.014	0	-0.015	0	-0.022	0	-0.026	0	-0.040	0	-0.052	0	-0.261	0	0	0	0	0	0
S17	-0.010	0	-0.011	0	-0.017	0	-0.018	0	-0.030	0	-0.035	0	-0.078	0	-0.166	0	0	0	0	0
S18	0	-0.010	0	-0.011	0	-0.017	0	-0.018	0	-0.030	0	-0.035	0	-0.078	0	-0.166	0	0	0	0
S19	0	0	0	0	-0.014	0	-0.016	0	-0.023	0	-0.027	0	-0.048	0	-0.072	0	-0.155	0	0	0
S20	0	0	0	0	0	-0.014	0	-0.016	0	-0.023	0	-0.027	0	-0.048	0	-0.072	0	-0.155	0	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	-2.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	-2.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S31	-0.152	0	-0.308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	0	-0.152	0	-0.308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S33	-0.084	0	-0.121	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	0	-0.084	0	-0.121	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S35	-0.046	0	-0.056	0	-0.360	0	1.737	0	0	0	0	0	0	0	0	0	0	0	0	0
S36	0	-0.046	0	-0.056	0	-0.360	0	1.736	0	0	0	0	0	0	0	0	0	0	0	0
S37	-0.038	0	-0.046	0	-0.150	0	-0.341	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	0	-0.038	0	-0.046	0	-0.150	0	-0.341	0	0	0	0	0	0	0	0	0	0	0	0
S39	-0.025	0	-0.029	0	-0.057	0	-0.074	0	-2.16	0	0	0	0	0	0	0	0	0	0	0
S40	0	-0.025	0	-0.029	0	-0.057	0	-0.074	0	-2.15	0	0	0	0	0	0	0	0	0	0
S41	-0.208	0	-0.442	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	0	-0.208	0	-0.442	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S43	-0.166	0	-0.289	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S44	0	-0.166	0	-0.289	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S45	-0.038	0	-0.044	0	-0.102	0	-0.152	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	0	-0.038	0	-0.044	0	-0.102	0	-0.152	0	0	0	0	0	0	0	0	0	0	0	0
S47	-0.036	0	-0.041	0	-0.088	0	-0.125	0	0	0	0	0	0	0	0	0	0	0	0	0
S48	0	-0.036	0	-0.041	0	-0.088	0	-0.125	0	0	0	0	0	0	0	0	0	0	0	0
S49	-0.017	0	-0.019	0	-0.030	0	-0.034	0	-0.062	0	-0.087	0	0	0	0	0	0	0	0	0
S50	0	-0.017	0	-0.019	0	-0.030	0	-0.034	0	-0.062	0	-0.087	0	0	0	0	0	0	0	0
S51	-0.016	0	-0.018	0	-0.027	0	-0.031	0	-0.055	0	-0.073	0	-1.84	0	0	0	0	0	0	0
S52	0	-0.016	0	-0.018	0	-0.027	0	-0.031	0	-0.055	0	-0.073	0	-1.84	0	0	0	0	0	0
S53	-0.010	0	-0.011	0	-0.017	0	-0.018	0	-0.029	0	-0.033	0	-0.059	0	-0.109	0	-1.44	0	0	0
S54	0	-0.010	0	-0.011	0	-0.017	0	-0.018	0	-0.029	0	-0.033	0	-0.059	0	-0.109	0	-1.44	0	0
S55	0	0	-0.011	0	-0.016	0	-0.017	0	-0.026	0	-0.030	0	-0.049	0	-0.078	0	-0.280	0	0	0
S56	0	0	0	-0.011	0	-0.016	0	-0.017	0	-0.026	0	-0.030	0	-0.049	0	-0.078	0	-0.280	0	0
S57	0	0	0	0	0	0	-0.011	0	-0.014	0	-0.016	0	-0.026	0	-0.032	0	-0.044	0	-0.079	0
S58	0	0	0	0	0	0	0	-0.011	0	-0.014	0	-0.016	0	-0.026	0	-0.032	0	-0.044	0	-0.079
S59	0	0	0	0	0	0	-0.010	0	-0.013	0	-0.015	0	-0.023	0	-0.029	0	-0.038	0	-0.062	0
S60	0	0	0	0	0	0	0	-0.010	0	-0.013	0	-0.015	0	-0.023	0	-0.029	0	-0.038	0	-0.062

SCEN	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
S1	-0.070	0	-0.037	0	-0.173	0	-1.24	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S2	0	-0.070	0	-0.037	0	-0.173	0	-1.24	0	0	0	0	-0.001	0.000	-0.001	0.000	-0.001	0.000	-0.002	0.000
S3	-0.059	0	-0.033	0	-0.115	0	-0.278	0	1.82	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S4	0	-0.059	0	-0.033	0	-0.115	0	-0.278	0	1.82	0	0	-0.001	0.000	-0.001	0.000	-0.001	0.000	-0.001	0.000
S5	-0.030	0	-0.020	0	-0.046	0	-0.063	0	-0.083	0	-0.173	0	-0.508	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S6	0	-0.030	0	-0.020	0	-0.046	0	-0.063	0	-0.083	0	-0.173	-0.001	-0.509	-0.001	0.000	-0.001	0.000	-0.001	0.000
S7	-0.027	0	-0.018	0	-0.040	0	-0.053	0	-0.066	0	-0.111	0	-0.185	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S8	0	-0.027	0	-0.018	0	-0.040	0	-0.053	0	-0.066	0	-0.111	-0.001	-0.185	-0.001	0.000	-0.001	0.000	-0.001	0.000
S9	-0.017	0	-0.012	0	-0.024	0	-0.028	0	-0.033	0	-0.044	0	-0.056	0.000	-0.102	0.000	-0.138	0.000	0.000	0.000
S10	0	-0.017	0	-0.012	0	-0.023	0	-0.028	0	-0.033	0	-0.044	-0.001	-0.056	-0.001	-0.102	-0.001	-0.138	-0.001	0.000
S11	-0.015	0	-0.011	0	-0.021	0	-0.025	0	-0.029	0	-0.038	0	-0.044	0.000	-0.072	0.000	-0.085	0.000	-1.310	0.000
S12	0	-0.015	0	-0.011	0	-0.021	0	-0.025	0	-0.029	0	-0.038	-0.001	-0.044	-0.001	-0.072	-0.001	-0.085	-0.001	-1.312
S13	-0.011	0	0	0	-0.015	0	-0.017	0	-0.019	0	-0.022	0	-0.021	0.000	-0.027	0.000	-0.038	0.000	-0.067	0.000
S14	0	-0.011	0	0	0	-0.015	0	-0.017	0	-0.019	0	-0.022	-0.001	-0.021	-0.001	-0.027	-0.001	-0.038	-0.001	-0.067
S15	-0.010	0	0	0	-0.013	0	-0.015	0	-0.017	0	-0.020	0	-0.017	0.000	-0.021	0.000	-0.030	0.000	-0.048	0.000
S16	0	-0.010	0	0	0	-0.013	0	-0.015	0	-0.017	0	-0.020	-0.001	-0.017	-0.001	-0.021	-0.001	-0.030	-0.001	-0.048
S17	0	0	0	0	0	0	-0.010	0	-0.011	0	-0.013	0	-0.015	0.000	-0.018	0.000	-0.020	0.000	-0.029	0.000
S18	0	0	0	0	0	0	0	-0.010	0	-0.011	0	-0.013	-0.001	-0.015	-0.001	-0.018	-0.001	-0.020	-0.001	-0.029
S19	0	0	0	0	0	0	0	0	-0.010	0	-0.012	0	-0.012	0.000	-0.015	0.000	-0.017	0.000	-0.023	0.000
S20	0	0	0	0	0	0	0	0	0	-0.010	0	-0.012	-0.001	-0.012	-0.001	-0.015	-0.001	-0.017	-0.001	-0.023
S21	0	0	-0.125	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S22	0	0	0	-0.125	0	0	0	0	0	0	0	0	-0.002	0.000	-0.002	0.000	-0.002	0.000	-0.002	0.000
S23	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S24	0	0	0	0	0	0	0	0	0	0	0	0	-0.002	0.000	-0.002	0.000	-0.002	0.000	-0.002	0.000
S25	-0.152	0	-0.055	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S26	0	-0.152	0	-0.055	0	0	0	0	0	0	0	0	-0.001	0.000	-0.002	0.000	-0.002	0.000	-0.002	0.000
S27	-0.090	0	-0.043	0	-0.363	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S28	0	-0.090	0	-0.043	0	-0.363	0	0	0	0	0	0	-0.001	0.000	-0.001	0.000	-0.002	0.000	-0.002	0.000
S29	-0.061	0	-0.033	0	-0.156	0	-0.451	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S30	0	-0.061	0	-0.033	0	-0.156	0	-0.451	0	0	0	0	-0.001	0.000	-0.001	0.000	-0.002	0.000	-0.002	0.000
S31	-0.045	0	-0.027	0	-0.088	0	-0.147	0	-0.306	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S32	0	-0.045	0	-0.027	0	-0.088	0	-0.147	0	-0.306	0	0	-0.001	0.000	-0.001	0.000	-0.001	0.000	-0.002	0.000
S33	-0.031	0	-0.020	0	-0.053	0	-0.077	0	-0.123	0	-0.438	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S34	0	-0.031	0	-0.020	0	-0.053	0	-0.077	0	-0.123	0	-0.438	-0.001	0.000	-0.001	0.000	-0.001	0.000	-0.001	0.000
S35	-0.023	0	-0.016	0	-0.036	0	-0.047	0	-0.062	0	-0.101	0	-0.197	0	0	0	0	0	0	0
S36	0	-0.023	0	-0.016	0	-0.036	0	-0.047	0	-0.062	0	-0.101	0	-0.197	0	0	0	0	0	0
S37	-0.022	0	-0.016	0	-0.034	0	-0.042	0	-0.054	0	-0.078	0	-0.101	0	-0.529	0	0	0	0	0
S38	0	-0.022	0	-0.016	0	-0.034	0	-0.042	0	-0.054	0	-0.078	0	-0.101	0	-0.529	0	0	0	0
S39	-0.017	0	-0.013	0	-0.025	0	-0.029	0	-0.035	0	-0.046	0	-0.049	0	-0.082	0	-0.138	0	0	0
S40	0	-0.017	0	-0.013	0	-0.025	0	-0.029	0	-0.035	0	-0.046	0	-0.049	0	-0.082	0	-0.138	0	0
S41	-0.045	0	-0.028	0	-0.073	0	-0.123	0	-0.244	0	0	0	0	0	0	0	0	0	0	0
S42	0	-0.045	0	-0.028	0	-0.073	0	-0.123	0	-0.244	0	0	0	0	0	0	0	0	0	0
S43	-0.042	0	-0.026	0	-0.066	0	-0.104	0	-0.175	0	2.327	0	0	0	0	0	0	0	0	0
S44	0	-0.042	0	-0.026	0	-0.066	0	-0.104	0	-0.175	0	2.327	0	0	0	0	0	0	0	0
S45	-0.020	0	-0.014	0	-0.028	0	-0.034	0	-0.039	0	-0.053	0	-0.060	0	-0.136	0	-0.309	0	0	0
S46	0	-0.020	0	-0.014	0	-0.028	0	-0.034	0	-0.039	0	-0.053	0	-0.060	0	-0.136	0	-0.309	0	0
S47	-0.019	0	-0.014	0	-0.026	0	-0.032	0	-0.036	0	-0.049	0	-0.054	0	-0.109	0	-0.202	0	0	0
S48	0	-0.019	0	-0.014	0	-0.026	0	-0.032	0	-0.036	0	-0.049	0	-0.054	0	-0.109	0	-0.202	0	0
S49	-0.011	0	0	0	-0.015	0	-0.017	0	-0.019	0	-0.023	0	-0.023	0	-0.030	0	-0.037	0	-0.067	0
S50	0	-0.011	0	0	0	-0.015	0	-0.017	0	-0.019	0	-0.023	0	-0.023	0	-0.030	0	-0.037	0	-0.067
S51	-0.011	0	0	0	-0.014	0	-0.016	0	-0.018	0	-0.021	0	-0.021	0	-0.028	0	-0.034	0	-0.058	0
S52	0	-0.011	0	0	0	-0.014	0	-0.016	0	-0.018	0	-0.021	0	-0.021	0	-0.028	0	-0.034	0	-0.058
S53	0	0	0	0	0	0	0	0	-0.011	0	-0.012	0	-0.015	0	-0.019	0	-0.018	0	-0.026	0
S54	0	0	0	0	0	0	0	0	0	-0.011	0	-0.012	0	-0.015	0	-0.019	0	-0.018	0	-0.026
S55	0	0	0	0	0	0	0	0	-0.010	0	-0.012	0	-0.014	0	-0.017	0	-0.017	0	-0.023	0
S56	0	0	0	0	0	0	0	0	0	-0.010	0	-0.012	0	-0.014	0	-0.017	0	-0.017	0	-0.023
S57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.015	0
S58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.015
S59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.014	0
S60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.011	0	-0.014

SCEN	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	-0.162	0	-0.213	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	-0.162	0	-0.213	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S7	-0.107	0	-0.127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S8	0	-0.107	0	-0.127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S9	-0.038	0	-0.041	0	-0.484	0	-1.8	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	0	-0.038	0	-0.041	0	-0.484	0	-1.8	0	0	0	0	0	0	0	0	0	0	0	0
S11	-0.032	0	-0.034	0	-0.167	0	-0.226	0	0	0	0	0	0	0	0	0	0	0	0	0
S12	0	-0.032	0	-0.034	0	-0.167	0	-0.226	0	0	0	0	0	0	0	0	0	0	0	0
S13	-0.020	0	-0.020	0	-0.049	0	-0.053	0	26.4	0	0	0	0	0	0	0	0	0	0	0
S14	0	-0.020	0	-0.020	0	-0.049	0	-0.053	0	25.53	0	0	0	0	0	0	0	0	0	0
S15	-0.017	0	-0.018	0	-0.037	0	-0.040	0	-0.217	0	-0.410	0	0	0	0	0	0	0	0	0
S16	0	-0.017	0	-0.018	0	-0.037	0	-0.039	0	-0.217	0	-0.409	0	0	0	0	0	0	0	0
S17	-0.011	0	-0.012	0	-0.023	0	-0.025	0	-0.075	0	-0.095	0	0	0	0	0	0	0	0	0
S18	0	-0.011	0	-0.012	0	-0.023	0	-0.025	0	-0.075	0	-0.095	0	0	0	0	0	0	0	0
S19	0	0	-0.010	0	-0.019	0	-0.020	0	-0.047	0	-0.054	0	-0.196	0	-0.476	0	0	0	0	0
S20	0	0	0	-0.010	0	-0.019	0	-0.020	0	-0.047	0	-0.054	0	-0.196	0	-0.476	0	0	0	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S33	-0.291	0	-0.621	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	0	-0.291	0	-0.620	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S35	-0.072	0	-0.085	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S36	0	-0.072	0	-0.085	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S37	-0.059	0	-0.066	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S38	0	-0.059	0	-0.066	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S39	-0.033	0	-0.035	0	-0.242	0	-0.411	0	0	0	0	0	0	0	0	0	0	0	0	0
S40	0	-0.033	0	-0.035	0	-0.242	0	-0.411	0	0	0	0	0	0	0	0	0	0	0	0
S41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S43	-57.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S44	0	-57.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S45	-0.057	0	-0.063	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	0	-0.057	0	-0.063	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S47	-0.052	0	-0.057	0	-5.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S48	0	-0.052	0	-0.057	0	-5.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S49	-0.021	0	-0.022	0	-0.056	0	-0.061	0	0	0	0	0	0	0	0	0	0	0	0	0
S50	0	-0.021	0	-0.022	0	-0.056	0	-0.061	0	0	0	0	0	0	0	0	0	0	0	0
S51	-0.020	0	-0.021	0	-0.049	0	-0.054	0	-1.39	0	0	0	0	0	0	0	0	0	0	0
S52	0	-0.020	0	-0.021	0	-0.049	0	-0.054	0	-1.39	0	0	0	0	0	0	0	0	0	0
S53	-0.012	0	-0.012	0	-0.024	0	-0.025	0	-0.071	0	-0.085	0	0	0	0	0	0	0	0	0
S54	0	-0.012	0	-0.012	0	-0.024	0	-0.025	0	-0.071	0	-0.085	0	0	0	0	0	0	0	0
S55	-0.011	0	-0.012	0	-0.022	0	-0.023	0	-0.058	0	-0.069	0	-0.862	0	0	0	0	0	0	0
S56	0	-0.011	0	-0.012	0	-0.022	0	-0.023	0	-0.058	0	-0.069	0	-0.862	0	0	0	0	0	0
S57	0	0	0	0	-0.014	0	-0.014	0	-0.027	0	-0.030	0	-0.050	0	-0.059	0	0	0	0	0
S58	0	0	0	0	0	-0.014	0	-0.014	0	-0.027	0	-0.030	0	-0.050	0	-0.059	0	0	0	0
S59	0	0	0	0	-0.013	0	-0.013	0	-0.024	0	-0.027	0	-0.042	0	-0.048	0	-0.587	0	0	0
S60	0	0	0	0	0	-0.013	0	-0.013	0	-0.024	0	-0.027	0	-0.042	0	-0.048	0	-0.587	0	0

Appendix E Site-specific Effect Analyses

E.1 Geospatial Effects within Watershed

In order to research the geospatial site-specific effect within the watershed, the set of subbasin level WQT parameters which were calculated in previous analyzing processes are drawn for each subbasin as shown in below Figure E-1. For each WQT parameters, it classified into 7 to 9 classes plus some special value level such as -1, 0, or 1. For each level of parameters, it rendered in a series of color such green to red or blue to red to visualize the magnitude of each level. The GIS software, ESRI ArcGIS Desktop 9.2, is used to finish these data classification and rendering works. The common data classification method is Nature Breaks (Jenks) method but the other methods such as Standard Deviation or Quantile might be applied. Figure E-1 illustrates the subbasin delineation and its numbers in study watershed: Lower Kansas watershed (USGS HUC8:10270104), northeastern Kansas. The scenario number will follow either the Table A-20 for the annual analyses or the Table A-21 for the monthly analyses in following sections.

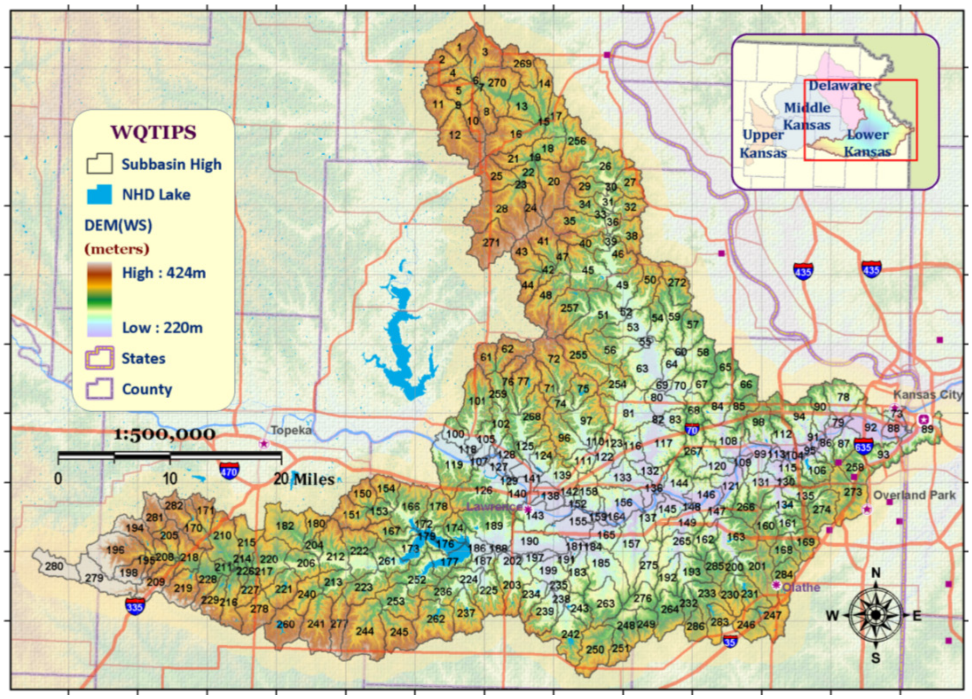


Figure E-1 Subbasin Delineation and Elevation of Study Watershed

E.1.1 Geospatial Site-Specific Effect for Potential Nutrient Load

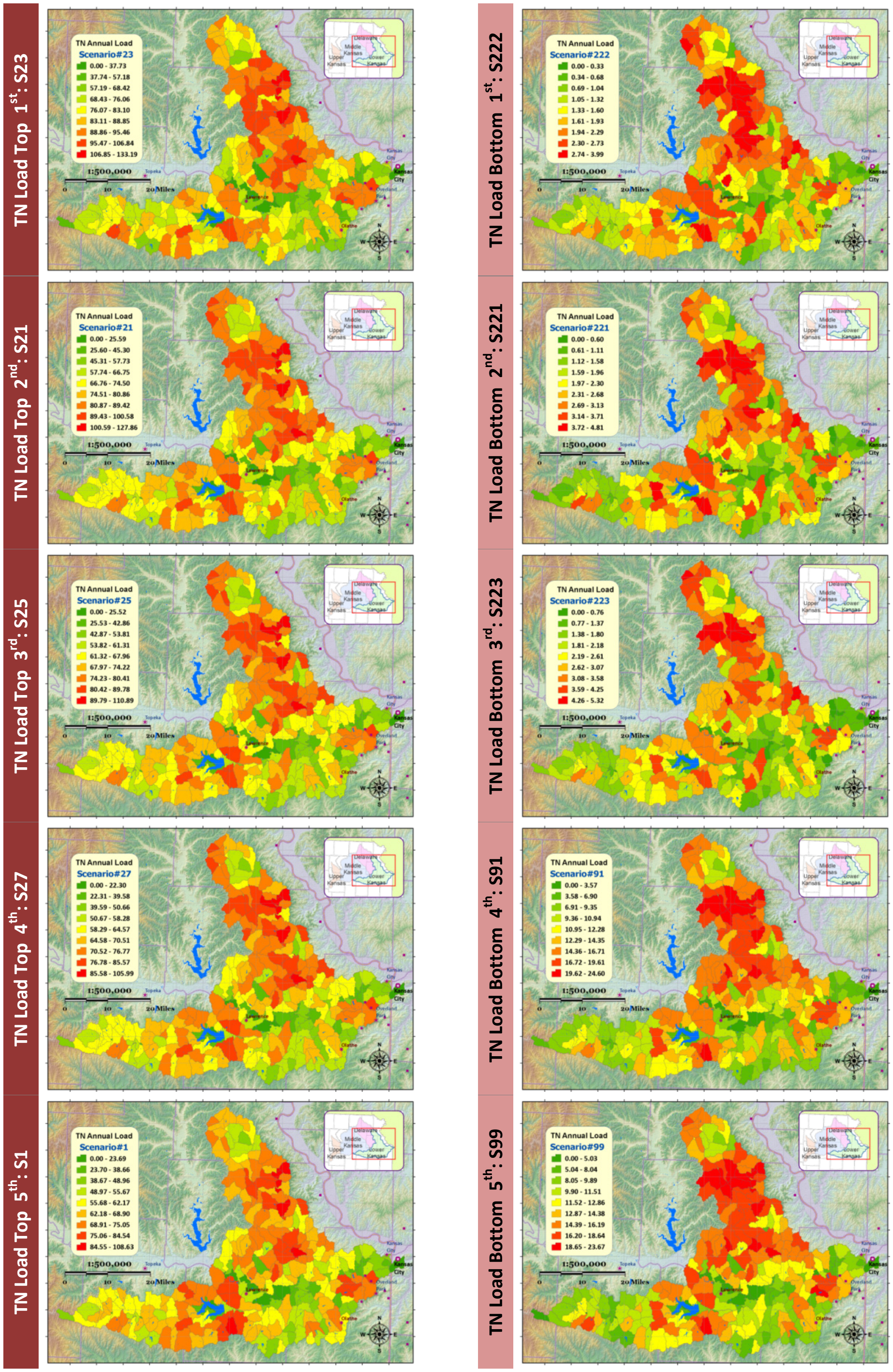


Figure E-2 Annual TN Load of Each Subbasin for Top Scenarios

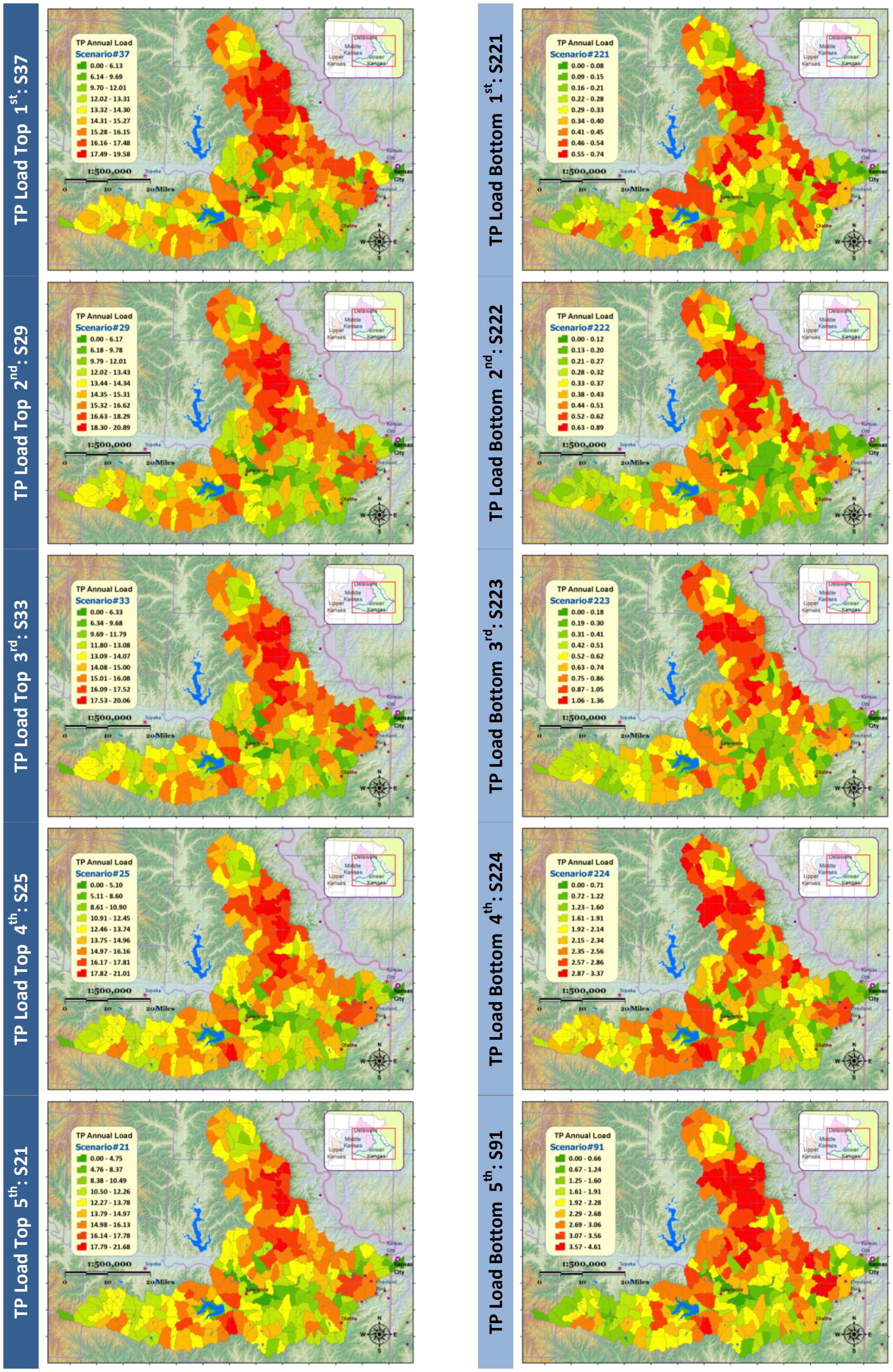
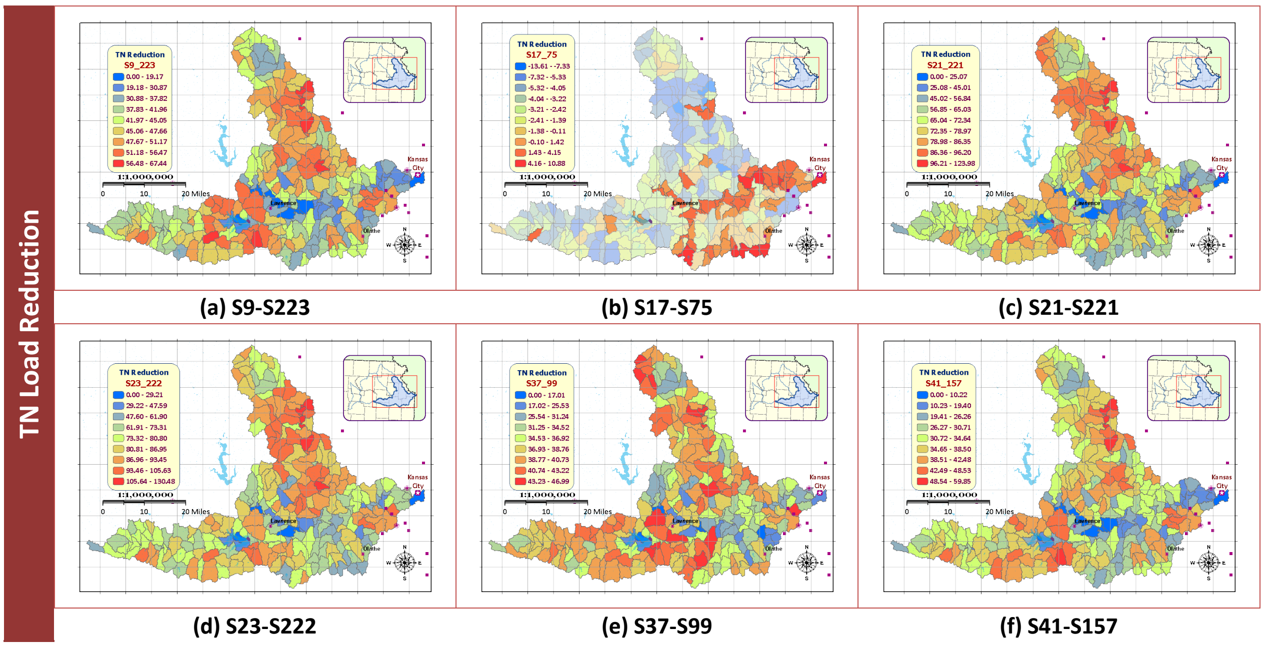


Figure E-3 Annual TP Load of Each Subbasin for Top Scenarios

E.1.2 Geospatial Site-Specific Effect for Load Reduction and Reduction Index

Table E-1 Watershed Level Load Reduction and Reduction Index for Selected Scenario Pairs

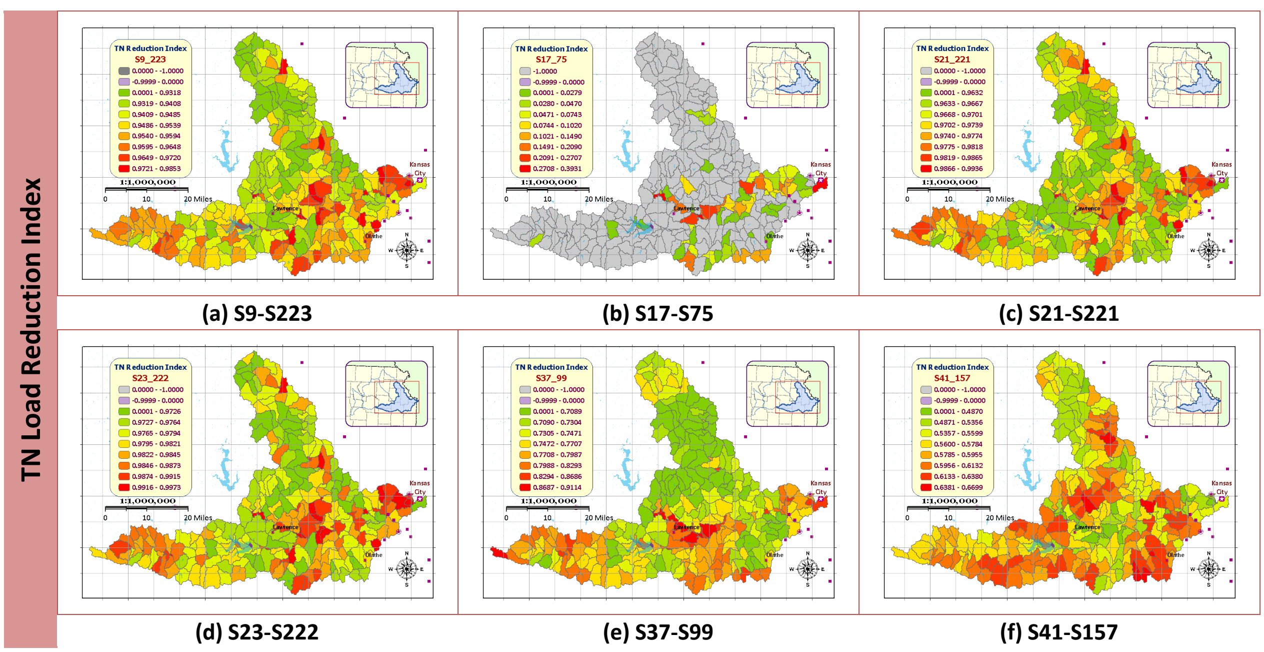
Scenario		Aggregated (Current-Alternative)				Watershed Level Average				Cumulative Probability				Top Ranking			
CUR	ALT	AGCROP	AGTILL	AGFERT	AGBMPS	TN	TP	TNRI	TPRI	TN	TP	TNRI	TPRI	TN	TP	TNRI	TPRI
9	223	CS-FESC	RT-NP	SB-NA	WO-WO	42.025	12.001	94.740%	95.339%	98.287%	99.853%	98.885%	98.862%	227	20	148	151
17	75	CS-G	NT-OT	SB-DB	WO-WO	-2.052	4.835	-1	39.253%	44.208%	89.017%	44.208%	84.722%	7379	1453	7379	2021
21	221	C-BBLS	CT-NP	SB-NA	WO-WO	68.406	12.492	96.998%	97.460%	99.966%	99.913%	99.875%	99.966%	5	12	17	5
23	222	C-SWCH	CT-NP	DB-NA	WO-WO	77.312	12.199	98.000%	97.203%	99.996%	99.860%	99.996%	99.868%	1	19	1	18
37	99	C-W	NT-NT	SB-DB	WO-WO	35.756	11.377	74.583%	82.388%	97.100%	99.724%	96.783%	97.365%	384	37	426	349
41	157	S-WF	CT-NT	SB-SB	WO-WO	31.833	5.977	57.293%	52.302%	95.270%	93.403%	92.858%	91.331%	626	873	945	1147



(a) S9-S223 (b) S17-S75 (c) S21-S221

(d) S23-S222 (e) S37-S99 (f) S41-S157

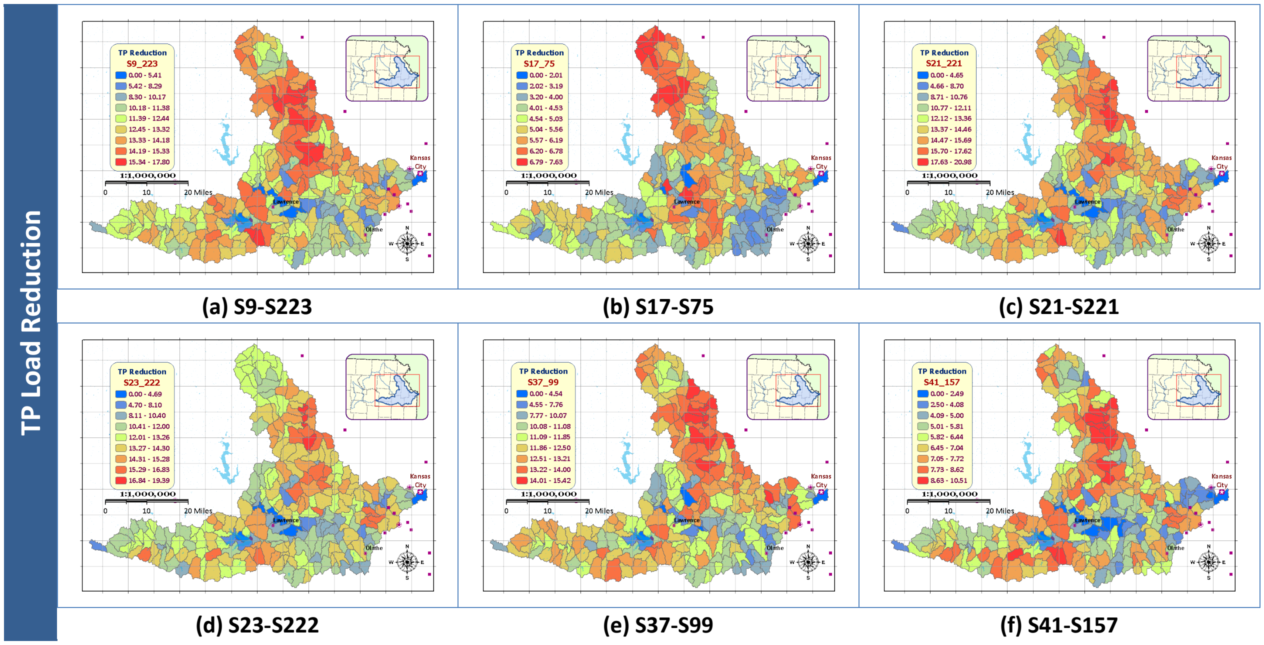
Figure E-4 Subbasin Level TN Load Reduction of Selected Scenario Pairs



(a) S9-S223 (b) S17-S75 (c) S21-S221

(d) S23-S222 (e) S37-S99 (f) S41-S157

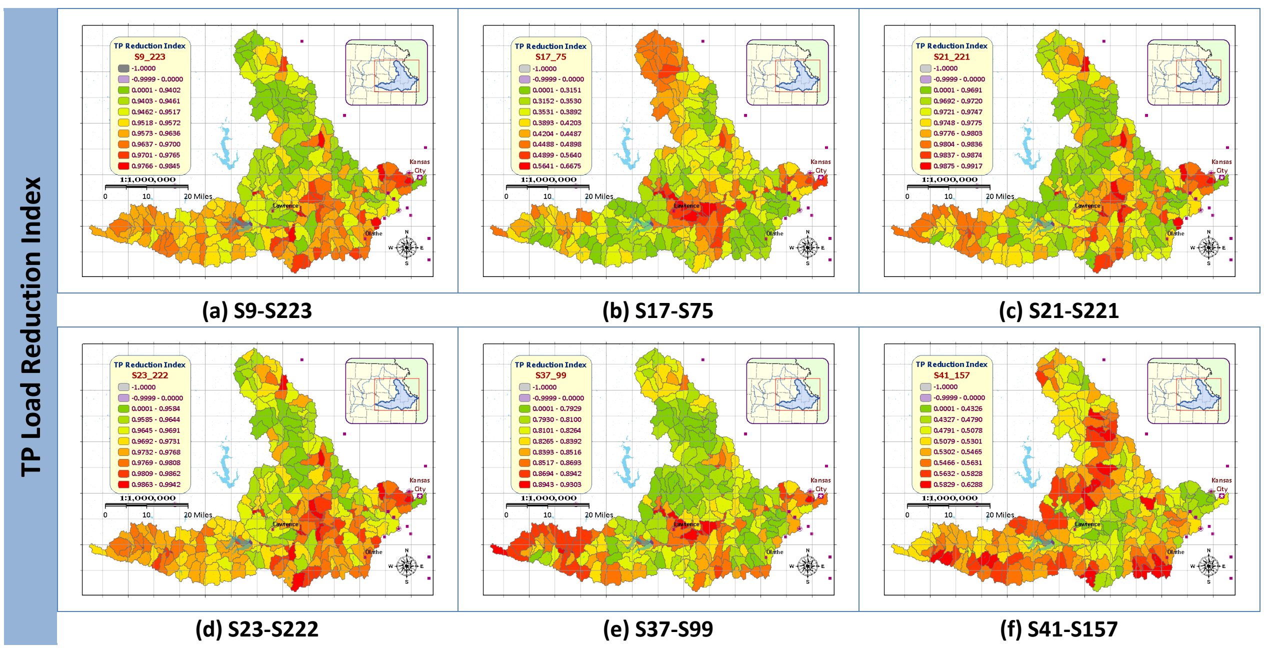
Figure E-5 Subbasin Level TN Load Reduction Index of Selected Scenario Pairs



(a) S9-S223 (b) S17-S75 (c) S21-S221

(d) S23-S222 (e) S37-S99 (f) S41-S157

Figure E-6 Subbasin Level TP Load Reduction of Selected Scenario Pairs



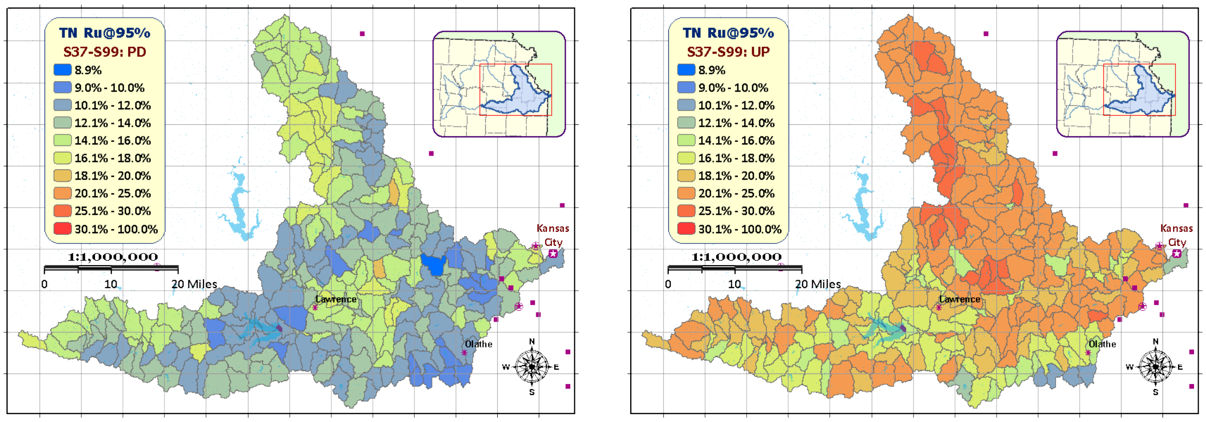
(a) S9-S223 (b) S17-S75 (c) S21-S221

(d) S23-S222 (e) S37-S99 (f) S41-S157

Figure E-7 Subbasin Level TP Load Reduction Index of Selected Scenario Pairs

E.1.3 Geospatial Site-Specific Effect for Uncertainty Ratio

As discussed previously, Table D-5 presents the watershed level TN load reduction R_U with UP analysis at 95% confidence level. However, these values are the average of the R_U in each individual subbasin. Moreover, for the same alternative scenario at the same subbasin, the PD and UP analysis might not present a similar R_U. Figure E-8 illustrates TN load reduction R_U with either PD or UP analysis for S37-S99 scenario pair. The classes of R_U in Figure E-8 (a) and (b) are identical. In Figure E-8, UP analysis tends to produce higher R_U than PD analysis cross the watershed. Figure E-9 illustrates the TN load reduction R_U difference between PD and UP analysis method for S37-S99 alternative scenario at 95% confidence level. The subbasin level R_U differences between PD-UP analyses range from 0.0% to -13.33% across the watershed while the watershed average is -0.5%.



(a) Paired (PD) Analysis Method (b) Unpaired (UP) Analysis Method

Figure E-8 Subbasin Level TN Load Reduction R_U for S37-S99

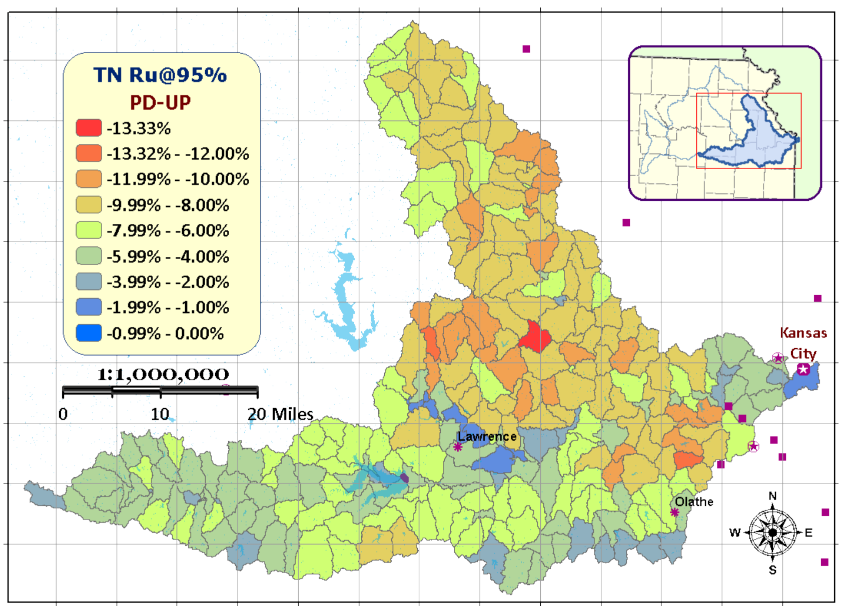
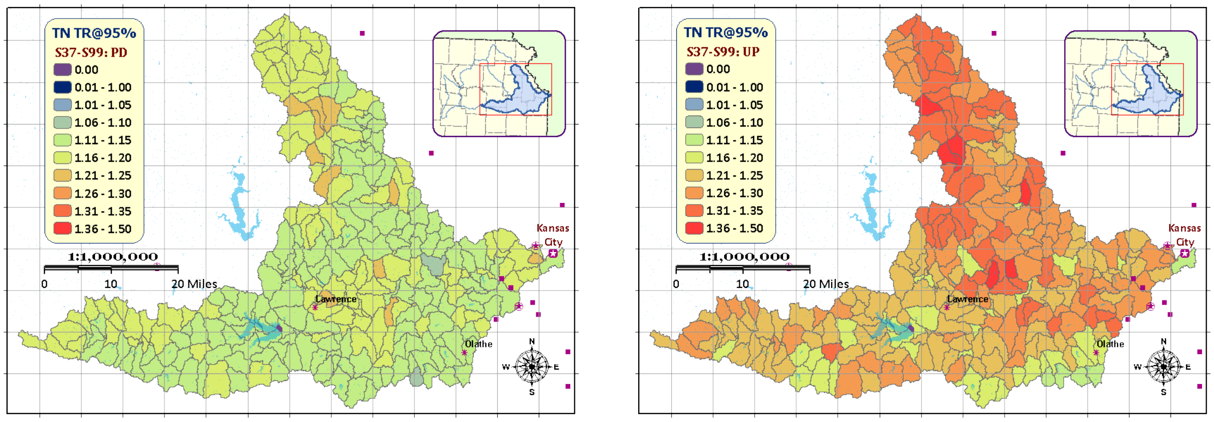


Figure E-9 Difference of TN Load Reduction R_U between PD-UP Analyses for S37-S99 at CL=95%

E.1.4 Geospatial Site-Specific Effect for Trading Ratio

Figure E-10 illustrates TN load reduction TR with either PD or UP analysis for S37-S99 scenario pair. The classes of TR in both Figure E-10 (a) and (b) are identical. In these figures, UP analysis TR tends to produce higher value than PD analysis. Figure E-11 illustrates difference of TN load reduction TR between PD and UP analyses for S37-S99 scenario pair at 95% confidence level. The TR differences range from 0.0% to -19.43% across the watershed with an average at -0.48%.



(a) Paired (PD) Analysis Method **(b) Unpaired (UP) Analysis Method**

Figure E-10 Subbasin TN Load Reduction TR for S37-S99 Alternative Scenario

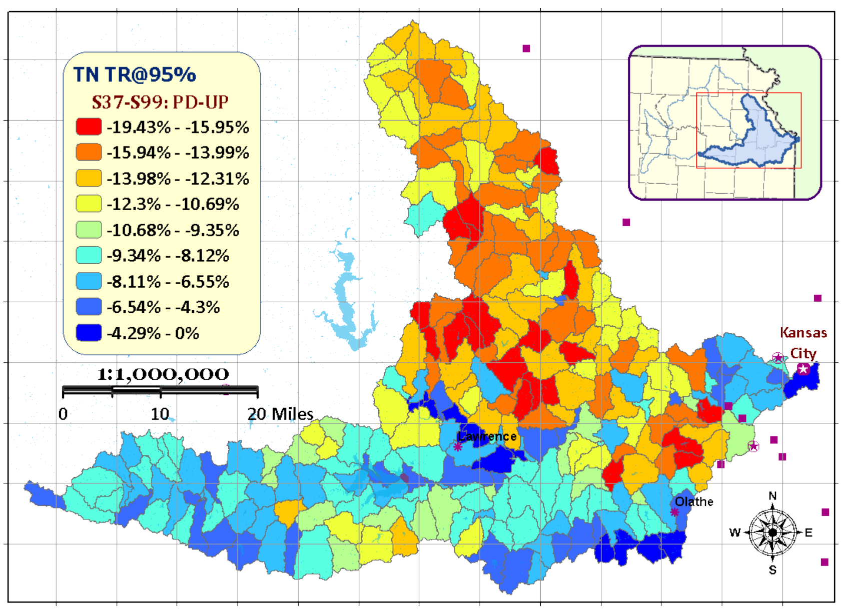


Figure E-11 TN Load Reduction TR Difference between PD-UP Analyses for S37-S99 at CL=95%

E.2 Temporal Effect within Scenarios

E.2.1 Temporal Effect for Nutrient Load

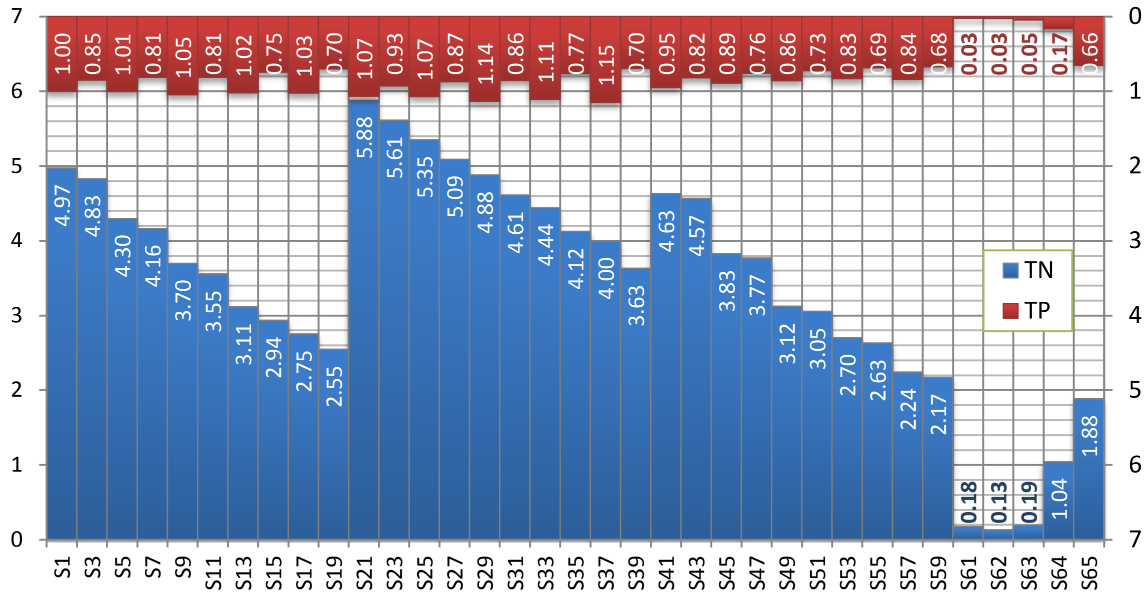


Figure E-12 Potential Monthly Nutrient Load of Selected Scenarios

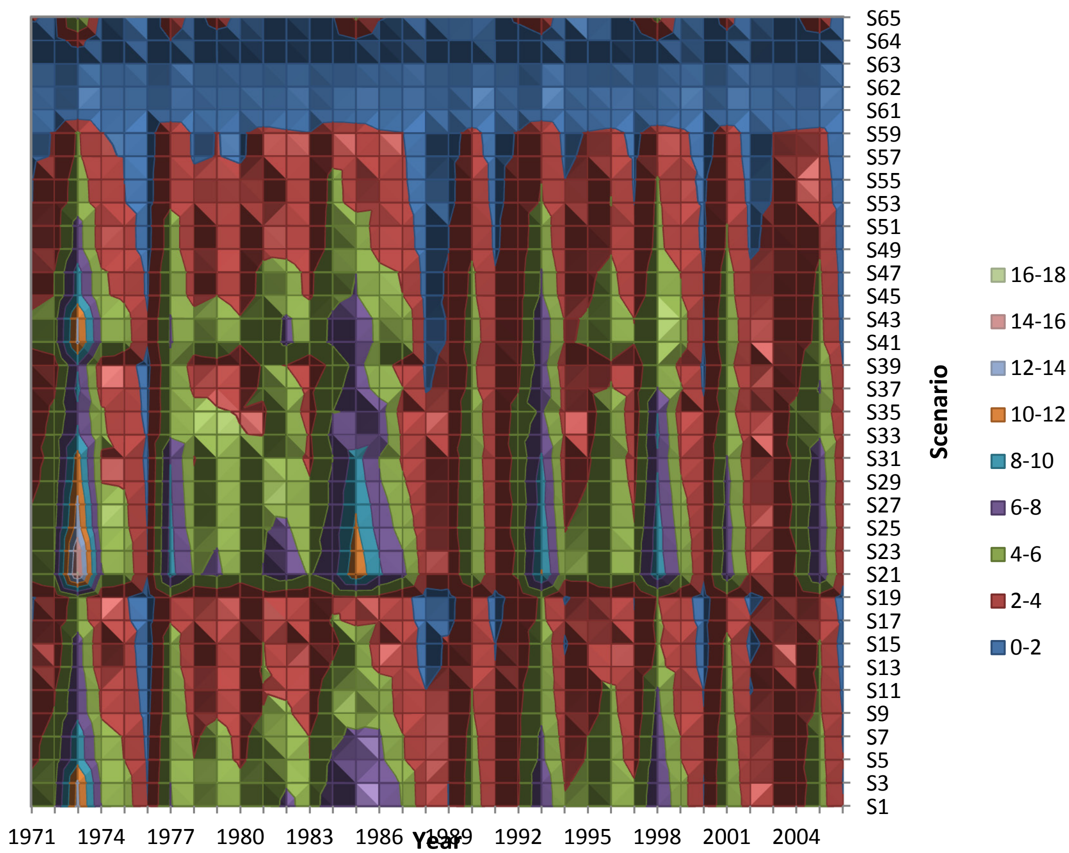


Figure E-13 Potential Monthly TN Load of Selected Scenarios for Year 1971-2006

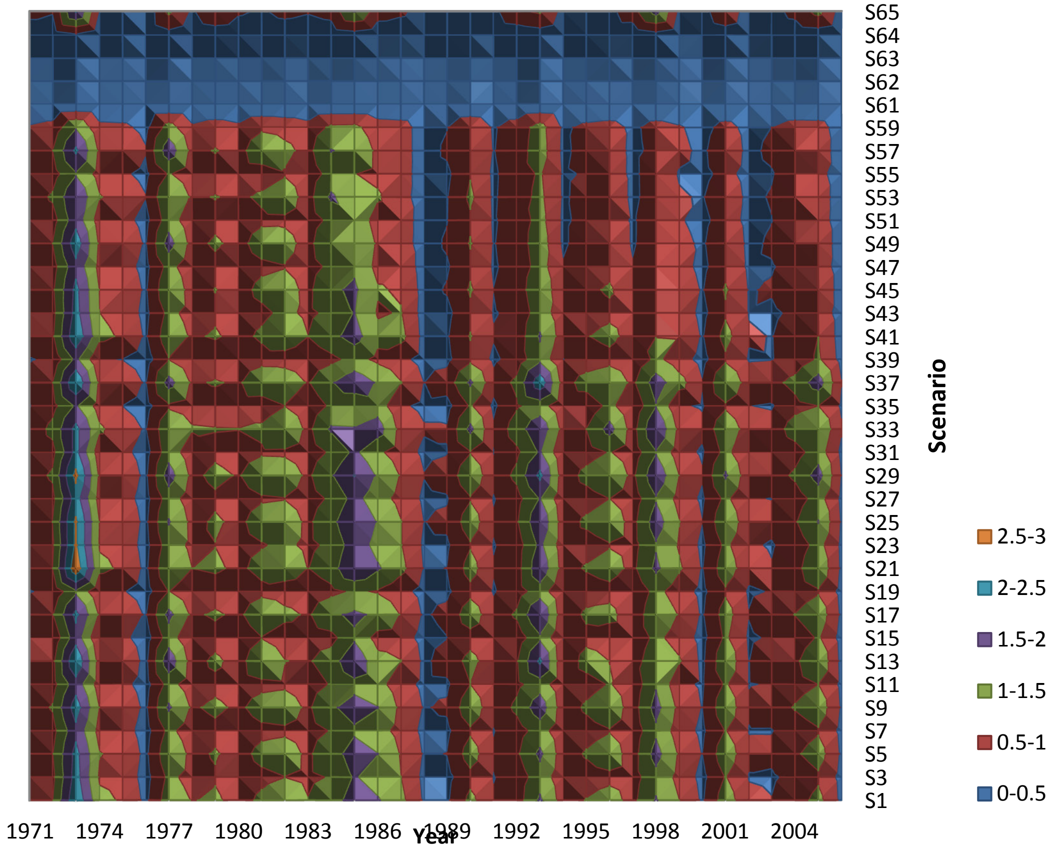


Figure E-14 Potential Monthly TP Load of Selected Scenarios for Year 1971-2006

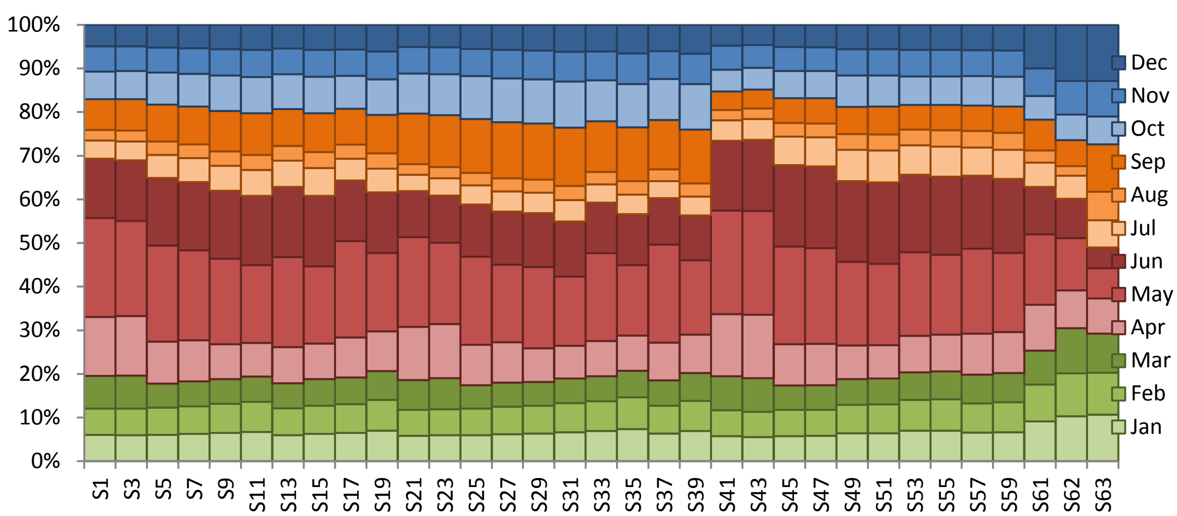


Figure E-15 Percentage of Monthly TN Load in Each Month for Selected Scenarios

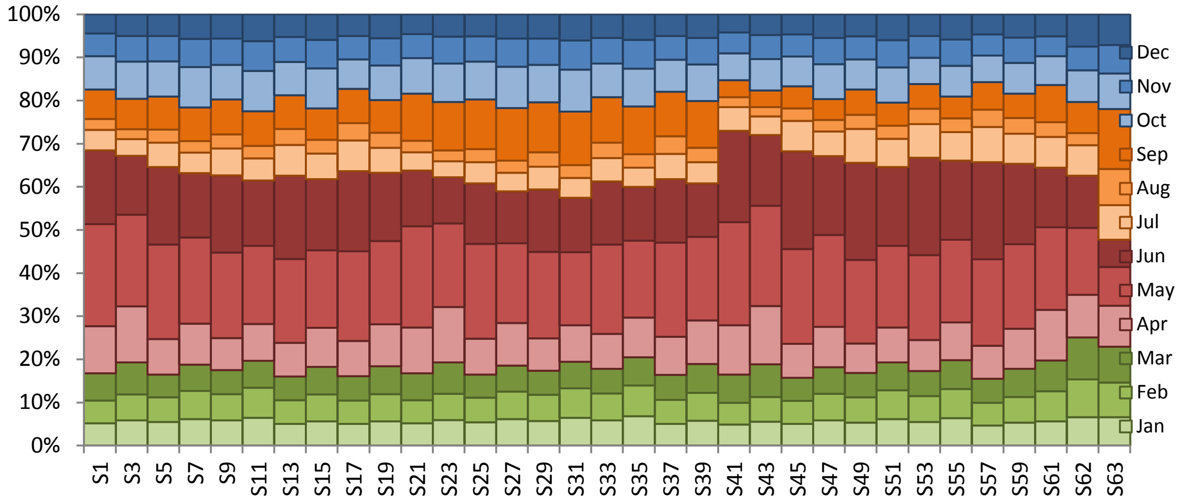


Figure E-16 Percentage of Monthly TP Load in Each Month for Selected Scenarios

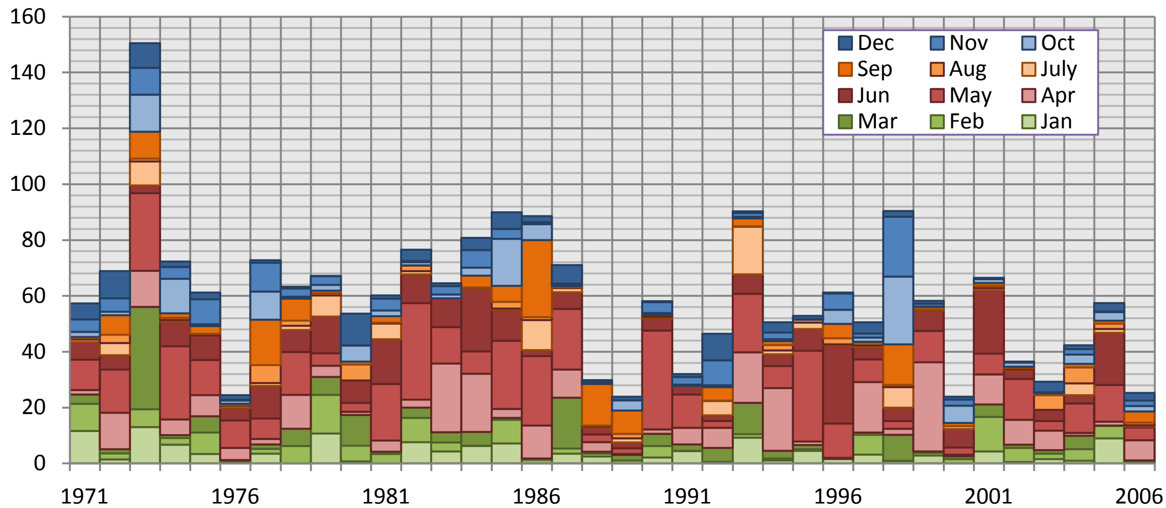


Figure E-17 Monthly TN Load for Every Month in Year 1971-2006

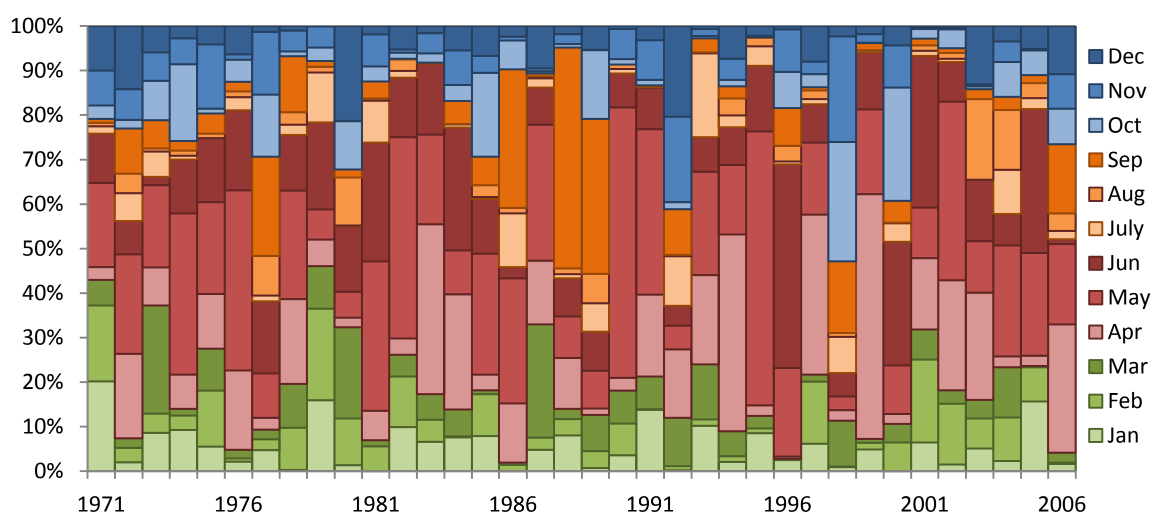


Figure E-18 Percentage of Monthly TN Load for Every Month in Year 1971-2006

E.2.2 Temporal Effect for Nutrient Load Reduction

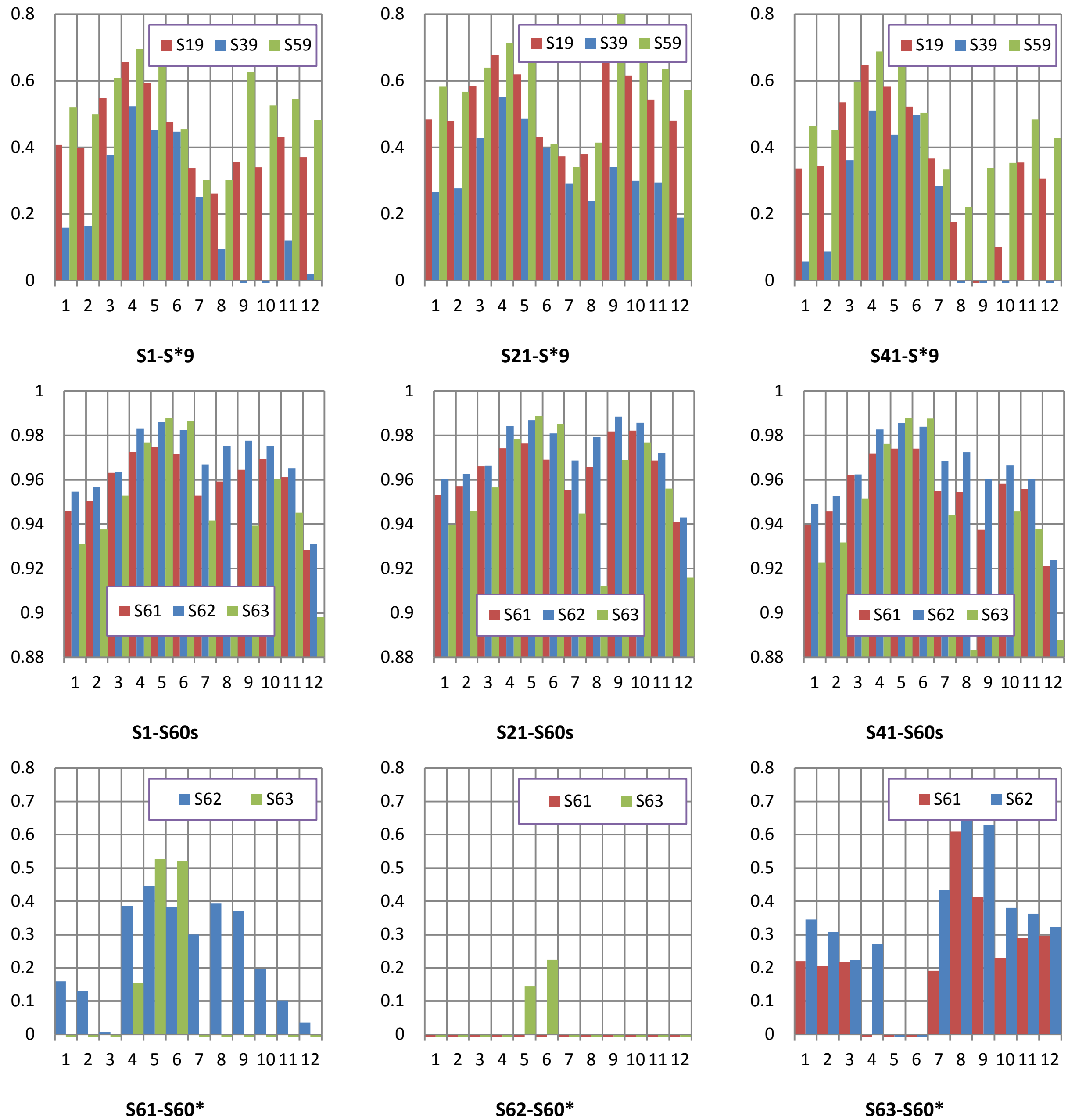


Figure E-19 Monthly TN Load Reduction Distribution of a Year

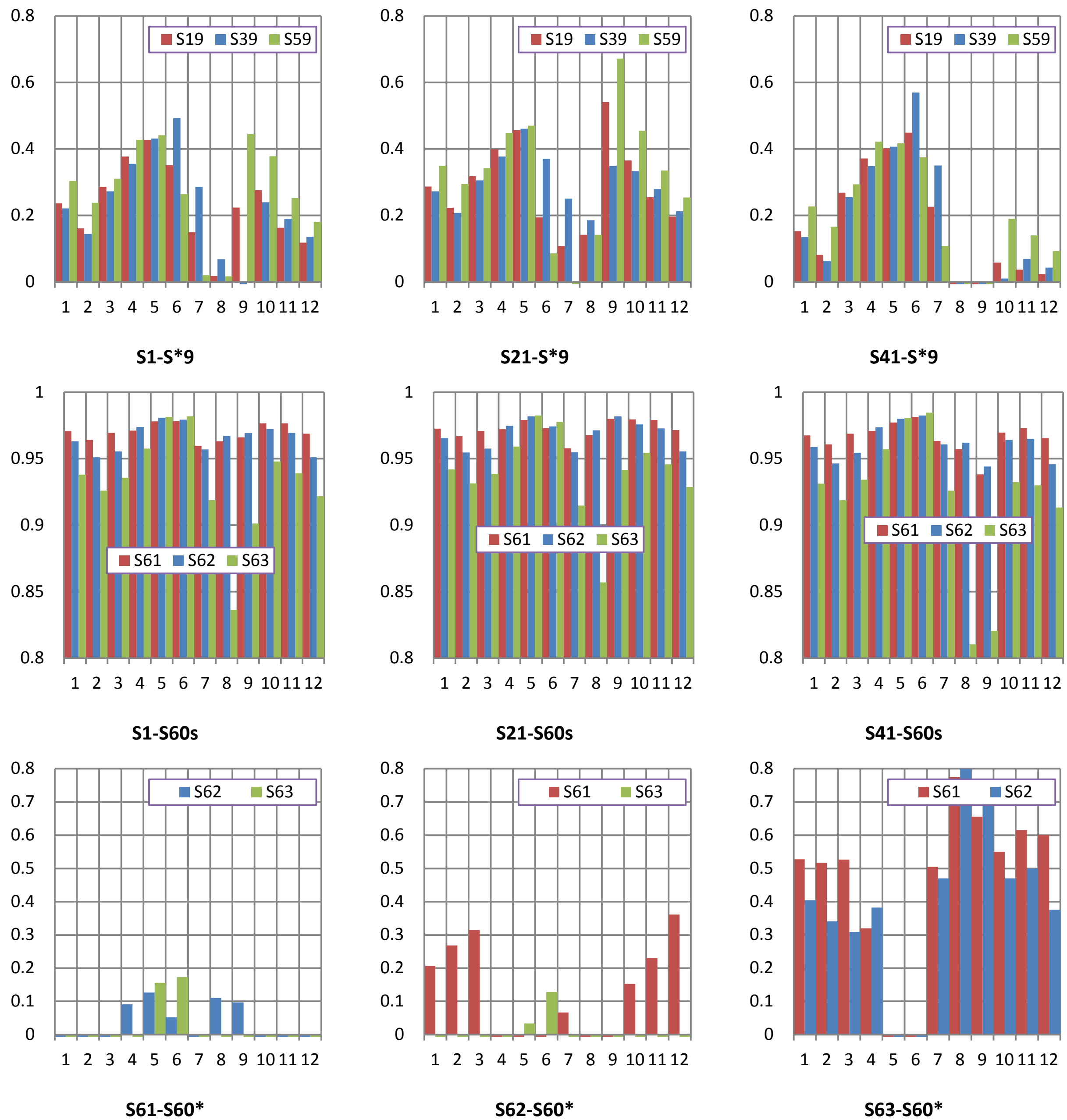


Figure E-20 Monthly TP Load Reduction Distribution of a Year

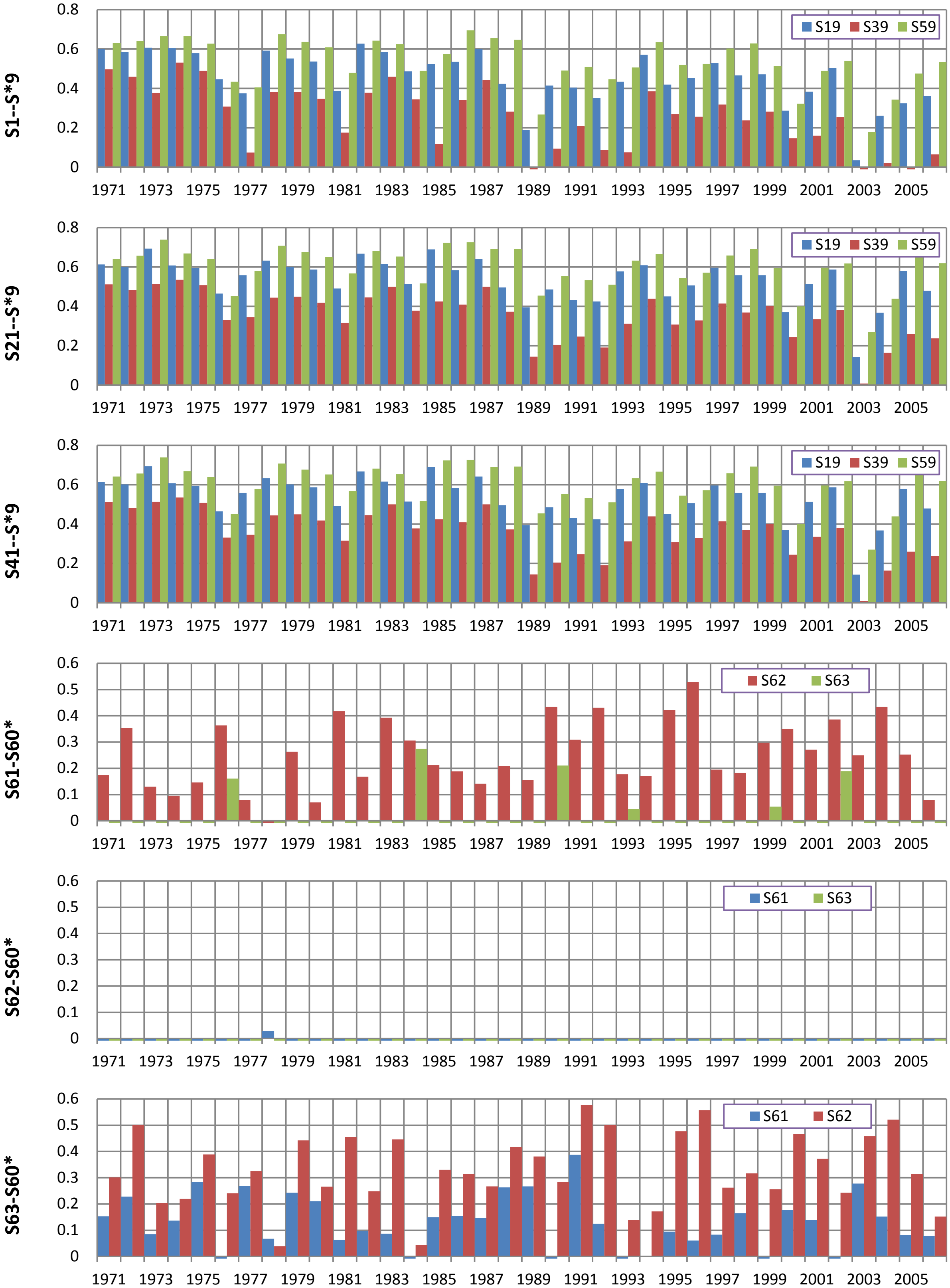


Figure E-21 Monthly TN Load Reduction for Year 1971 -1 2006

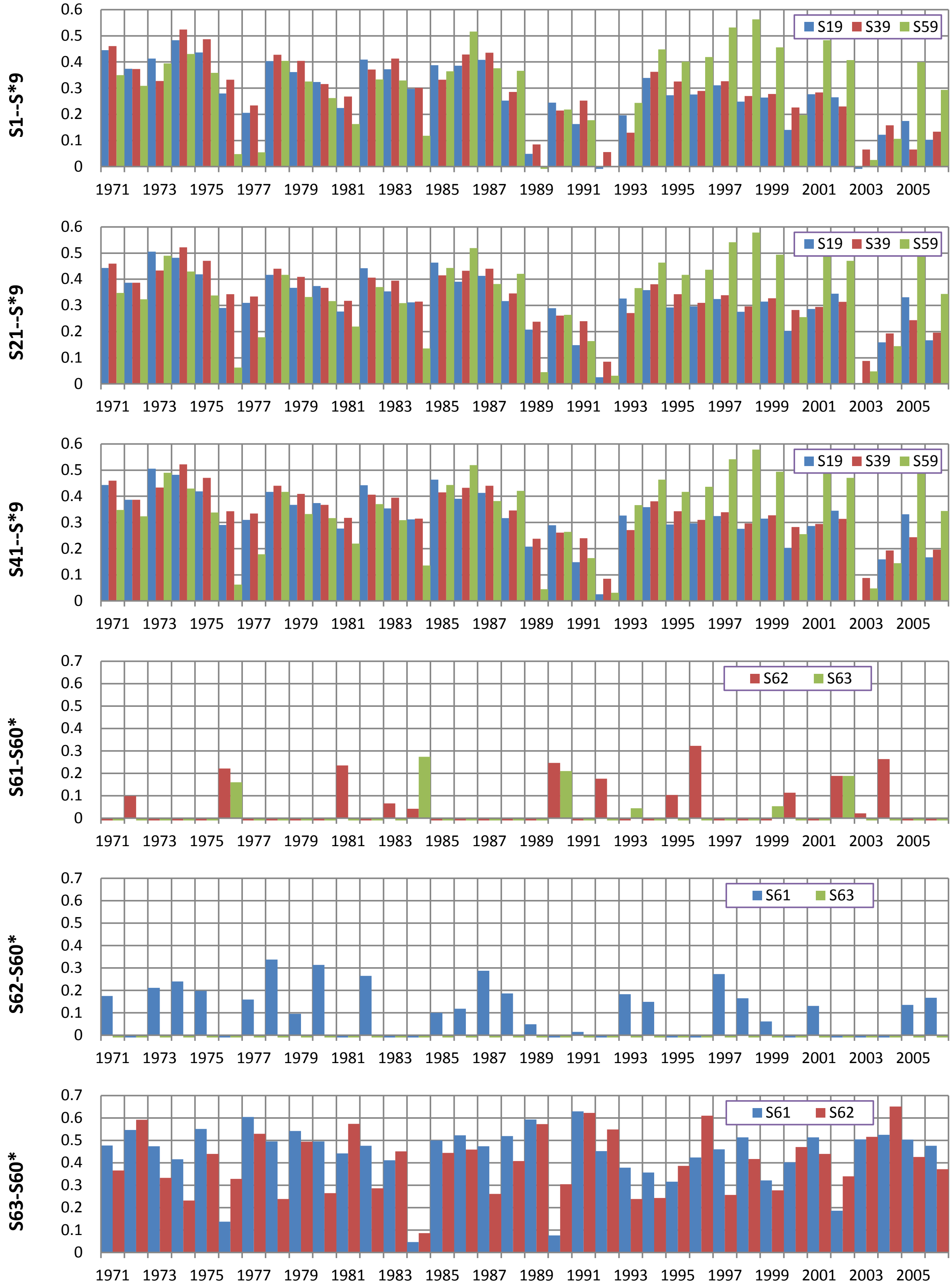


Figure E-22 Monthly TP Load Reduction for Year 1971 -1 2006

Appendix F Scenario Trends Analysis

F.1 Annual Nutrient Load

F.1.1 ANOVA Overall Information

F.1.1.1 *Class Level:*

Class	Levels	Values
CROP	11	C CS G GS S W WC WF WG WGS WS
TILL	5	CT MT NT OT RT
FERT	2	DB SB
BMPS	2	FS WO

F.1.1.2 *Total Nitrogen (TN)*

Overall ANOVA:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	179	76904.08	429.63	760.89	<.0001
Error	40	22.59	0.56		
Corrected Total	219	76926.67			

Model ANOVA:

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BMPS	1	60898.817	60898.817	107853	<.0001
CROP	10	5251.35677	525.13568	930.03	<.0001
FERT	1	21.86829	21.86829	38.73	<.0001
TILL	4	3623.95541	905.98885	1604.53	<.0001
CROP*BMPS	10	3412.46933	341.24693	604.36	<.0001
FERT*BMPS	1	14.21049	14.21049	25.17	<.0001
TILL*BMPS	4	2354.90563	588.72641	1042.65	<.0001
CROP*FERT	10	3.15059	0.31506	0.56	0.8376
CROP*TILL	40	775.44679	19.38617	34.33	<.0001
TILL*FERT	4	4.36124	1.09031	1.93	0.124
CROP*FERT*BMPS	10	2.04732	0.20473	0.36	0.9556
CROP*TILL*BMPS	40	503.90125	12.59753	22.31	<.0001
TILL*FERT*BMPS	4	2.83405	0.70851	1.25	0.3037
CROP*TILL*FERT	40	34.75648	0.86891	1.54	0.0886

F.1.1.3 *Total Phosphorus (TP)*

Overall ANOVA:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	179	3734.69	20.86	285.65	<.0001
Error	40	2.92	0.07		
Corrected Total	219	3737.61			

Model ANOVA:

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BMPS	1	3042.13	3042.13	41649.20	<.0001
CROP	10	313.93	31.39	429.80	<.0001
FERT	1	51.73	51.73	708.20	<.0001
TILL	4	14.60	3.65	49.97	<.0001

Source	DF	Type I SS	Mean Square	F Value	Pr > F
CROP*BMPS	10	204.01	20.40	279.31	<.0001
FERT*BMPS	1	33.62	33.62	460.23	<.0001
TILL*BMPS	4	9.48	2.37	32.46	<.0001
CROP*FERT	10	14.88	1.49	20.37	<.0001
CROP*TILL	40	16.11	0.40	5.51	<.0001
TILL*FERT	4	5.79	1.45	19.82	<.0001
CROP*FERT*BMPS	10	9.67	0.97	13.24	<.0001
CROP*TILL*BMPS	40	10.47	0.26	3.58	<.0001
TILL*FERT*BMPS	4	3.76	0.94	12.88	<.0001
CROP*TILL*FERT	40	4.50	0.11	1.54	0.0886

F.1.2 ANOVA Main Effect

Pr > |t| for H0: LSMean(i)=LSMean(j)

Least Squares Means for effect BMPS

TN

BMPS	LSMEAN	Pr > |t|
FS	4.0022	<.0001
WO	37.2776	

TP

BMPS	LSMEAN	Pr > |t|
FS	0.896	<.0001
WO	8.333	

Least Squares Means for effect CROP

TN

CROP	LSMEAN	Number
C	32.268	1
CS	24.486	2
G	21.455	3
GS	21.915	4
S	21.734	5
W	11.537	6
WC	20.117	7
WF	16.843	8
WG	18.640	9
WGS	20.093	10
WS	17.951	11

TP

CROP	LSMEAN	Number
C	6.498	1
CS	6.005	2
G	5.203	3
GS	5.508	4
S	5.352	5
W	2.211	6
WC	4.440	7
WF	3.366	8
WG	4.036	9
WGS	4.403	10
WS	3.733	11

TN

i/j	1	2	3	4	5	6	7	8	9	10	11
1		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		0.0601	0.2472	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	0.0601		0.4514	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	0.2472	0.4514		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	0.9205	<.0001
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	0.006
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.9205	<.0001	<.0001		<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.006	<.0001	

TP

i/j	1	2	3	4	5	6	7	8	9	10	11
1		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		0.001	0.0889	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	0.001		0.0756	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	0.0889	0.0756		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	0.6673	<.0001
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	0.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.0001	0.001
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.6673	<.0001	0.0001		<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0001	0.001	<.0001	

Least Squares Means for effect FERT

TN	FERT	LSMEAN	Pr > |t|
	DB	20.325	<.0001
	SB	20.955	

TP	FERT	LSMEAN	Pr > |t|
	DB	4.1292	<.0001
	SB	5.0990	

Least Squares Means for effect TILL

TN	TILL	LSMEAN	Number
	CT	26.838	1
	MT	23.170	2
	NT	14.890	3
	OT	19.297	4
	RT	19.003	5

TP	TILL	LSMEAN	Number
	CT	5.043	1
	MT	4.735	2
	NT	4.289	3
	OT	4.532	4
	RT	4.471	5

TN

i/j	1	2	3	4	5
1		<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001
4	<.0001	<.0001	<.0001		0.0744
5	<.0001	<.0001	<.0001	0.0744	

TP

i/j	1	2	3	4	5
1		<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	0.0011	<.0001
3	<.0001	<.0001		0.0001	0.0029
4	<.0001	0.0011	0.0001		0.2988
5	<.0001	<.0001	0.0029	0.2988	

F.1.3 ANOVA Two-Way Interaction Effect

Table F-1 Variable Levels and Least Squares Means for Cross Effect: TILL x FERT

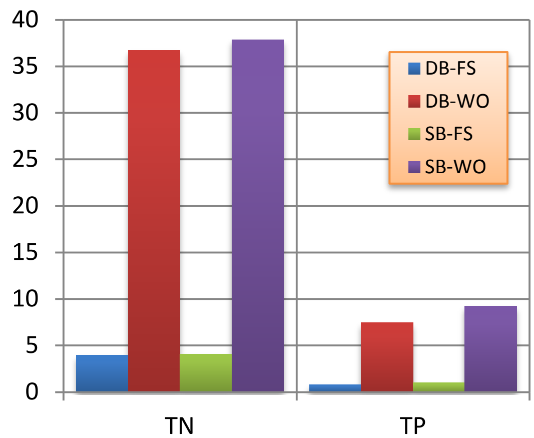
TILL	FERT	TN Load LSMEAN	Number	TILL	FERT	TP Load LSMEAN	Number
CT	DB	26.762	1	CT	DB	4.764	1
CT	SB	26.915	2	CT	SB	5.323	2
MT	DB	22.918	3	MT	DB	4.364	3
MT	SB	23.423	4	MT	SB	5.106	4
NT	DB	14.406	5	NT	DB	3.531	5
NT	SB	15.375	6	NT	SB	5.047	6
OT	DB	18.894	7	OT	DB	4.007	7
OT	SB	19.700	8	OT	SB	5.057	8
RT	DB	18.644	9	RT	DB	3.980	9
RT	SB	19.363	10	RT	SB	4.963	10

Table F-2 the p-Value for the TN Loads Difference on Cross Effect: TILL x FERT

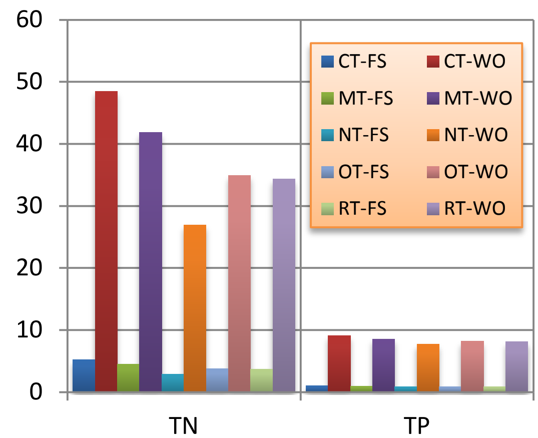
i/j	1	2	3	4	5	6	7	8	9	10
1		0.503	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	0.503		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		0.0313	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	0.0313		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		0.0001	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	0.0001		<.0001	<.0001	<.0001	<.0001
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.001	0.2758	0.0449
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.001		<.0001	0.1451
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2758	<.0001		0.0029
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0449	0.1451	0.0029	

Table F-3 the p-Value for the TP Loads Difference on Cross Effect: TILL x FERT

i/j	1	2	3	4	5	6	7	8	9	10
1		<.0001	<.0001	0.0001	<.0001	0.0012	<.0001	0.0009	<.0001	0.0194
2	<.0001		<.0001	0.0112	<.0001	0.0016	<.0001	0.0022	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
4	0.0001	0.0112	<.0001		<.0001	0.4748	<.0001	0.5476	<.0001	0.0861
5	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001
6	0.0012	0.0016	<.0001	0.4748	<.0001		<.0001	0.9089	<.0001	0.3055
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	0.7388	<.0001
8	0.0009	0.0022	<.0001	0.5476	<.0001	0.9089	<.0001		<.0001	0.2557
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.7388	<.0001		<.0001
10	0.0194	<.0001	<.0001	0.0861	<.0001	0.3055	<.0001	0.2557	<.0001	



(a) Cross Effect: FERT*BMPS



(b) Cross Effect: TILL*BMPS

Figure F-1 Nutrient Load Cross Effect of FERT*BMPS and TILL*BMPS

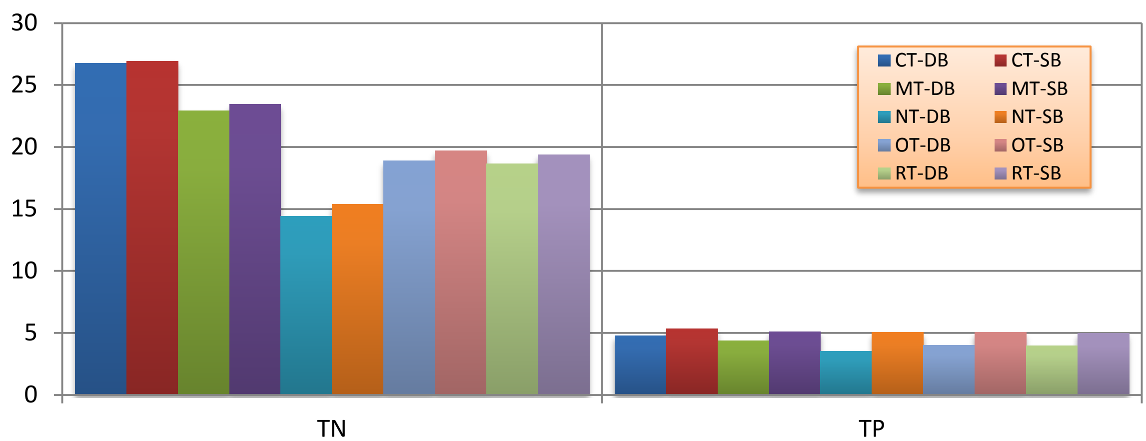


Figure F-2 Nutrient Load Cross Effect of TILL*FERT

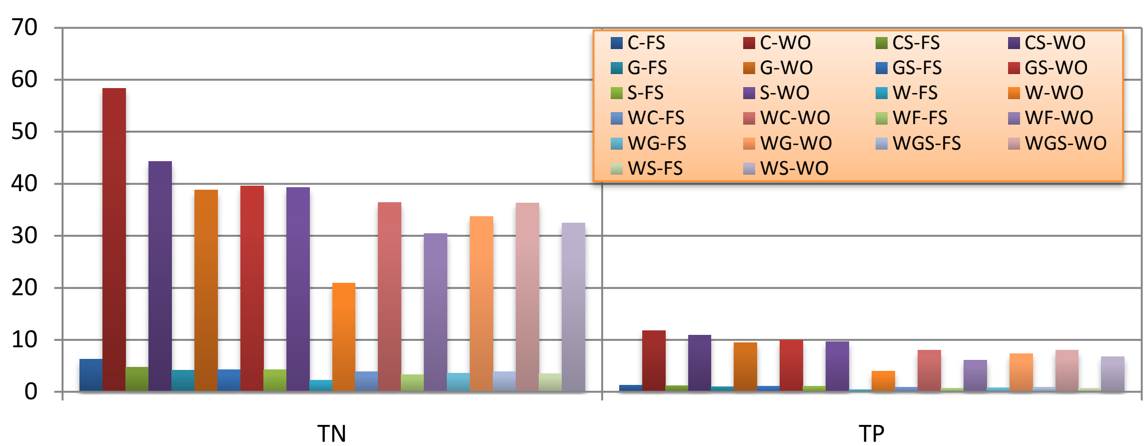


Figure F-3 Nutrient Load Cross Effect of CROP*BMPS

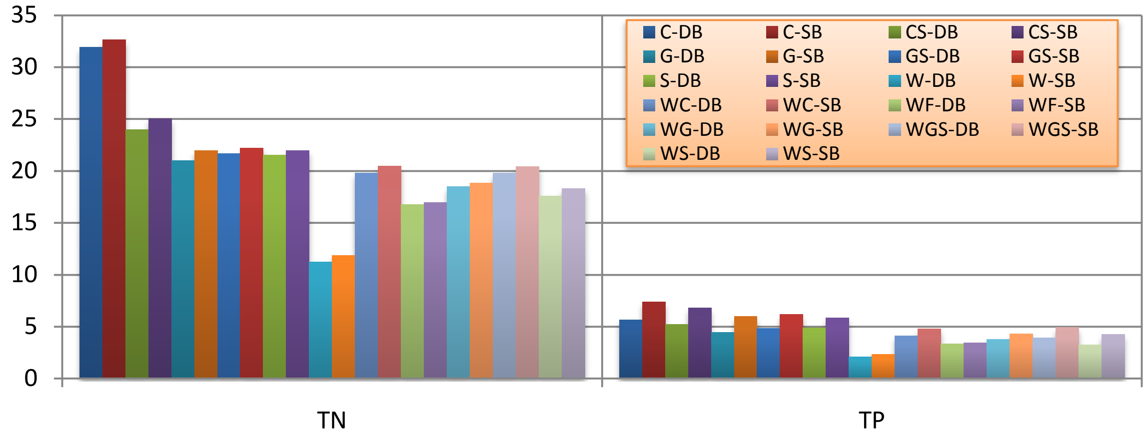


Figure F-4 Nutrient Load Cross Effect of CROP*FERT

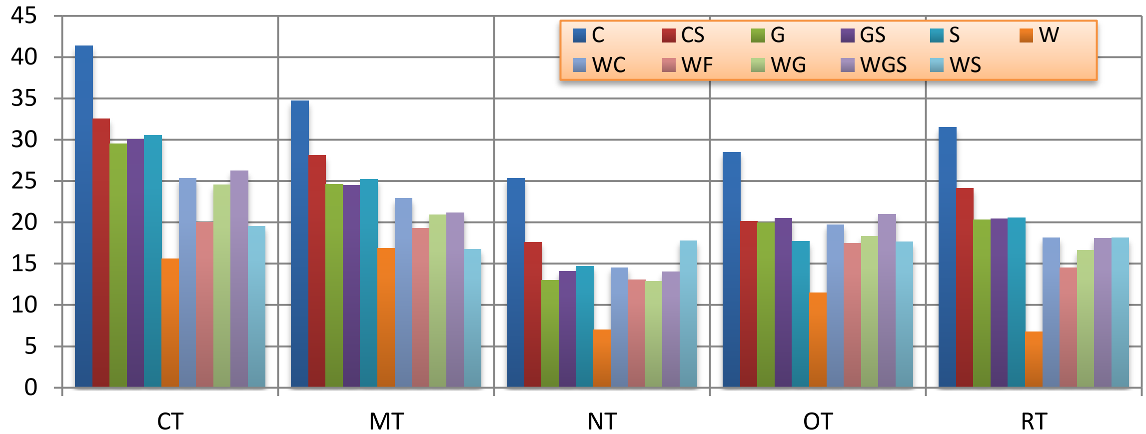


Figure F-5 TN Load Cross Effect of CROP*TILL

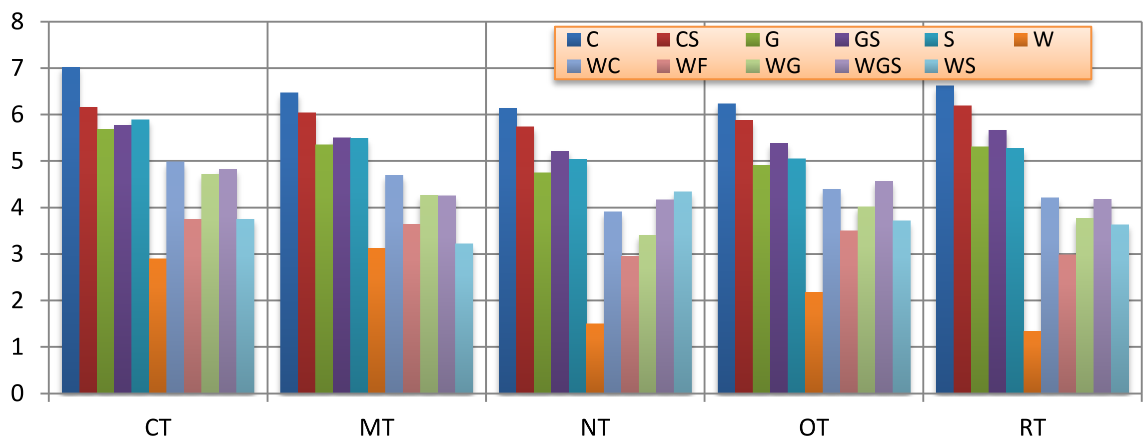


Figure F-6 TP Load Cross Effect of CROP*TILL

F.1.4 ANOVA Three-Way Interaction Effect

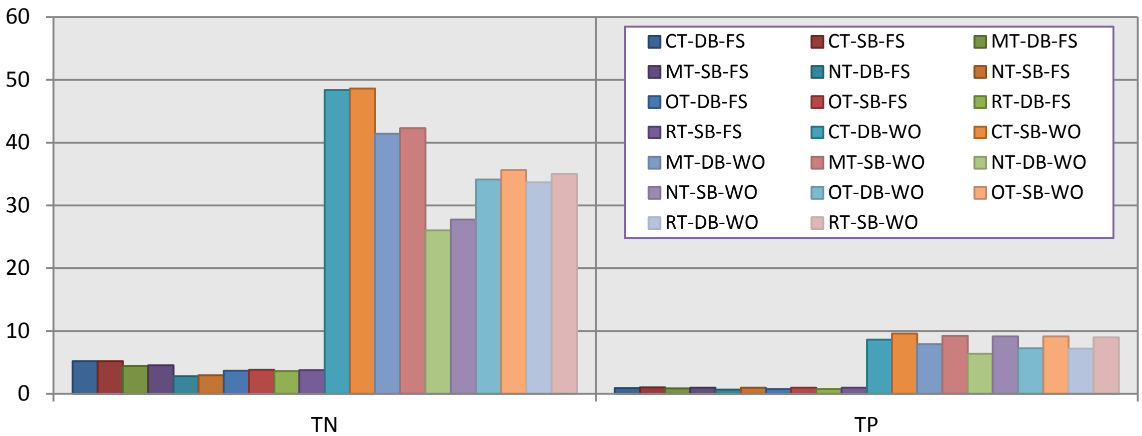
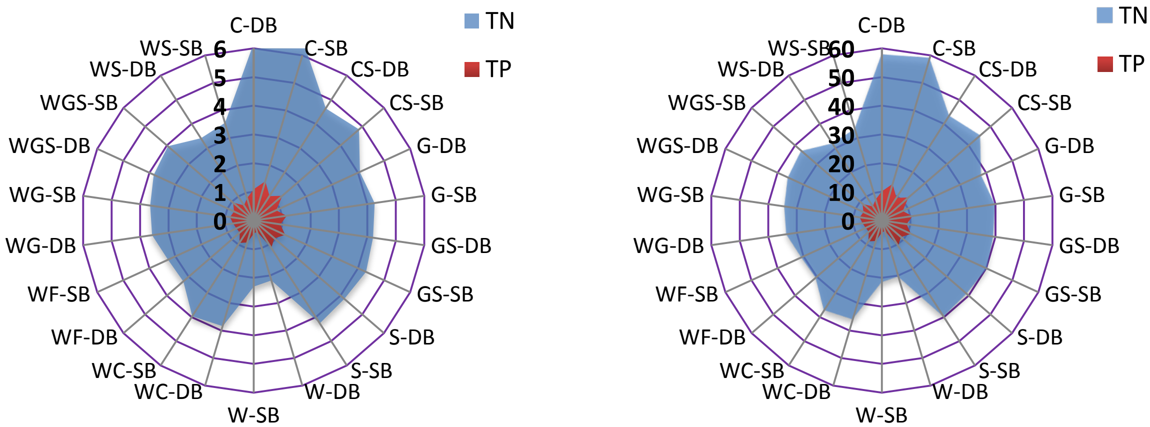
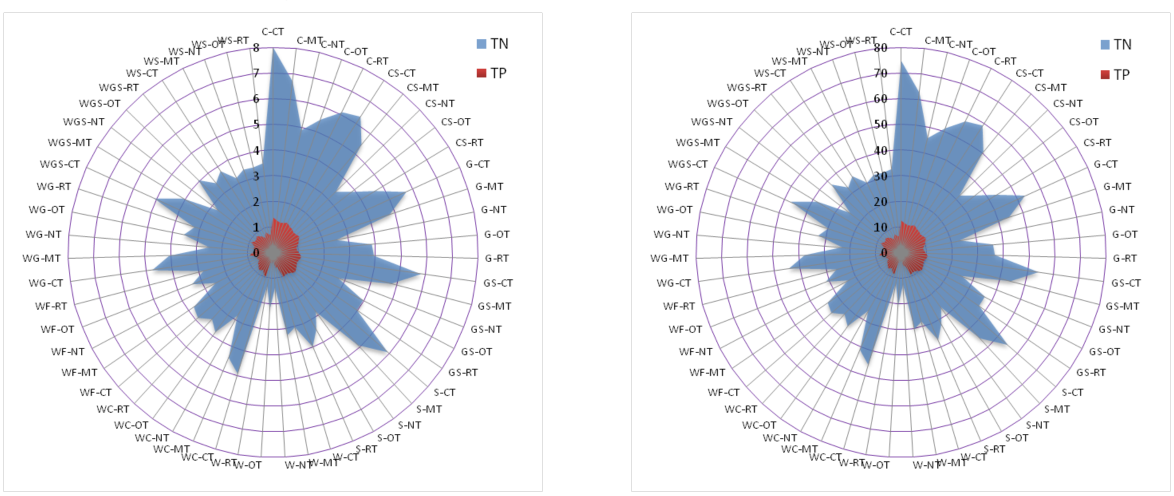


Figure F-7 Nutrient Load Cross Effect of TILL*FERT*BMPS



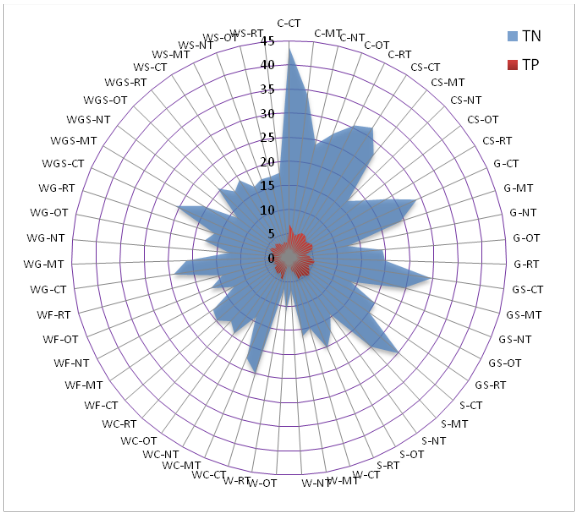
(a) With VFS **(b) Without VFS**

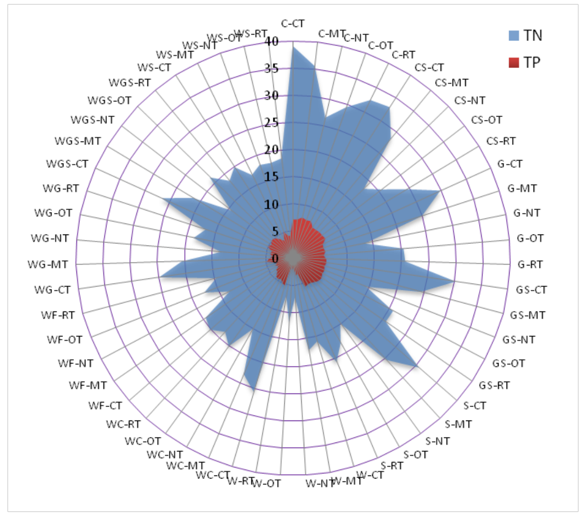
Figure F-8 Nutrient Load Cross Effect of CROP*FERT*BMPS



(a) With VFS **(b) Without VFS**

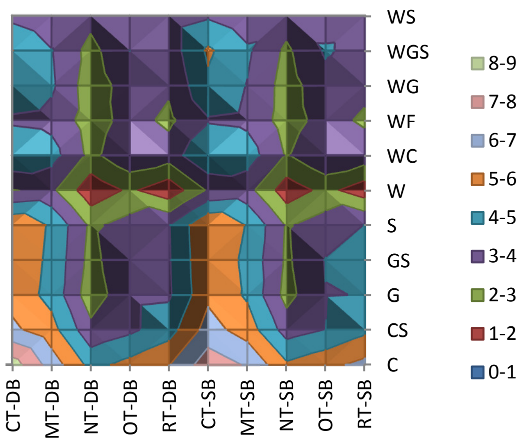
Figure F-9 Nutrient Load Cross Effect of CROP*TILL*BMPS



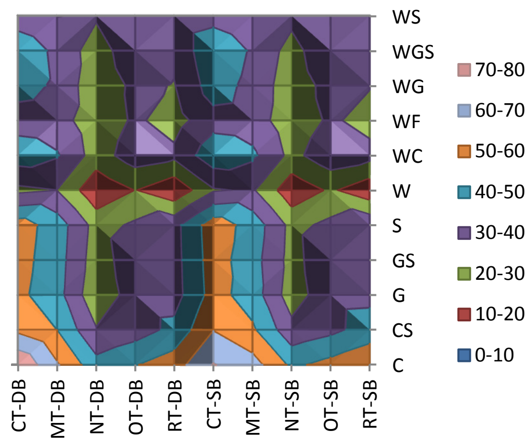


(a) Sub-surface Fertilizer (DB) (b) Surface Fertilizer (SB)

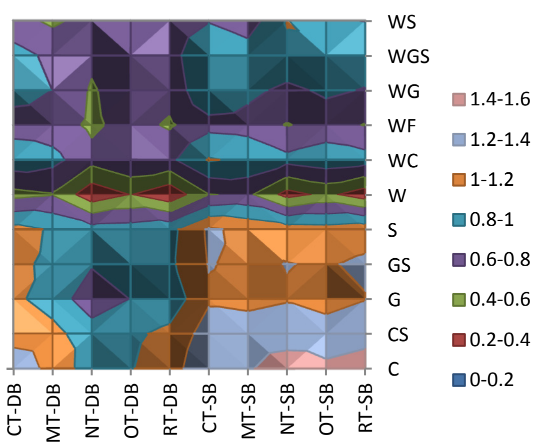
Figure F-10 Nutrient Load Cross Effect of CROP*TILL*FERT



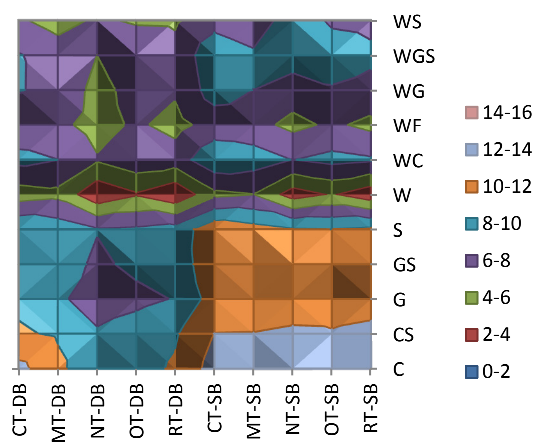
(a) TN Load With VFS



(b) TN Load Without VFS



(c) TP Load With VFS



(d) TP Load Without VFS

Figure F-11 Nutrient Load Cross Effect of CROP*TILL*FERT*BMPS

F.1.5 Fish's Least-Significant-Difference (LSD)

Table F-4 LSD Test for TN and TP Load on CROP

TN t Group	Mean	CROP	TP t Group		Mean	CROP
A	32.268	C		A	6.498	C
B	24.486	CS		B	6.005	CS
C	21.915	GS		C	5.508	GS
C	21.734	S	D	C	5.352	S
C	21.455	G	D		5.203	G
D	20.117	WC		E	4.440	WC
D	20.093	WGS		E	4.403	WGS
E	18.640	WG		F	4.036	WG
F	17.951	WS		G	3.733	WS
G	16.843	WF		H	3.366	WF
H	11.537	W		I	2.211	W

Table F-5 LSD Test for TN and TP Load on TILL

TN t Grouping	Mean	TILL	TP t Grouping	Mean	TILL
A	26.838	CT	A	5.043	CT
B	23.170	MT	B	4.735	MT
C	19.297	OT	C	4.532	OT
C	19.004	RT	C	4.471	RT
D	14.890	NT	D	4.289	NT

Table F-6 LSD Test for TN and TP Load on FERT

TN t Grouping	Mean	FERT	TP t Grouping	Mean	FERT
A	20.955	SB	A	5.099	SB
B	20.325	DB	B	4.129	DB

Table F-7 LSD Test for TN and TP Load on BMPS

TN t Grouping	Mean	BMPS	TP t Grouping	Mean	BMPS
A	37.278	WO	A	8.333	WO
B	4.002	FS	B	0.896	FS

F.2 Annual Nutrient Load Reduction

F.2.1 ANOVA Overall Information

F.2.1.1 *Class Level:*

Class	Levels	Values
AGCROP	121	CS_C CS_CS CS_G CS_GS CS_S CS_W CS_WC CS_WF CS_WG CS_WGS CS_WS C_C C_CS C_G C_GS C_S C_W C_WC C_WF C_WG C_WGS C_WS GS_C GS_CS GS_G GS_GS GS_S GS_W GS_WC GS_WF GS_WG GS_WGS GS_WS G_C G_CS G_G G_GS G_S G_W G_WC G_WF G_WG G_WGS G_WS S_C S_CS S_G S_GS S_S S_W S_WC S_WF S_WG S_WGS S_WS WC_C WC_CS WC_G WC_GS WC_S WC_W WC_WC WC_WF WC_WG WC_WGS WC_WS WF_C WF_CS WF_G WF_GS WF_S WF_W WF_WC WF_WF WF_WG WF_WGS WF_WS WGS_C WGS_CS WGS_G WGS_GS WGS_S WGS_W WGS_WC WGS_WF WGS_WG WGS_WGS WGS_WS WG_C WG_CS WG_G WG_GS WG_S WG_W WG_WC WG_WF WG_WG WG_WGS WG_WS WS_C WS_CS WS_G WS_GS WS_S WS_W WS_WC WS_WF WS_WG WS_WGS WS_WS W_C W_CS W_G W_GS W_S W_W W_WC W_WF W_WG W_WGS W_WS
AGTILL	25	CT_CT CT_MT CT_NT CT_OT CT_RT MT_CT MT_MT MT_NT MT_OT MT_RT NT_CT NT_MT NT_NT NT_OT NT_RT OT_CT OT_MT OT_NT OT_OT OT_RT RT_CT RT_MT RT_NT RT_OT RT_RT
AGFERT	4	DB_DB DB_SB SB_DB SB_SB
AGBMPS	4	FS_FS FS_WO WO_FS WO_WO

F.2.1.2 *Total Nitrogen (TN)*

Overall ANOVA:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3903	33598638.30	8608.41	1537.73	<.0001
Error	44496	249094.96	5.60		
Corrected Total	48399	33847733.26			

Model ANOVA:

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AGBMPS	3	26795479.50	8931826.50	1595498.16	<.0001
AGCROP	120	2310596.98	19254.97	3439.53	<.0001
AGFERT	3	9622.05	3207.35	572.93	<.0001
AGTILL	24	1594540.38	66439.18	11868.08	<.0001
AGCROP*AGBMPS	360	1501486.51	4170.80	745.03	<.0001
AGFERT*AGBMPS	9	6252.62	694.74	124.10	<.0001
AGTILL*AGBMPS	72	1036158.48	14391.09	2570.69	<.0001
AGCROP*AGFERT	360	1386.26	3.85	0.69	1
AGCROP*AGTILL	2880	341196.59	118.47	21.16	<.0001
AGTILL*AGFERT	72	1918.94	26.65	4.76	<.0001

F.2.1.3 *Total Phosphorus (TP)*

Overall ANOVA:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3903	1630767.27	417.82	1349.16	<.0001
Error	44496	13780.07	0.31		
Corrected Total	48399	1644547.33			

Model ANOVA:

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AGBMPS	3	1338539.04	446179.68	1440719.67	<.0001
AGCROP	120	138131.22	1151.09	3716.89	<.0001
AGFERT	3	22760.52	7586.84	24498.00	<.0001
AGTILL	24	6423.38	267.64	864.22	<.0001
AGCROP*AGBMPS	360	89765.94	249.35	805.15	<.0001
AGFERT*AGBMPS	9	14790.94	1643.44	5306.68	<.0001
AGTILL*AGBMPS	72	4173.02	57.96	187.15	<.0001
AGCROP*AGFERT	360	6547.46	18.19	58.73	<.0001
AGCROP*AGTILL	2880	7087.41	2.46	7.95	<.0001
AGTILL*AGFERT	72	2548.33	35.39	114.29	<.0001

F.2.2 ANOVA Main Effect

Pr > |t| for H0: LSMean(i)=LSMean(j)

Least Squares Means for effect AGBMPS

TN	AGBMPS	LSMEAN	Number	TP	AGBMPS	LSMEAN	Number
	FS_FS	0.000	1		FS_FS	0.000	1
	FS_WO	-33.275	2		FS_WO	-7.437	2
	WO_FS	33.275	3		WO_FS	7.437	3
	WO_WO	0.000	4		WO_WO	0.000	4

TN	i/j	1	2	3	4	TP	i/j	1	2	3	4
	1		<.0001	<.0001	1		1		<.0001	<.0001	1
	2	<.0001		<.0001	<.0001		2	<.0001		<.0001	<.0001
	3	<.0001	<.0001		<.0001		3	<.0001	<.0001		<.0001
	4	1	<.0001	<.0001			4	1	<.0001	<.0001	

Least Squares Means for effect AGFERT

TN	AGFERT	LSMEAN	Number	TP	AGFERT	LSMEAN	Number
	DB_DB	0.000	1		DB_DB	0.000	1
	DB_SB	-0.631	2		DB_SB	-0.970	2
	SB_DB	0.631	3		SB_DB	0.970	3
	SB_SB	0.000	4		SB_SB	0.000	4

TN	i/j	1	2	3	4	TP	i/j	1	2	3	4
	1		<.0001	<.0001	1		1		<.0001	<.0001	1
	2	<.0001		<.0001	<.0001		2	<.0001		<.0001	<.0001
	3	<.0001	<.0001		<.0001		3	<.0001	<.0001		<.0001
	4	1	<.0001	<.0001			4	1	<.0001	<.0001	

Least Squares Means for effect AGTILL

TN	AGTILL	LSMEAN	Number	TP	AGTILL	LSMEAN	Number
	CT_CT	0.000	1		CT_CT	0.000	1
	CT_MT	3.668	2		CT_MT	0.308	2
	CT_NT	11.948	3		CT_NT	0.755	3
	CT_OT	7.541	4		CT_OT	0.511	4
	CT_RT	7.835	5		CT_RT	0.572	5
	MT_CT	-3.668	6		MT_CT	-0.308	6

TN	AGTILL	LSMEAN	Number
	MT_MT	0.000	7
	MT_NT	8.280	8
	MT_OT	3.873	9
	MT_RT	4.167	10
	NT_CT	-11.948	11
	NT_MT	-8.280	12
	NT_NT	0.000	13
	NT_OT	-4.407	14
	NT_RT	-4.113	15
	OT_CT	-7.541	16
	OT_MT	-3.873	17
	OT_NT	4.407	18
	OT_OT	0.000	19
	OT_RT	0.294	20
	RT_CT	-7.835	21
	RT_MT	-4.167	22
	RT_NT	4.113	23
	RT_OT	-0.294	24
	RT_RT	0.000	25

TP	AGTILL	LSMEAN	Number
	MT_MT	0.000	7
	MT_NT	0.446	8
	MT_OT	0.203	9
	MT_RT	0.264	10
	NT_CT	-0.755	11
	NT_MT	-0.446	12
	NT_NT	0.000	13
	NT_OT	-0.243	14
	NT_RT	-0.183	15
	OT_CT	-0.511	16
	OT_MT	-0.203	17
	OT_NT	0.243	18
	OT_OT	0.000	19
	OT_RT	0.061	20
	RT_CT	-0.572	21
	RT_MT	-0.264	22
	RT_NT	0.183	23
	RT_OT	-0.061	24
	RT_RT	0.000	25

TN Load Reduction

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.0247	<.0001	<.0001	<.0001	0.0247	1.0000
2	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.5348	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	0.0247		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.5348	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
7	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.0247	<.0001	<.0001	<.0001	0.0247	1.0000
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	0.5348	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2173	<.0001	<.0001
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2173	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
12	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
13	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.0247	<.0001	<.0001	<.0001	0.0247	1.0000
14	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2173	<.0001	<.0001	<.0001
15	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247		<.0001	0.2173	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001
16	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001
17	<.0001	<.0001	<.0001	<.0001	<.0001	0.5348	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2173	<.0001		<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001
18	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2173	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001
19	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001		0.0247	<.0001	<.0001	<.0001	0.0247	1.0000
20	0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247		<.0001	<.0001	<.0001	<.0001	0.0247
21	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
22	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2173	1.0000	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
23	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.2173	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001
24	0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001	<.0001	0.0247	<.0001	<.0001	<.0001	<.0001		0.0247
25	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.0247	<.0001	<.0001	<.0001	0.0247	

TP Load Reduction

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.1149	<.0001	<.0001	<.0001	0.1149	1.0000
2	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.6900	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0516	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		0.1149	<.0001	<.0001	0.0516	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	0.1149		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0516	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.6900	<.0001	<.0001	<.0001
7	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.1149	<.0001	<.0001	<.0001	0.1149	1.0000
8	<.0001	<.0001	<.0001	0.0516	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.1149	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.8590	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001
10	<.0001	0.6900	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	0.0016	<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
12	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	0.0516	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
13	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.1149	<.0001	<.0001	<.0001	0.1149	1.0000
14	<.0001	<.0001	<.0001	<.0001	<.0001	0.0516	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.1149	<.0001	0.8590	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001
15	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149		<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	0.0016	<.0001	<.0001	<.0001
16	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0516	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001
17	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.8590	1.0000	<.0001		<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001
18	<.0001	0.0516	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.8590	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001
19	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001		0.1149	<.0001	<.0001	<.0001	0.1149	1.0000
20	0.1149	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149		<.0001	<.0001	<.0001	<.0001	0.1149
21	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
22	<.0001	<.0001	<.0001	<.0001	<.0001	0.6900	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.0016	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
23	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.0016	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001
24	0.1149	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001	<.0001	0.1149	<.0001	<.0001	<.0001	<.0001		0.1149
25	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.1149	<.0001	<.0001	<.0001	0.1149	

Least Squares Means for effect AGCROP

TN		LSMEAN	TN		LSMEAN	TN		LSMEAN	AGCROP	LSMEAN	Number
AGCROP	LSMEAN	Number	AGCROP	LSMEAN	Number	AGCROP	LSMEAN	Number	WG_G	-2.815	91
CS_C	-7.782	1	GS_WG	3.274	31	WC_W	8.579	61	WG_GS	-3.274	92
CS_CS	0.000	2	GS_WGS	1.822	32	WC_WC	0.000	62	WG_S	-3.094	93
CS_G	3.031	3	GS_WS	3.964	33	WC_WF	3.274	63	WG_W	7.103	94
CS_GS	2.572	4	G_C	-10.813	34	WC_WG	1.476	64	WG_WC	-1.476	95
CS_S	2.752	5	G_CS	-3.031	35	WC_WGS	0.024	65	WG_WF	1.798	96
CS_W	12.949	6	G_G	0.000	36	WC_WS	2.165	66	WG_WG	0.000	97
CS_WC	4.370	7	G_GS	-0.460	37	WF_C	-15.425	67	WG_WGS	-1.452	98
CS_WF	7.644	8	G_S	-0.279	38	WF_CS	-7.644	68	WG_WS	0.689	99
CS_WG	5.846	9	G_W	9.918	39	WF_G	-4.612	69	WS_C	-14.317	100
CS_WGS	4.394	10	G_WC	1.338	40	WF_GS	-5.072	70	WS_CS	-6.535	101
CS_WS	6.535	11	G_WF	4.612	41	WF_S	-4.892	71	WS_G	-3.504	102
C_C	0.000	12	G_WG	2.815	42	WF_W	5.305	72	WS_GS	-3.964	103
C_CS	7.782	13	G_WGS	1.362	43	WF_WC	-3.274	73	WS_S	-3.783	104
C_G	10.813	14	G_WS	3.504	44	WF_WF	0.000	74	WS_W	6.414	105
C_GS	10.353	15	S_C	-10.534	45	WF_WG	-1.798	75	WS_WC	-2.165	106
C_S	10.534	16	S_CS	-2.752	46	WF_WGS	-3.250	76	WS_WF	1.109	107
C_W	20.730	17	S_G	0.279	47	WF_WS	-1.109	77	WS_WG	-0.689	108
C_WC	12.151	18	S_GS	-0.181	48	WGS_C	-12.175	78	WS_WGS	-2.142	109
C_WF	15.425	19	S_S	0.000	49	WGS_CS	-4.394	79	WS_WS	0.000	110
C_WG	13.628	20	S_W	10.197	50	WGS_G	-1.362	80	W_C	-20.730	111
C_WGS	12.175	21	S_WC	1.617	51	WGS_GS	-1.822	81	W_CS	-12.949	112
C_WS	14.317	22	S_WF	4.892	52	WGS_S	-1.641	82	W_G	-9.918	113
GS_C	-10.353	23	S_WG	3.094	53	WGS_W	8.555	83	W_GS	-10.377	114
GS_CS	-2.572	24	S_WGS	1.641	54	WGS_WC	-0.024	84	W_S	-10.197	115
GS_G	0.460	25	S_WS	3.783	55	WGS_WF	3.250	85	W_W	0.000	116
GS_GS	0.000	26	WC_C	-12.151	56	WGS_WG	1.452	86	W_WC	-8.579	117
GS_S	0.181	27	WC_CS	-4.370	57	WGS_WGS	0.000	87	W_WF	-5.305	118
GS_W	10.377	28	WC_G	-1.338	58	WGS_WS	2.142	88	W_WG	-7.103	119
GS_WC	1.798	29	WC_GS	-1.798	59	WG_C	-13.628	89	W_WGS	-8.555	120
GS_WF	5.072	30	WC_S	-1.617	60	WG_CS	-5.846	90	W_WS	-6.414	121

TP AGCROP	LSMEAN	LSMEAN Number	TP AGCROP	LSMEAN	LSMEAN Number	TP AGCROP	LSMEAN	LSMEAN Number	TP AGCROP	LSMEAN	LSMEAN Number
CS_C	-0.493	1	GS_WG	1.473	31	WC_W	2.229	61	WG_G	-1.168	91
CS_CS	0.000	2	GS_WGS	1.105	32	WC_WC	0.000	62	WG_GS	-1.473	92
CS_G	0.802	3	GS_WS	1.775	33	WC_WF	1.074	63	WG_S	-1.317	93
CS_GS	0.497	4	G_C	-1.295	34	WC_WG	0.404	64	WG_W	1.825	94
CS_S	0.653	5	G_CS	-0.802	35	WC_WGS	0.037	65	WG_WC	-0.404	95
CS_W	3.795	6	G_G	0.000	36	WC_WS	0.707	66	WG_WF	0.669	96
CS_WC	1.565	7	G_GS	-0.305	37	WF_C	-3.132	67	WG_WG	0.000	97
CS_WF	2.639	8	G_S	-0.149	38	WF_CS	-2.639	68	WG_WGS	-0.367	98
CS_WG	1.970	9	G_W	2.993	39	WF_G	-1.837	69	WG_WS	0.302	99
CS_WGS	1.602	10	G_WC	0.763	40	WF_GS	-2.142	70	WS_C	-2.765	100
CS_WS	2.272	11	G_WF	1.837	41	WF_S	-1.986	71	WS_CS	-2.272	101
C_C	0.000	12	G_WG	1.168	42	WF_W	1.156	72	WS_G	-1.470	102
C_CS	0.493	13	G_WGS	0.800	43	WF_WC	-1.074	73	WS_GS	-1.775	103
C_G	1.295	14	G_WS	1.470	44	WF_WF	0.000	74	WS_S	-1.619	104
C_GS	0.990	15	S_C	-1.146	45	WF_WG	-0.669	75	WS_W	1.523	105
C_S	1.146	16	S_CS	-0.653	46	WF_WGS	-1.037	76	WS_WC	-0.707	106
C_W	4.288	17	S_G	0.149	47	WF_WS	-0.367	77	WS_WF	0.367	107
C_WC	2.058	18	S_GS	-0.156	48	WGS_C	-2.095	78	WS_WG	-0.302	108
C_WF	3.132	19	S_S	0.000	49	WGS_CS	-1.602	79	WS_WGS	-0.670	109
C_WG	2.463	20	S_W	3.142	50	WGS_G	-0.800	80	WS_WS	0.000	110
C_WGS	2.095	21	S_WC	0.912	51	WGS_GS	-1.105	81	W_C	-4.288	111
C_WS	2.765	22	S_WF	1.986	52	WGS_S	-0.949	82	W_CS	-3.795	112
GS_C	-0.990	23	S_WG	1.317	53	WGS_W	2.192	83	W_G	-2.993	113
GS_CS	-0.497	24	S_WGS	0.949	54	WGS_WC	-0.037	84	W_GS	-3.298	114
GS_G	0.305	25	S_WS	1.619	55	WGS_WF	1.037	85	W_S	-3.142	115
GS_GS	0.000	26	WC_C	-2.058	56	WGS_WG	0.367	86	W_W	0.000	116
GS_S	0.156	27	WC_CS	-1.565	57	WGS_WGS	0.000	87	W_WC	-2.229	117
GS_W	3.298	28	WC_G	-0.763	58	WGS_WS	0.670	88	W_WF	-1.156	118
GS_WC	1.068	29	WC_GS	-1.068	59	WG_C	-2.463	89	W_WG	-1.825	119
GS_WF	2.142	30	WC_S	-0.912	60	WG_CS	-1.970	90	W_WGS	-2.192	120
									W_WS	-1.523	121

F.2.3 Fish's Least-Significant-Difference (LSD)

Table F-8 LSD Test for TN and TP Load Reduction on AGCROP

TN t Grouping		Mean	N	AGCROP	TP t Grouping		Mean	N	AGCROP
	A	20.730	400	C_W		A	4.288	400	C_W
	B	15.425	400	C_WF		B	3.795	400	CS_W
	C	14.317	400	C_WS		C	3.298	400	GS_W
	D	13.628	400	C_WG		D	3.142	400	S_W
	E	12.949	400	CS_W		D	3.132	400	C_WF
	F	12.175	400	C_WGS		E	2.993	400	G_W
	F	12.151	400	C_WC		F	2.765	400	C_WS
	G	10.813	400	C_G		G	2.639	400	CS_WF
H	G	10.534	400	C_S		H	2.463	400	C_WG
H	I	10.377	400	GS_W		I	2.272	400	CS_WS
H	I	10.353	400	C_GS	J	I	2.229	400	WC_W
J	I	10.197	400	S_W	J	K	2.192	400	WGS_W
J		9.918	400	G_W	L	K	2.142	400	GS_WF
	K	8.579	400	WC_W	L	M	2.095	400	C_WGS
	K	8.555	400	WGS_W	N	M	2.058	400	C_WC
	L	7.782	400	C_CS	N	O	1.986	400	S_WF
	L	7.644	400	CS_WF		O	1.970	400	CS_WG
	M	7.103	400	WG_W		P	1.837	400	G_WF
	N	6.535	400	CS_WS		P	1.825	400	WG_W
	N	6.414	400	WS_W		P	1.775	400	GS_WS

TN t Grouping			Mean	N	AGCROP
	O		5.846	400	CS_WG
	P		5.305	400	WF_W
Q	P		5.072	400	GS_WF
Q	R		4.892	400	S_WF
S	R		4.612	400	G_WF
S			4.394	400	CS_WGS
S			4.370	400	CS_WC
	T		3.964	400	GS_WS
U	T		3.783	400	S_WS
U	V		3.504	400	G_WS
W	V		3.274	400	GS_WG
W	V		3.274	400	WC_WF
W	V		3.250	400	WGS_WF
W	X		3.094	400	S_WG
W	X	Y	3.031	400	CS_G
Z	X	Y	2.815	400	G_WG
Z		Y	2.752	400	CS_S
Z			2.572	400	CS_GS
	A		2.165	400	WC_WS
B	A		2.142	400	WGS_WS
B	C		1.822	400	GS_WGS
D	C		1.798	400	GS_WC
D	C		1.798	400	WG_WF
D	C	E	1.641	400	S_WGS
D	C	E	1.617	400	S_WC
D		E	1.476	400	WC_WG
		E	1.452	400	WGS_WG
	F	E	1.362	400	G_WGS
	F	E	1.338	400	G_WC
	F		1.109	400	WS_WF
	G		0.689	400	WG_WS
H	G		0.460	400	GS_G
H	I		0.279	400	S_G
H	I		0.181	400	GS_S
J	I		0.024	400	WC_WGS
J	I		0.000	400	G_G
J	I		0.000	400	W_W
J	I		0.000	400	C_C
J	I		0.000	400	S_S
J	I		0.000	400	WS_WS
J	I		0.000	400	WC_WC
J	I		0.000	400	WF_WF
J	I		0.000	400	GS_GS
J	I		0.000	400	WG_WG
J	I		0.000	400	WGS_WGS
J	I		0.000	400	CS_CS
J	I		-0.024	400	WGS_WC
J	K		-0.181	400	S_GS
J	K		-0.279	400	G_S

TP t Grouping			Mean	N	AGCROP
	Q		1.619	400	S_WS
	Q		1.602	400	CS_WGS
R	Q		1.565	400	CS_WC
R	S		1.523	400	WS_W
	S		1.473	400	GS_WG
	S		1.470	400	G_WS
	T		1.317	400	S_WG
	T		1.295	400	C_G
	U		1.168	400	G_WG
	U		1.156	400	WF_W
V	U		1.146	400	C_S
V	U	W	1.105	400	GS_WGS
V		W	1.074	400	WC_WF
		W	1.068	400	GS_WC
	X	W	1.037	400	WGS_WF
Y	X		0.990	400	C_GS
Y	Z		0.949	400	S_WGS
	Z		0.912	400	S_WC
	A		0.802	400	CS_G
	A		0.800	400	G_WGS
B	A		0.763	400	G_WC
B	C		0.707	400	WC_WS
	C		0.670	400	WGS_WS
	C		0.669	400	WG_WF
	C		0.653	400	CS_S
	D		0.497	400	CS_GS
	D		0.493	400	C_CS
	E		0.404	400	WC_WG
F	E		0.367	400	WGS_WG
F	E		0.367	400	WS_WF
F			0.305	400	GS_G
F			0.302	400	WG_WS
	G		0.156	400	GS_S
	G		0.149	400	S_G
	H		0.037	400	WC_WGS
	H		0.000	400	C_C
	H		0.000	400	WC_WC
	H		0.000	400	WGS_WGS
	H		0.000	400	WG_WG
	H		0.000	400	WF_WF
	H		0.000	400	CS_CS
	H		0.000	400	W_W
	H		0.000	400	WS_WS
	H		0.000	400	S_S
	H		0.000	400	GS_GS
	H		0.000	400	G_G
	H		-0.037	400	WGS_WC
	I		-0.149	400	G_S
	I		-0.156	400	S_GS

TN t Grouping			Mean	N	AGCROP
L	K		-0.460	400	G_GS
L			-0.689	400	WS_WG
	M		-1.109	400	WF_WS
N	M		-1.338	400	WC_G
N	M		-1.362	400	WGS_G
N			-1.452	400	WG_WGS
N	O		-1.476	400	WG_WC
N	O	P	-1.617	400	WC_S
N	O	P	-1.641	400	WGS_S
	O	P	-1.798	400	WF_WG
	O	P	-1.798	400	WC_GS
	Q	P	-1.822	400	WGS_GS
R	Q		-2.142	400	WS_WGS
R			-2.165	400	WS_WC
	S		-2.572	400	GS_CS
T	S		-2.752	400	S_CS
T	S	U	-2.815	400	WG_G
T	V	U	-3.031	400	G_CS
	V	U	-3.094	400	WG_S
W	V		-3.250	400	WF_WGS
W	V		-3.274	400	WF_WC
W	V		-3.274	400	WG_GS
W	X		-3.504	400	WS_G
Y	X		-3.783	400	WS_S
Y			-3.964	400	WS_GS
	Z		-4.370	400	WC_CS
	Z		-4.394	400	WGS_CS
A	Z		-4.612	400	WF_G
A	B		-4.892	400	WF_S
C	B		-5.072	400	WF_GS
C			-5.305	400	W_WF
	D		-5.846	400	WG_CS
	E		-6.414	400	W_WS
	E		-6.535	400	WS_CS
	F		-7.103	400	W_WG
	G		-7.644	400	WF_CS
	G		-7.782	400	CS_C
	H		-8.555	400	W_WGS
	H		-8.579	400	W_WC
	I		-9.918	400	W_G
J	I		-10.197	400	W_S
J	K		-10.353	400	GS_C
J	K		-10.377	400	W_GS
L	K		-10.534	400	S_C
L			-10.813	400	G_C
	M		-12.151	400	WC_C
	M		-12.175	400	WGS_C
	N		-12.949	400	W_CS
	O		-13.628	400	WG_C

TP t Grouping			Mean	N	AGCROP
	J		-0.302	400	WS_WG
	J		-0.305	400	G_GS
K	J		-0.367	400	WF_WS
K	J		-0.367	400	WG_WGS
K			-0.404	400	WG_WC
	L		-0.493	400	CS_C
	L		-0.497	400	GS_CS
	M		-0.653	400	S_CS
	M		-0.669	400	WF_WG
	M		-0.670	400	WS_WGS
N	M		-0.707	400	WS_WC
N	O		-0.763	400	WC_G
	O		-0.800	400	WGS_G
	O		-0.802	400	G_CS
	P		-0.912	400	WC_S
Q	P		-0.949	400	WGS_S
Q	R		-0.990	400	GS_C
S	R		-1.037	400	WF_WGS
S			-1.068	400	WC_GS
S	T		-1.074	400	WF_WC
S	T	U	-1.105	400	WGS_GS
	T	U	-1.146	400	S_C
		U	-1.156	400	W_WF
		U	-1.168	400	WG_G
	V		-1.295	400	G_C
	V		-1.317	400	WG_S
	W		-1.470	400	WS_G
	W		-1.473	400	WG_GS
X	W		-1.523	400	W_WS
X	Y		-1.565	400	WC_CS
	Y		-1.602	400	WGS_CS
	Y		-1.619	400	WS_S
	Z		-1.775	400	WS_GS
	Z		-1.825	400	W_WG
	Z		-1.837	400	WF_G
	A		-1.970	400	WG_CS
B	A		-1.986	400	WF_S
B	C		-2.058	400	WC_C
D	C		-2.095	400	WGS_C
D	E		-2.142	400	WF_GS
F	E		-2.192	400	W_WGS
F	G		-2.229	400	W_WC
	G		-2.272	400	WS_CS
	H		-2.463	400	WG_C
	I		-2.639	400	WF_CS
	J		-2.765	400	WS_C
	K		-2.993	400	W_G
	L		-3.132	400	WF_C
	L		-3.142	400	W_S

TN t Grouping	Mean	N	AGCROP
P	-14.317	400	WS_C
Q	-15.425	400	WF_C
R	-20.730	400	W_C

TP t Grouping	Mean	N	AGCROP
M	-3.298	400	W_GS
N	-3.795	400	W_CS
O	-4.288	400	W_C

Table F-9 LSD Test for TN and TP Load Reduction on AGTILL

TN Group	Mean	N	AGFERT
A	0.631	12100	SB_DB
B	0.000	12100	DB_DB
B	0.000	12100	SB_SB
C	-0.631	12100	DB_SB

TP Group	Mean	N	AGFERT
A	0.970	12100	SB_DB
B	0.000	12100	SB_SB
B	0.000	12100	DB_DB
C	-0.970	12100	DB_SB

Table F-10 LSD Test for TN and TP Load Reduction on AGFERT

TN t Group	Mean	N	AGTILL
A	11.948	1936	CT_NT
B	8.280	1936	MT_NT
C	7.835	1936	CT_RT
D	7.541	1936	CT_OT
E	4.407	1936	OT_NT
F	4.167	1936	MT_RT
F	4.113	1936	RT_NT
G	3.873	1936	MT_OT
H	3.668	1936	CT_MT
I	0.294	1936	OT_RT
J	0.000	1936	MT_MT
J	0.000	1936	RT_RT
J	0.000	1936	NT_NT
J	0.000	1936	OT_OT
J	0.000	1936	CT_CT
K	-0.294	1936	RT_OT
L	-3.668	1936	MT_CT
M	-3.873	1936	OT_MT
N	-4.113	1936	NT_RT
N	-4.167	1936	RT_MT
O	-4.407	1936	NT_OT
P	-7.541	1936	OT_CT
Q	-7.835	1936	RT_CT
R	-8.280	1936	NT_MT
S	-11.948	1936	NT_CT

TP t Group	Mean	N	AGTILL
A	0.755	1936	CT_NT
B	0.572	1936	CT_RT
C	0.511	1936	CT_OT
D	0.446	1936	MT_NT
E	0.308	1936	CT_MT
F	0.264	1936	MT_RT
F	0.243	1936	OT_NT
G	0.203	1936	MT_OT
G	0.183	1936	RT_NT
H	0.061	1936	OT_RT
I	0.000	1936	RT_RT
I	0.000	1936	NT_NT
I	0.000	1936	OT_OT
I	0.000	1936	MT_MT
I	0.000	1936	CT_CT
J	-0.061	1936	RT_OT
K	-0.183	1936	NT_RT
K	-0.203	1936	OT_MT
L	-0.243	1936	NT_OT
L	-0.264	1936	RT_MT
M	-0.308	1936	MT_CT
N	-0.446	1936	NT_MT
O	-0.511	1936	OT_CT
P	-0.572	1936	RT_CT
Q	-0.755	1936	NT_CT

Table F-11 LSD Test for TN and TP Load Reduction on AGBMPS

TN t Group	Mean	N	AGBMPS
A	33.275	12100	WO_FS
B	0.000	12100	WO_WO
B	0.000	12100	FS_FS
C	-33.275	12100	FS_WO

TP t Group	Mean	N	AGBMPS
A	7.437	12100	WO_FS
B	0.000	12100	WO_WO
B	0.000	12100	FS_FS
C	-7.437	12100	FS_WO

F.3 Monthly Nutrient Load

F.3.1 ANOVA Overall Information

F.3.1.1 *Class Level:*

Class	Levels	Values
MN	12	1 2 3 4 5 6 7 8 9 10 11 12
SCEN	60	S1 S10 S11 S12 S13 S14 S15 S16 S17 S18 S19 S2 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S3 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S4 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S5 S50 S51 S52 S53 S54 S55 S56 S57 S58 S59 S6 S60 S7 S8 S9

F.3.1.2 *Total Nitrogen (TN)*

Overall ANOVA:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	70	3512.71	50.18	33.93	<.0001
Error	649	959.79	1.48		
Corrected Total	719	4472.50			

Model ANOVA:

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MN	11	955.61	86.87	58.74	<.0001
SCEN	59	2557.10	43.34	29.31	<.0001

F.3.1.3 *Total Phosphorus (TP)*

Overall ANOVA:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	70	181.03	2.59	32.25	<.0001
Error	649	52.05	0.08		
Corrected Total	719	233.09			

Model ANOVA:

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MN	11	59.69	5.43	67.65	<.0001
SCEN	59	121.35	2.06	25.64	<.0001

F.3.2 ANOVA Main Effect

Pr > |t| for H0: LSMean(i)=LSMean(j)

Least Squares Means for effect MN

TN	MN	LSMEAN	LSMean Number	TP	MN	LSMEAN	LSMean Number
	1	1.633	1		1	0.330	1
	2	1.658	2		2	0.354	2
	3	1.620	3		3	0.361	3
	4	2.551	4		4	0.544	4
	5	5.179	5		5	1.212	5
	6	3.702	6		6	0.983	6
	7	1.338	7		7	0.336	7
	8	0.786	8		8	0.185	8
	9	2.368	9		9	0.485	9
	10	2.091	10		10	0.473	10
	11	1.585	11		11	0.349	11
	12	1.438	12		12	0.314	12

TN i/j	1	2	3	4	5	6	7	8	9	10	11	12
1		1	1	0.002	< .0001	< .0001	0.975	0.008	0.045	0.652	1	1
2	1		1	0.004	< .0001	< .0001	0.955	0.005	0.064	0.728	1	0.998
3	1	1		0.002	< .0001	< .0001	0.982	0.010	0.038	0.610	1	1
4	0.002	0.004	0.002		< .0001	< .0001	< .0001	< .0001	1	0.641	0.001	< .0001
5	< .0001	< .0001	< .0001	< .0001		< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
6	< .0001	< .0001	< .0001	< .0001	< .0001		< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
7	0.975	0.955	0.982	< .0001	< .0001	< .0001		0.349	0.000	0.036	0.994	1
8	0.008	0.005	0.010	< .0001	< .0001	< .0001	0.349		< .0001	< .0001	0.018	0.130
9	0.045	0.064	0.038	1	< .0001	< .0001	0.000	< .0001		0.984	0.023	0.002
10	0.652	0.728	0.610	0.641	< .0001	< .0001	0.036	< .0001	0.984		0.494	0.130
11	1	1	1	0.001	< .0001	< .0001	0.994	0.018	0.023	0.494		1
12	1	0.998	1	< .0001	< .0001	< .0001	1	0.130	0.002	0.130	1	

TP i/j	1	2	3	4	5	6	7	8	9	10	11	12
1		1	1	0.002	< .0001	< .0001	1	0.175	0.115	0.204	1	1
2	1		1	0.014	< .0001	< .0001	1	0.050	0.327	0.487	1	1
3	1	1		0.023	< .0001	< .0001	1	0.033	0.416	0.585	1	0.999
4	0.002	0.014	0.023		< .0001	< .0001	0.004	< .0001	0.993	0.969	0.010	0.001
5	< .0001	< .0001	< .0001	< .0001		0.001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
6	< .0001	< .0001	< .0001	< .0001	0.001		< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
7	1	1	1	0.004	< .0001	< .0001		0.134	0.152	0.259	1	1
8	0.175	0.050	0.033	< .0001	< .0001	< .0001	0.134		< .0001	< .0001	0.069	0.344
9	0.115	0.327	0.416	0.993	< .0001	< .0001	0.152	< .0001		1	0.263	0.046
10	0.204	0.487	0.585	0.969	< .0001	< .0001	0.259	< .0001	1		0.409	0.091
11	1	1	1	0.010	< .0001	< .0001	1	0.069	0.263	0.409		1
12	1	1	0.999	0.001	< .0001	< .0001	1	0.344	0.046	0.091	1	

Least Squares Means for effect SCEN

TN	SCEN	LSMEAN	LSMean Number	TP	SCEN	LSMEAN	LSMean Number
	S1	4.971	1		S1	1.003	1
	S10	0.397	2		S10	0.113	2
	S11	3.554	3		S11	0.815	3
	S12	0.382	4		S12	0.087	4
	S13	3.114	5		S13	1.023	5
	S14	0.334	6		S14	0.110	6
	S15	2.935	7		S15	0.746	7
	S16	0.315	8		S16	0.080	8
	S17	2.751	9		S17	1.026	9
	S18	0.295	10		S18	0.110	10
	S19	2.547	11		S19	0.703	11
	S2	0.534	12		S2	0.108	12
	S20	0.273	13		S20	0.075	13
	S21	5.877	14		S21	1.068	14
	S22	0.631	15		S22	0.115	15
	S23	5.611	16		S23	0.931	16
	S24	0.602	17		S24	0.100	17
	S25	5.350	18		S25	1.073	18
	S26	0.574	19		S26	0.115	19
	S27	5.088	20		S27	0.875	20
	S28	0.546	21		S28	0.094	21
	S29	4.878	22		S29	1.135	22
	S3	4.827	23		S3	0.853	23
	S30	0.524	24		S30	0.122	24
	S31	4.609	25		S31	0.857	25
	S32	0.495	26		S32	0.092	26
	S33	4.439	27		S33	1.110	27
	S34	0.477	28		S34	0.119	28
	S35	4.124	29		S35	0.767	29
	S36	0.443	30		S36	0.082	30
	S37	3.995	31		S37	1.151	31
	S38	0.429	32		S38	0.124	32
	S39	3.631	33		S39	0.698	33

TN	SCEN	LSMEAN	LSMean Number	TP	SCEN	LSMEAN	LSMean Number
	S4	0.518	34		S4	0.092	34
	S40	0.390	35		S40	0.075	35
	S41	4.630	36		S41	0.952	36
	S42	0.497	37		S42	0.102	37
	S43	4.566	38		S43	0.822	38
	S44	0.490	39		S44	0.088	39
	S45	3.825	40		S45	0.893	40
	S46	0.411	41		S46	0.096	41
	S47	3.767	42		S47	0.761	42
	S48	0.404	43		S48	0.082	43
	S49	3.123	44		S49	0.861	44
	S5	4.296	45		S5	1.005	45
	S50	0.335	46		S50	0.092	46
	S51	3.055	47		S51	0.727	47
	S52	0.328	48		S52	0.078	48
	S53	2.700	49		S53	0.833	49
	S54	0.290	50		S54	0.089	50
	S55	2.630	51		S55	0.688	51
	S56	0.282	52		S56	0.074	52
	S57	2.242	53		S57	0.842	53
	S58	0.241	54		S58	0.090	54
	S59	2.173	55		S59	0.675	55
	S6	0.461	56		S6	0.108	56
	S60	0.233	57		S60	0.073	57
	S7	4.161	58		S7	0.814	58
	S8	0.447	59		S8	0.087	59
	S9	3.697	60		S9	1.049	60

F.3.3 Fish's Least-Significant-Difference (LSD)

Table F-12LSD Test for TN and TP Load on MN

TN t Group		Mean	N	MN	TP t Group	Mean	N	MN
	A	5.179	60	5	A	1.212	60	5
	B	3.702	60	6	B	0.983	60	6
	C	2.551	60	4	C	0.544	60	4
D	C	2.368	60	9	C	0.485	60	9
D	E	2.091	60	10	C	0.473	60	10
F	E	1.658	60	2	D	0.361	60	3
F		1.633	60	1	D	0.354	60	2
F		1.620	60	3	D	0.349	60	11
F		1.585	60	11	D	0.336	60	7
F		1.438	60	12	D	0.330	60	1
F		1.338	60	7	D	0.314	60	12
	G	0.786	60	8	E	0.185	60	8

Appendix G Delivery Ratio Analysis

G.1 SWAT Outputs Analysis

As described in Section:4.5.1, SWAT calculated and recorded in an RCH table the nutrient loads in each stream section for individual subbasins. With SWAT RCH tables, the nutrient load reduction for each individual stream section can be calculated. In Eq. G-1, the subbasin inflow nutrient load equals the outflow nutrient load at the previous subbasin outlet for the intermediate subbasin. In contrast, the inflow load for a source subbasin is the load in the overland flow itself. For example in Figure G-1, the upstream subbasin of Subbasin #4 is Subbasin #1 and #2. The in-flow nutrient load of Subbasin #4 is equal to the sum of outflow loads of Subbasin #1 and #2 plus the in-field nutrient yield from Subbasin #4. Following Eq. G-1, the R_D for individual subbasin is then calculated. Furthermore, the cumulative delivery ratio for each subbasin to downstream watershed outlet or specific points can be explained as the product of a series of R_D of each subbasin in the path from subbasin to watershed outlet as Eq. G-2.

OI	SUBBASIN	DATE	FLOW_IN	FLOW_OUT	ORGN_IN	ORGN_OUT	ORGP_IN	ORGP_OUT	NO3_IN	NO3_OUT
0	1	1971	0.05332	0.053	112400	$\boxed{112000}$	17990	17930	1683	1343
1	2	1971	0.09014	0.08953	172700	$\boxed{172000}$	27630	27520	3600	2911
2	3	1971	0.1742	0.1729	360400	359400	56280	56120	6943	5798
3	4	1971	0.1461	0.1459	$\boxed{291700}$	291600	46600	46580	4453	4363
4	5	1971	0.02936	0.0292	69890	69570	10460	10410	2295	985.3
5	6	1971	0.2021	0.2021	428900	428900	66530	66530	6784	6784

$$SB4_{in} = SB1_{out} + SB2_{out} + SB4_{EOF}$$

Figure G-1 SWAT Output RCH Table for Delivery Ratio Analyzing

$$R_D = \frac{N_{out}}{N_{in}} \qquad \text{Eq. G-1}$$

Where:

R_D = the delivery ratio for a single stream segment
N_{in} = the flow-in Nutrient (TN or TP) load for stream segment
N_{out} = the flow-out Nutrient (TN or TP) load for stream segment

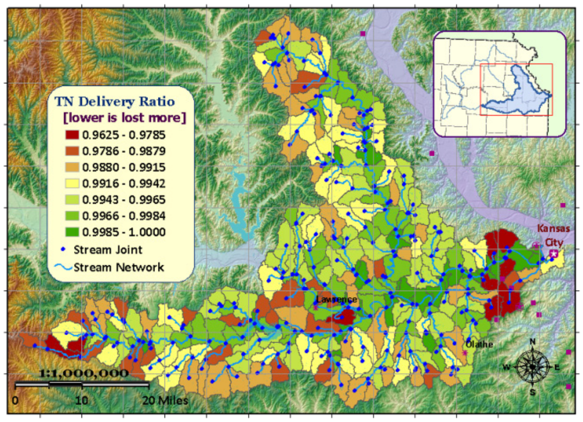
$$R_D^* = \frac{N_{out}}{N_{in}} \times R_{D_1} \times R_{D_2} \times R_{D_3} \times \cdots = \prod_{i=1}^{n} R_{D_i} \qquad \text{Eq. G-2}$$

Where:

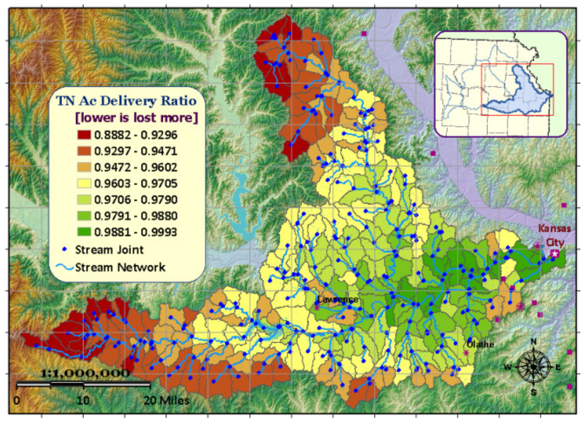
R_D^* = the cumulative delivery ratio from a subbasin to downstream watershed outlet or specific points
R_{D_i} = the delivery ratio for an individual stream segment i in delivery path

Figure G-2 (a) demonstrates the TN load R_D for each individual subbasin. Similarly, Figure G-2 (b) shows the TN load cumulative R_D for each subbasin to watershed outlet. Figure G-2 (a) seems no particular trend or cluster. Conversely, Figure G-2 (b) has a strong trend between flow length and cumulative R_D. The flow length will affect the storm water traveling time from upland to downstream;

and then traveling time will affect the nutrient loads decay or deposition. Therefore, an alternative method to develop R_D is using first-order kinetics function of nutrient load.



(a) Delivery Ratio for Each Individual Subbasin



(b) Cumulative Delivery Ratio to Watershed Outlet

Figure G-2 A General Pattern of the Delivery Ratio in Study Watershed

G.2 First-Order (Exponential) Kinetics

As described in Section: 4.4.6, A general first-order kinetics equation can be expressed as Eq. G-3. In Eq. G-3, C_{OUT} is the pollutant load concentration at the outlet while C_{IN} is the inflow pollutant load concentration; k_T is the decay coefficients at water temperature T (°C), and t (day) is the overall water traveling time from the remotest point of subbasin to downstream watershed outlet or specific points. The decay coefficient k_T might be affected by the water temperature (Eq. G-4), and the traveling time t might be affected by the watershed topography and its characteristics. In Eq. G-4, the k_T is the reaction rate at temperature T (°C) and θ is the temperature coefficient for a specific pollutant reaction. The water temperature can be estimated using the average daily air temperature (see Eq. G-5), which is used by SWAT (Neitsch et al., 2005). In Eq. G-5, the T_w is water temperature (°C) for a well-mixed stream segment, and $\bar{T}_{av}$ is the average daily air temperature on the ground (°C). Figure G-3 illustrates the monthly average air temperature which ranged from -3 to 26°C in the study watershed. In Figure G-3, the annual average air temperature in a red horizontal line is around 12.4°C.

$$C_{out} = C_{in} \cdot e^{-k_T t} \qquad \text{Eq. G-3}$$

$$k_T = k_{20} \cdot \theta^{T-20} \qquad \text{Eq. G-4}$$

$$T_w = 5.0 + 0.75 \times \bar{T}_{av} \qquad \text{Eq. G-5}$$

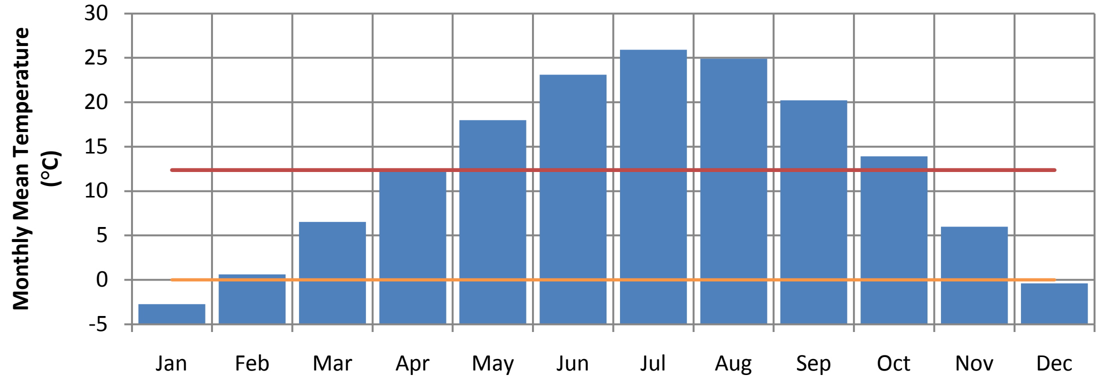


Figure G-3 Monthly Mean Temperature in Lowe Kansas Watershed

G.3 Travel Time Approximation

The travel time of the pollutant loads flow to the downstream watershed outlet or specific points are the summation of the time which storm water travel within the subbasin and the stream network. The traveling time with in a subbasin can be separated as the time of overland flow (storm water flows from the remotest point of subbasin to the edge of channel) and the time of channel flow (storm water flow from upstream channels to subbasin outlet). From the subbasin outlet to the watershed outlet, the storm water flows through stream network is in the channel flow status. Therefore, Eq. G-6 explained the potential traveling time of a subbasin. Moreover, SWAT assumed each subbasin is homogeneous and used the same hydraulic equations (Manning's formula) as Eq. G-7 to estimate the time of concentration for overland flow and traveling time of channel flow, but with different assumptions and parameters in channel geomorphometry (Neitsch et al., 2005).

$$t = T_{OC} + T_T = t_{ov} + t_{ch} + TT \qquad \text{Eq. G-6}$$

where:

T_{OC} = the time of concentration within a subbasin (hr)
t_{ov} = the time of concentration for overland flow (hr)
t_{ch} = the time of concentration for channel flow (hr)
T_T = traveling time through stream network (hr)
TT = traveling time for the channel flow in stream network (hr)

$$v = \frac{R^{\frac{2}{3}} S^{\frac{1}{2}}}{n} \qquad \text{Eq. G-7}$$

where:

v = average velocity (m/s)
R = hydraulic radius (m) and is equal to a/p_w
S = slope of the hydraulic grade line (channel slope, m/m)
n = Manning's roughness coefficient for open channel flow.
a = cross sectional flow area (m^2)
p_w = wetted perimeter (m)

G.3.1 Subbasin Time of Concentration

The time of concentration describes a period of time that storm water flow from the beginning of a rainfall event to the entire rainfall drop reaching at the subbasin outlet. The time of concentration is composed with overland flow time and channel flow time. SWAT assumed the average flow rate of the rain drop from the remotest point to outlet of subbasin is 6.35 mm/hr (2.5 in./hr) and converting the units, the time of overland flow concentration (t_{ov}) is defined as Eq. G-8 (Neitsch et al., 2005). In Eq. G-8, where the L is the subbasin field slope length in meter (m), S is the subbasin slope (m/m), n is the Manning's roughness coefficient for the subbasin and 18 is the unit conversion factor.

$$t_{ov} = \frac{L^{0.6} \times n^{0.6}}{18 \times S^{0.3}} \qquad \text{Eq. G-8}$$

where:

t_{ov} = the time of concentration for overland flow (hr)
L = the subbasin (overland flow) slope length (m)
S = the average slope in the subbasin (m/m)
n = Manning’s roughness coefficient for the subbasin (overland).
18 = a unit conversion factor.

In SWAT, the time of concentration of rain drop traveling in the channel was expressed as the length of longest flow path of a subbasin divided by the flow velocity (Neitsch et al., 2005). Based on Manning's equation and assuming a trapezoidal channel with 2:1 channel side slope and 10:1 flood plan bottom width-depth ratio, SWAT explained the time of channel flow concentration (t_{ch}) with the channel length (L) in kilometer (km), subbasin area (A) in square kilometer (km^2), longest path slope (m/m), Manning's roughness coefficient (n) for the tributary stream in the subbasin, and the unit conversion factor 0.62 as Eq. G-9 (Neitsch et al., 2005). The final time of concentration (T_{oc}) for each subbasin can be then estimated by combining Eq. G-8 and Eq. G-9 in hours.

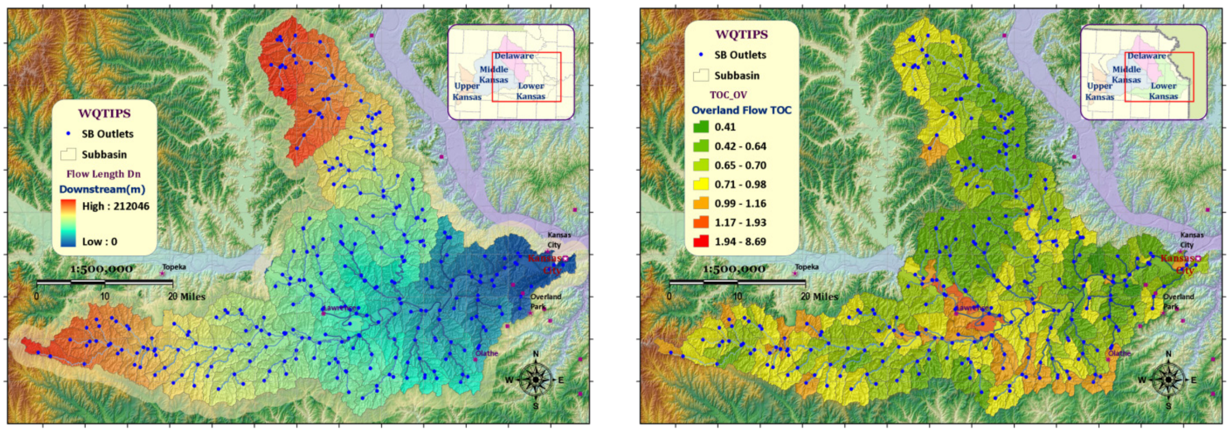
$$t_{ch} = \frac{0.62 \times L \times n^{0.75}}{A^{0.125} \times S^{0.375}} \qquad \text{Eq. G-9}$$

where:

t_{ch} = the time of concentration for channel flow (hr)
L = the channel length from the most distant point to the subbasin outlet (km)
n = Manning’s roughness coefficient for the channel
A = the subbasin (source) area (km^2)
S = the channel slope (m/m).

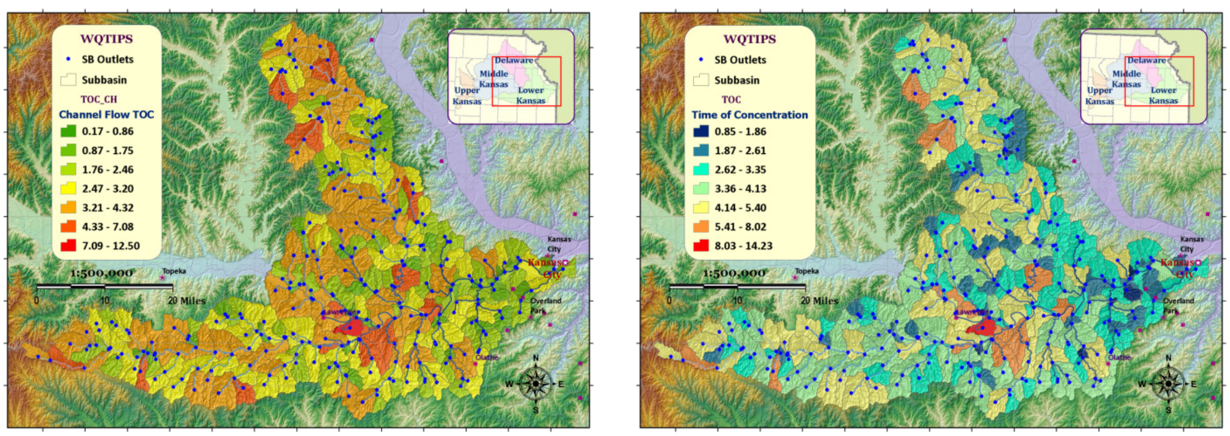
Figure G-4 (a) displays the downstream flow length from each subbasin to the watershed outlet in study area. Following the Eq. G-8 and Eq. G-9, the time of concentration (TOC) for storm water runoff in both overland flow and channel flow status are calculated. Figure G-4 (b) illustrate the TOC for overland flow in each subbasin and Figure G-5 (a) illustrate the TOC for channel flow in each subbasin. Figure G-5

(b) displays the potential TOC from the remotest point of each subbasin to its outlet. The more reddish blocks in Figure G-5 (b), the longer period of time are needed for storm water concentrating through that subbasin to its outlet. The time of concentration rendered in Figure G-5 (b) is only for the demonstration purpose. Actually the TOC number for each subbasin only represents the TOC at each subbasin outlet. The TOC for any other point within the subbasin needs to be calculated by above Eq. G-8 and Eq. G-9.



(a) Stream Length **(b) Time of Concentration of Overland Flow**

Figure G-4 Stream Length and TOC of Overland Flow of Each Subbasin in Study Watershed



(a) Time of Concentration of Channel Flow (b) Overall Time of Concentration

Figure G-5 Time of Concentration of Each Subbasin in Study Watershed

G.3.2 Stream Network Travel Time

SWAT assumes the main channels or reaches have a trapezoidal shape with a 2:1 channel side slope (z_{ch}) (Neitsch et al., 2005). The bottom width of channel (W_b) can be explained with bank-full width (W) and depth (D) which can be extracted from SWAT subbasin and reach input datasets as Eq. G-10. For potential zero results in Eq. G-10 when the W is less than quarter D, the SWAT assume the W_b will equal to half W for this special cases (Neitsch et al., 2005). The crossing sectional area (A) of the channel modeled by SWAT and the wetted perimeter (P) are calculated with Eq. G-11 and Eq. G-12. Following these equations, the hydraulic radius (R) of the channel is defined as Eq. G-13. The potential volume of water (Q) that channel can hold in a specific section is calculated with the length of that channel section (L) and the crossing sectional area (A) as Eq. G-14.

$$W_b = W - 2 \times z_{ch} \times D = W - 4D \qquad \text{Eq. G-10}$$

$$A = \frac{1}{2}(W + W_b) \times D = (W - 2D)D \qquad \text{Eq. G-11}$$

$$P = W_b + 2 \times \sqrt{(1^2 + 2^2)}D = W_b + 2\sqrt{5}D = W + \left(2\sqrt{5} - 4\right)D \qquad \text{Eq. G-12}$$

$$R = \frac{A}{P} = \frac{(W - 2D)D}{W + \left(2\sqrt{5} - 4\right)D} \qquad \text{Eq. G-13}$$

$$Q = L \times A = (W - 2D)DL \qquad \text{Eq. G-14}$$

The Manning's equation for a uniform flow in a channel is used to estimate the rate (q) of flow for a given stream section. Eq. G-15 explained the in-stream flow rate (q) equal to the channel crossing sectional area (A) multiplied by the flow velocity which used Manning's equations with, hydraulic radius (R), channel slope (S) and Manning's n coefficient (n).

$$q = \frac{A \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}}{n} = \frac{1}{n}(W - 2D)D \times \left(\frac{(W - 2D)D}{W + \left(2\sqrt{5} - 4\right)D}\right)^{\frac{2}{3}} \times S^{\frac{1}{2}} = \frac{\left((W - 2D)D\right)^{\frac{5}{3}} \times S^{\frac{1}{2}}}{n\left(W + \left(2\sqrt{5} - 4\right)D\right)^{\frac{2}{3}}} \qquad \text{Eq. G-15}$$

Based on these assumptions and Manning's equation for a uniform flow in a channel, the variable storage routing method developed by Williams (1969) and used in SWAT (Neitsch et al., 2005) can estimate the travel time (TT) of water flowing through a specific channel section with Eq. G-16. Eq. G-16 describes the TT equation based on the storage volume (Q) and discharge rate (q) of that stream section. Following Eq. G-6, the TT of water flow from one subbasin outlet through the stream network to another one or even the main watershed outlet can be estimated. Figure G-6 demonstrates the storm water traveling time for each individual subbasin.

$$TT = \frac{Q}{q} = \frac{nL}{R^{\frac{2}{3}} \times S^{\frac{1}{2}}} = \frac{nL\left(W + \left(2\sqrt{5} - 4\right)D\right)^{\frac{2}{3}}}{\left((W - 2D)D\right)^{\frac{2}{3}} \times S^{\frac{1}{2}}} \qquad \text{Eq. G-16}$$

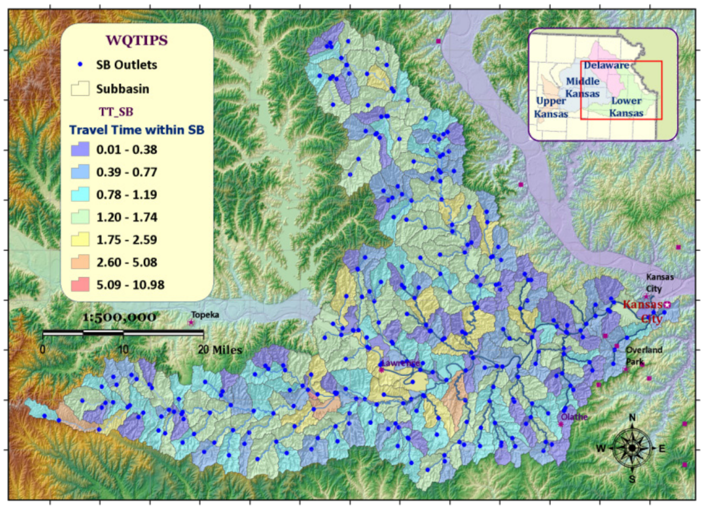


Figure G-6 Traveling Time for Storm Water Runoff via Stream Network to Subbasin Outlet

G.3.3 Watershed Travel Time Estimation

SWAT default assigns Manning's roughness coefficient as 0.14 for an overland flow and 0.014 for a channel flow. However, this assumption may be only suitable for some types of tillage systems and channel conditions. Some suggestions for Manning's n can be found in SWAT theory document (Neitsch et al., 2005), or prior researches (Wanielista et al., 1997), which are tabulated according to the factors that affect channel roughness. Therefore, we estimated the channel flow roughness coefficients with the channel conditional for Manning's n which addressed by Wanielista et al. (1997). The global channel roughness coefficients for estimating watershed travel time are 0.05 for a tributary and 0.025 for the main channel in study watershed. Moreover, different tillage system and crop rotation may have its specific roughness coefficient. Therefore, we picked the average of all tillage systems and assign 0.25 as the overland flow Manning's n in the following calculation. Figure G-7 displays the time of concentration (TOC) for each subbasin versus the subbasin area with different Manning's roughness coefficient. As described above, the Manning's roughness coefficient for this study is 0.25 for overland flow and 0.025 for channel flow while the n of SWAT default values are 0.14 and 0.014 for overland and channel flow, respectively. In Figure G-7, the average of TOC with SWAT defaults is around 1.61 hours which is lower than the TOC with parameters in this study at 3.49 hours. Thus, the time of concentration in this study would be longer than SWAT internal defaults.

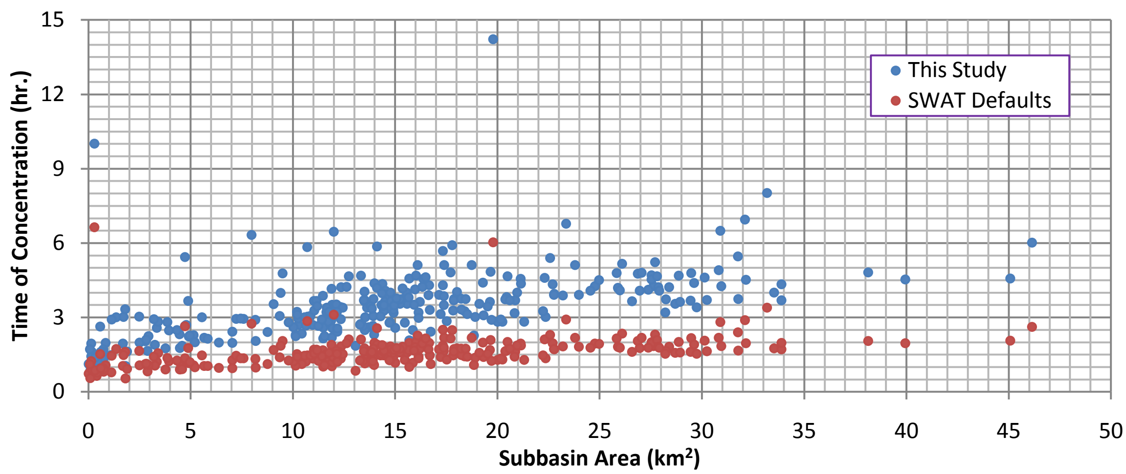


Figure G-7 Time of Concentration for each Subbasin with Different Manning's n

Following the Eq. G-16, the travel time of storm water flow from one subbasin outlet through stream network to another one can be estimated. Based on Eq. G-10 and Eq. G-11, the time of concentration for storm water from the remotest point of subbasin to the outlet also can be calculated. Therefore, following the Eq. G-8, the watershed traveling time can be estimated for each subbasin to watershed outlet or downstream specific points. Figure G-8 illustrates the potential overall travel time for storm water from the remotest point of each subbasin to the watershed outlet. Due to the limitations in GIS software and the watershed characteristics, only the points along the stream network in the Figure G-8 are meaningful. In Figure G-8, the more reddish color represents a longer time needed for travelling.

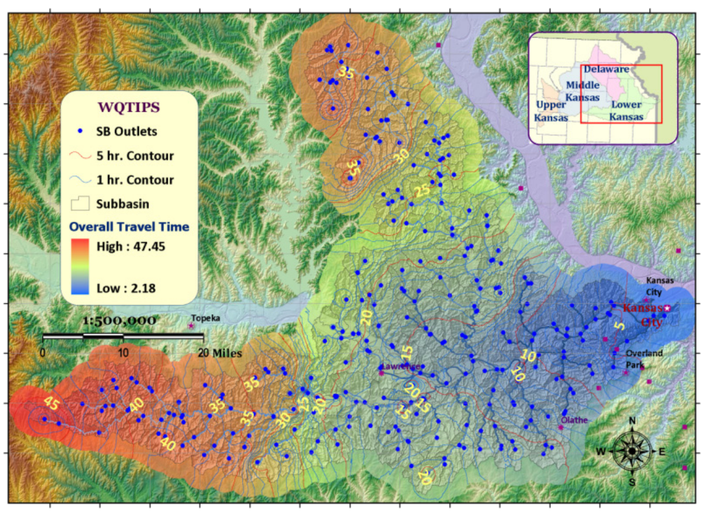


Figure G-8 Overall Traveling Time for Each Subbasin to Watershed Outlet

G.4 First-Order Kinetics Coefficient

Curley (2003) used the first-order kinetics equation to describe the decay of nitrogen load in surface water transports. The de-nitrification and volatilization processes in water caused the decay of nitrogen (Curley, 2003). Due to the most of nitrogen in water is in the form of nitrate (NO_3-), the kinetics of nitrate decay can represent the kinetics of the decay of TN in the stream (Curley, 2003). Therefore, if the transform of TN can be neglected, the de-nitrification rate would capture the most amount of TN decay in the water (Curley, 2003). However, to select a set of reasonable decay coefficient is a tedious process. Several researches presented their specific k_T for the first-order kinetics equation to address the nitrogen decay in the water. Metcalf & Eddy, Inc. (1991) suggest a typical k_T coefficient of the de-nitrification process for designed engineering structures, which ranges from 0.04/day to 0.08/day. USEPA identified the de-nitrification rate at 0.1/day in Chapter 5 of its standard (USEPA, 1985). Smith et al. (1997) quantified the in-stream decay coefficients for calculating TN decay with SPARROW Model, which range from 0.035/day to 0.29/day depended on its stream flow rate. Therefore, the de-nitrification rate was selected at 0.08/day for estimating the TN decay coefficient at 20 °C while θ equaled to 1.045. Following Eq. G-10, the relationships between storm water travel time and delivery ratio (C_{OUT}/C_{IN}) are illustrated as Figure G-9.

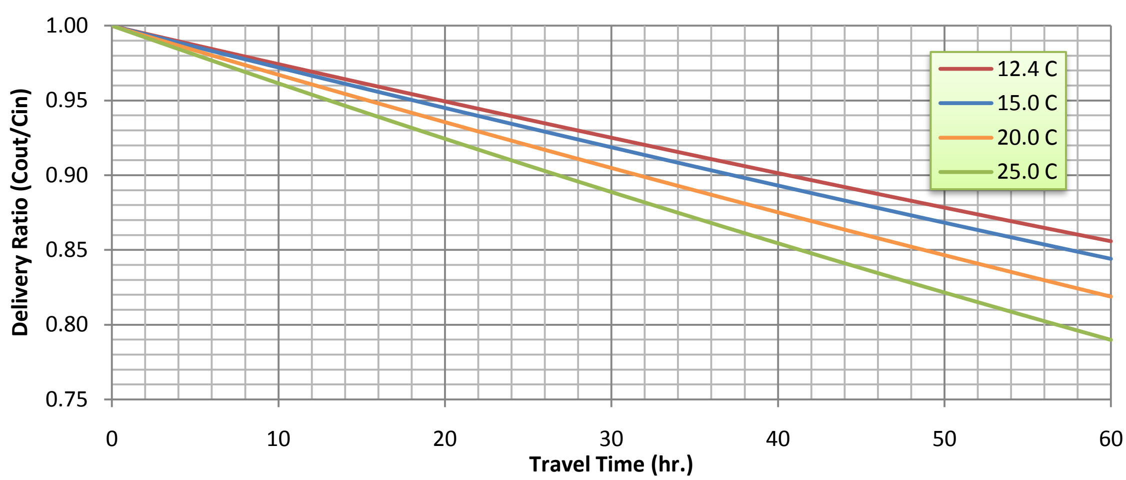


Figure G-9 Delivery Ratio with First-Order Kinetics Equation versus Travel Time

G.5 EUTROMOD: Lake Detention Ratio Analysis

As described in Section: 4.4.5, in order to estimate the nutrient load delivery/detention ratio in Clinton Lake, Kansas, we used Reckhow's EUTROMOD Loading Functions (Eq. G-17). We first estimated the potential in-lake nutrient concentration and then the delivery/detention ratio.

G.5.1 Model Description

EUTROMOD is a spreadsheet-based model that is used for the prediction of nutrient runoff and eutrophication for individual lakes in the US. With model, phosphorus and nitrogen runoff may be predicted using either nutrient loading functions or nutrient export coefficients (Reckhow, 1992). The EUTROMOD loading function utilizing regression analyses have been developed by Kenneth Reckhow for the EUTROMOD Watershed and Lake Model (Reckhow et al., 1992). It is based on the rational formula for dissolved nutrients, and the universal soil loss equation for sediment-attached nutrients (Reckhow, 1992). By utilizing this equation in Clinton Lake, the required inputs include: lake mean depth: 5.18m (17 ft) (KWO, 2008); hydraulic residence time: 9 month or 0.75 years (KWO, 2008); and the average annual Inflow: 197,357,100 m^3 (160,000 ac-ft) (USACE, 2007). The equation of the predicted in-lake TN and TP concentration is as follows Eq. G-17:

$$\log_{10}(\hat{C}) = \log_{10}\left[\frac{C_{in}}{1 + k\tau}\right] \qquad \text{Eq. G-17}$$

where:

$\hat{C}$= predicted in-lake nutrient concentration (mg/L)
C_{IN} = average influent nutrient concentrations (mg/L)
τ = hydraulic detention time (yr)
k = lake factor, depends on its location, hydraulic detention time, lake mean depth and influent concentration

G.5.2 Parameters and Constraints

Original EUTROMOD didn't include the lakes in Kansas. In order to use EUTROMOD in Kansas, we borrowed the model parameters from Mid-West version of EUTROMOD. Therefore, the k factor in Eq. G-17 can then be calculated with Eq. G-18 for TP and Eq. G-19 for TN.

$$k_P = 10.77 \times \tau^{-0.61} \times z^{0.01} \times P_{in}^{0.82} \qquad \text{Eq. G-18}$$

$$k_N = 0.46 \times \tau^{-0.75} \times z^{0.22} \times N_{in}^{0.95} \qquad \text{Eq. G-19}$$

where:

τ = hydraulic detention time (yr)
z = lake mean depth (m)
C_{IN} = average influent nutrient concentrations (mg/L)

The eutrophication prediction of a lake is based on a set of regional statistical models. Response variables include TP concentration, TN concentration, chlorophyll a level, Secchi disk depth, and in some cases, probability of hypolimnetic anoxia and probability of blue-green algae dominance. The global format for the k factor in EUTROMOD loading equation can be expressed as Eq. G-20. For different Regions, States and nutrient, the parameters are listed in Tab (Reckhow, 1992; Reckhow et al., 1992).

$$k = a \times \tau^b \times z^c \times C_{in}^d \qquad \text{Eq. G-20}$$

Table G-1 EUTROMOD k Factor Parameters for Each Regional Statistical Model

	Total Phosphorus (TP)					Total Nitrogen (TN)				
Area (State)	**a**	**b**	**c**	**d**	**Std Err**	**a**	**b**	**c**	**d**	**Std Err**
Florida	1.71	-0.21	1.01	0.40	0.189	0.20	-0.89	1.56	0.33	0.136
GL_MOD (MI, WI, MN)	2.52	-0.34	-0.31	0.21	0.236	NONE				
MW_MOD (KA, MO, OK, AK, IA, NE)	10.77	-0.61	0.01	0.82	0.219	0.46	-0.75	0.22	0.95	0.108
NORTEAST (NY, MA, CT, RI, VT, NH, ME)	12.26	-0.55	-0.16	0.50	0.169	0.016	-0.59		0.59	
OVMOD (IN, IL, OH)	3.36	-0.54	0.29	0.47	0.172	0.93	-0.62	-0.10	0.33	0.119
WEST (CA, OR, WA, ID, WY, MT, CO, NV, UT, NM, AZ)	4.16	-0.69	0.39	0.84	0.214	0.69	-0.94	0.29	0.998	0.160

Several constraints are applied in EUTROMOD to reflect the dataset used to fit the model in different area. The constraints for MW_MOD area are tabulated in Table G-2. In some instances (e.g., nutrient retention < 0), additional constraints were imposed to create homogeneity in the data set or to eliminate suspected errors (Reckhow, 1992; Reckhow et al., 1992). Following the constraints in Table G-2 for EUTROMOD Loading Function, the relationship between influent concentration and the in-lake nutrient concentration can be illustrated as Figure G-10.

Table G-2 EUTROMOD Constraints for Predicting In-Lake Nutrient Concentration

Criteria	**EUTROMOD Constraints**		
For P:	Phosphorus Retention > 0	0.003mg/l < $\hat{P}$ < 0.424mg/l	0.010mg/l < P_{in} < 1.334mg/l
For N:	Nitrogen Retention > 0	0.090mg/l < $\hat{N}$ < 7.185mg/l	0.268mg/l < N_{in} < 10mg/l
Global:	0.008yr < τ < 285yr	1.2m < z < 21.4m	0.1m < SD < 3.6m

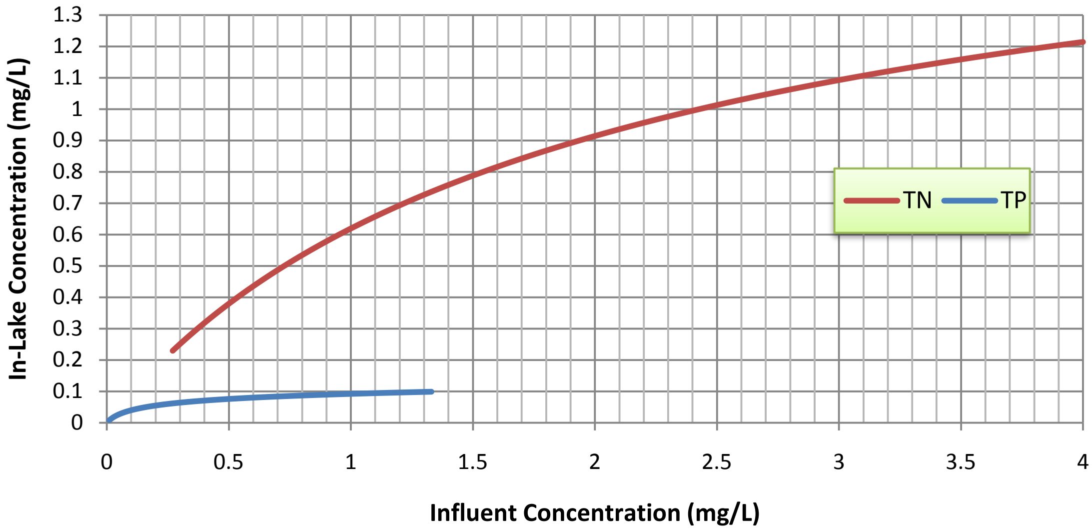


Figure G-10 Relationship between Influent and In-lake Nutrient Concentration

G.5.3 Lake Delivery/ Detention Ratio Calculation

Assume L_{in-N} is the TN load and L_{in-P} is the TP load for the annual Clinton Lake influent nutrient loads. Assuming the annual influent volume of Clinton Lake is V_{in} and outflow volume is V_{out}, the nutrient load of inflow (L_{in}) and outflow (L_{out}) can be explained as the inflow or in-lake nutrient concentration multiplied by its flow volume (Eq. G-21 and Eq. G-22). For calculating lake delivery/detention ratio, Eq. G-23 described the needed information. If we assume the inflow and outflow volume is the same, R_D can be rewritten as an equation using only the nutrient concentration parameters. Using the EUTROMOD Loading Function in Eq. G-17, Eq. G-18, and Eq. G-19 to replace the parameters in Eq. G-23, the new lake delivery/detention ratio can be described as Eq. G-24 for TN and Eq. G-25 for TP load. Therefore, generally, the Kansas lake delivery/detention ratio for TN and TP load can be roughly estimated by Eq. G-24 and Eq. G-25 based on the EUTROMOD model. The relationship between lake influent concentrations versus general lake delivery/detention ratio is demonstrated in Figure G-11.

$$L_{in-N} = V_{in} \times N_{in} \text{ and } L_{in-P} = V_{in} \times P_{in} \qquad \text{Eq. G-21}$$

$$L_{out-N} = V_{out} \times \hat{N} \text{ and } L_{out-P} = V_{out} \times \hat{P} \qquad \text{Eq. G-22}$$

$$R_D = \frac{L_{out}}{L_{in}} = \frac{V_{out} \times \hat{C}}{V_{in} \times C_{in}} = \frac{\hat{C}}{C_{in}} \qquad \text{Eq. G-23}$$

$$R_D = \frac{\hat{C}}{C_{in}} = \frac{\frac{C_{in}}{1+k\tau}}{C_{in}} = \frac{1}{1+k\tau} = \frac{1}{1+\tau\left(0.46 \times \tau^{-0.75} \times z^{0.22} \times N_{in}^{0.95}\right)} \qquad \text{Eq. G-24}$$

$$R_D = \frac{\hat{C}}{C_{in}} = \frac{\frac{C_{in}}{1+k\tau}}{C_{in}} = \frac{1}{1+k\tau} = \frac{1}{1+\tau\left(10.77 \times \tau^{-0.61} \times z^{0.01} \times P_{in}^{0.82}\right)}$$ Eq. G-25

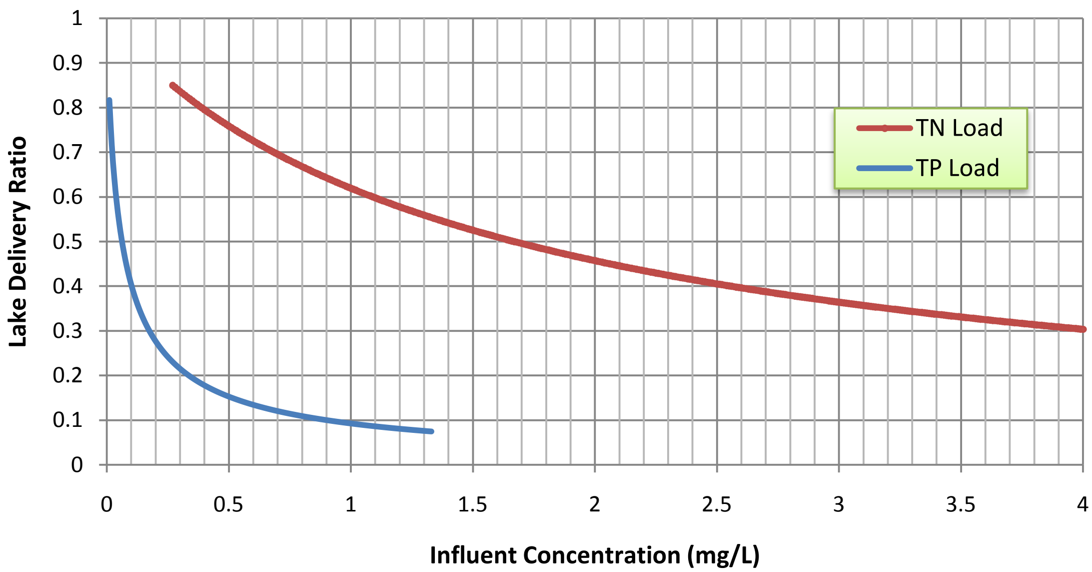


Figure G-11 Relationship between Influent and Lake Delivery/Detention Ratio

G.6 Reference:

Curley, D. E. 2003. An analysis of trading ratio for water pollution control trading system using a geographic information system and the finite segment method. PhD diss. Philadelphia, PA: University of Pennsylvania, Department of City and Regional Planning.

KWO, 2008. Clinton Lake, Reservoir Fact Sheet. Kansas Water Office. Available at: www.kwo.org/ReservoirInformation/ReservoirFactSheets/Clinton_Lake.pdf. Accessed April 30, 2009.

Metcalf & Eddy, Inc. 1991. *Wastewater Engineering: Treatment, Disposal and Reuse*. 3rd ed. revised by G. Tchobanoglous and F.L. Burton., New York: McGraw-Hill.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, and J. R. Williams. 2005. *Soil and Water Assessment Tool Theoretical Documentation version 2005*. Temple, TX: Grassland, Soil and Water Research Laboratory, USDA-ARS & Blackland Research and Extension Center, Texas A&M University.

Reckhow, K. H. 1992. Unpublished document. EUTROMOD Spreadsheet Program, A regional modeling scheme for nutrient runoff and lake trophic state modeling. Duke University.

Reckhow, K. H., S. Coffey, M. H. Henning, K. Smith, and R. Banting. 1992. Technical Guidance and Spreadsheet Models for Nutrient Loading and Lake Eutrophication. Draft technical report, Duke University.

Smith, R. A., G. E. Schwarz, and R. B. Alexander. 1997. Regional interpretation of water-quality monitoring data. *Water Resour. Res.* 33(12): 2781-2798.

USACE. 2007. Annual Water Quality Report 2006 - Kansas City District. U.S. Army Corps of Engineering (USACE), Kansas City District. Available at:

www.nwk.usace.army.mil/lakes/WaterQualityReport/06_Annual_Report.pdf. Accessed April 30, 2009.

USEPA. 1985. Rates, constants, and kinetics formulations in surface water quality modeling, 2nd ed. EPA/600/3-85/040. Athens, GA: USEPA, Environmental Research Laboratory.

Wanielista, M. P., R. Kersten, and R. Ealgin, 1997. *Hydrology: Water Quantity and Quality Control*. New York, NY: John Wiley & Sons.

Williams, J. R. 1969. Flood routing with variable travel time or variable storage coefficients. *Trans. ASAE* 12(1):100-103.

Appendix H Cluster Analysis

The SAS PROC CLUSTER statement starts the CLUSTER procedure, identifies a clustering method, and optionally identifies details for clustering methods, data sets, data processing, and displayed output (SAS Institute Inc., 2004). As described in Section: 4.4.7, SAS CLUSTER procedure hierarchically clusters the observations in the dataset using either the coordinates or distances method (SAS Institute Inc., 2004). After tested each SAS cluster method, the Ward (WAR) method was used in this study to determine the data clustering. Ward's minimum-variance method (error sum of squares, trace W) was developed by Ward (1963). In Ward's minimum-variance method, the distance between two clusters is the ANOVA sum of squares between the two clusters added up over all the variables as Eq. H-1 (SAS Institute Inc., 2004). If $d(x, y) = (1/2)|x - y|^2$, the combinatorial formula is Eq. H-2. At its cluster analyzing iteration, the within-cluster sum of squares is minimized over all partitions obtainable by merging two clusters from the previous step (SAS Institute Inc., 2004). The advantage for using Ward method for cluster analysis is the results are easier to interpret by utilizing the proportions of variance (squared semi-partial correlations), which is the sums of squares divided by the total sum of squares. Ward's method tends to join clusters with a small number of observations, and it is strongly biased toward producing clusters with roughly the same number of observations (SAS Institute Inc., 2004).

$$D_{KL} = B_{KL} = \frac{\|\bar{X}_K - \bar{X}_L\|^2}{\frac{1}{N_K} + \frac{1}{N_L}} \qquad \text{Eq. H-1}$$

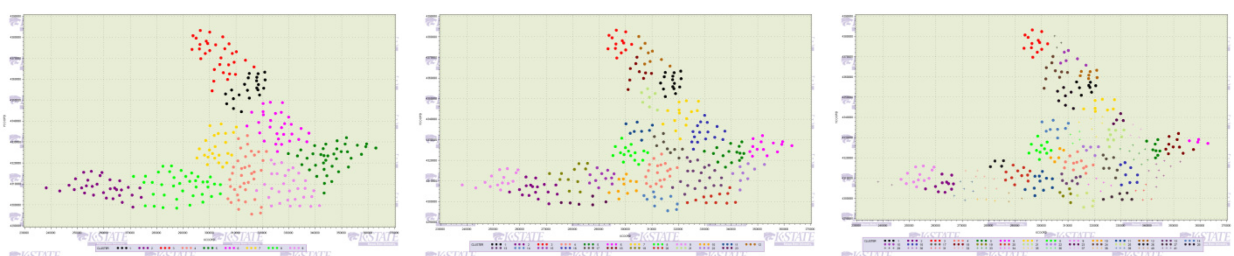
$$D_{JM} = \frac{(N_J + N_K)D_{JK} + (N_J + N_L)D_{JL} - N_J D_{KL}}{N_J + N_M} \qquad \text{Eq. H-2}$$

Where:

C_K: K^{th} cluster, subset of {1, 2, ... , n }
N_K: number of observations in C_K
$\bar{X}_K$: mean vector for cluster C_K
X_i: i^{th} observation (row vector if coordinate data)
W_K: $\sum_{i \in C_K} \|X_i - \bar{X}_K\|^2$
D_{KL}: any distance or dissimilarity measure between clusters C_K and C_L
B_{KL}: $W_M - W_K - W_L$, if $C_M = C_K \cup C_L$
d(x,y): any distance or dissimilarity measure between observations or vectors x and y

Using cluster analysis, we can create trading zones and estimate the TRs for each potential alternative scenario pair in the study watershed. Table H-1 shows a cluster analysis for both TN and TP load reductions of S7-S32 alternative scenario pair. Table H-1 also shows the last 50 generations of the cluster history from the SAS analysis. In Table H-1, the first two columns are the number of clusters (NCL) and the names of the clusters joined (Joined). Next column displays the frequency (FREQ) which is the number of observations in the new cluster. The latter column is the semi-partial R^2 (SPRSQ) which represents the decrease in the proportion of variance accounted for by joining the two clusters. Next listed is the squared multiple correlations (RSQ), R^2, which is the proportion of variance accounted for by the clusters. Table H-1 shows that, when the data are grouped into five clusters, the proportion of variance accounted for by the clusters (R^2) is about 83%. The approximate expected value of R^2 is given in the column labeled "ERSQ." The next three columns display the values of the cubic clustering criterion (CCC), pseudo F (PSF), and t^2 (PST2) statistics. Values of the cubic clustering criterion (CCC) greater than 2 or 3 indicate good clusters; values between 0 and 2 indicate potential clusters, but they should be considered with caution; large negative values can indicate outliers (SAS Institute Inc., 2004).

In Table H-1, the peak of cubic clustering criterion (CCC) shows potential clusters are 3 and 9, pseudo F statistic (PSF) indicates possible stopping points of clusters are at 9 and 4, and pseudo t^2 (PST2) statistic shows the possible clustering levels at 12, 9, 8, 7, 4, and 3 clusters. Based on the criteria described above, the 9, 23, and 41 clusters might be suitable for this dataset. When the data are grouped into 9 or 23 clusters, the proportion of variance accounted for by the clusters (R^2) at about 93% for 9 clusters or 97% for 23 clusters. Figure H-1 displays the potential clusters in the study watershed. In these figures, each dot represent the centroid of a subbasin, the dots in the same color are in the same cluster.



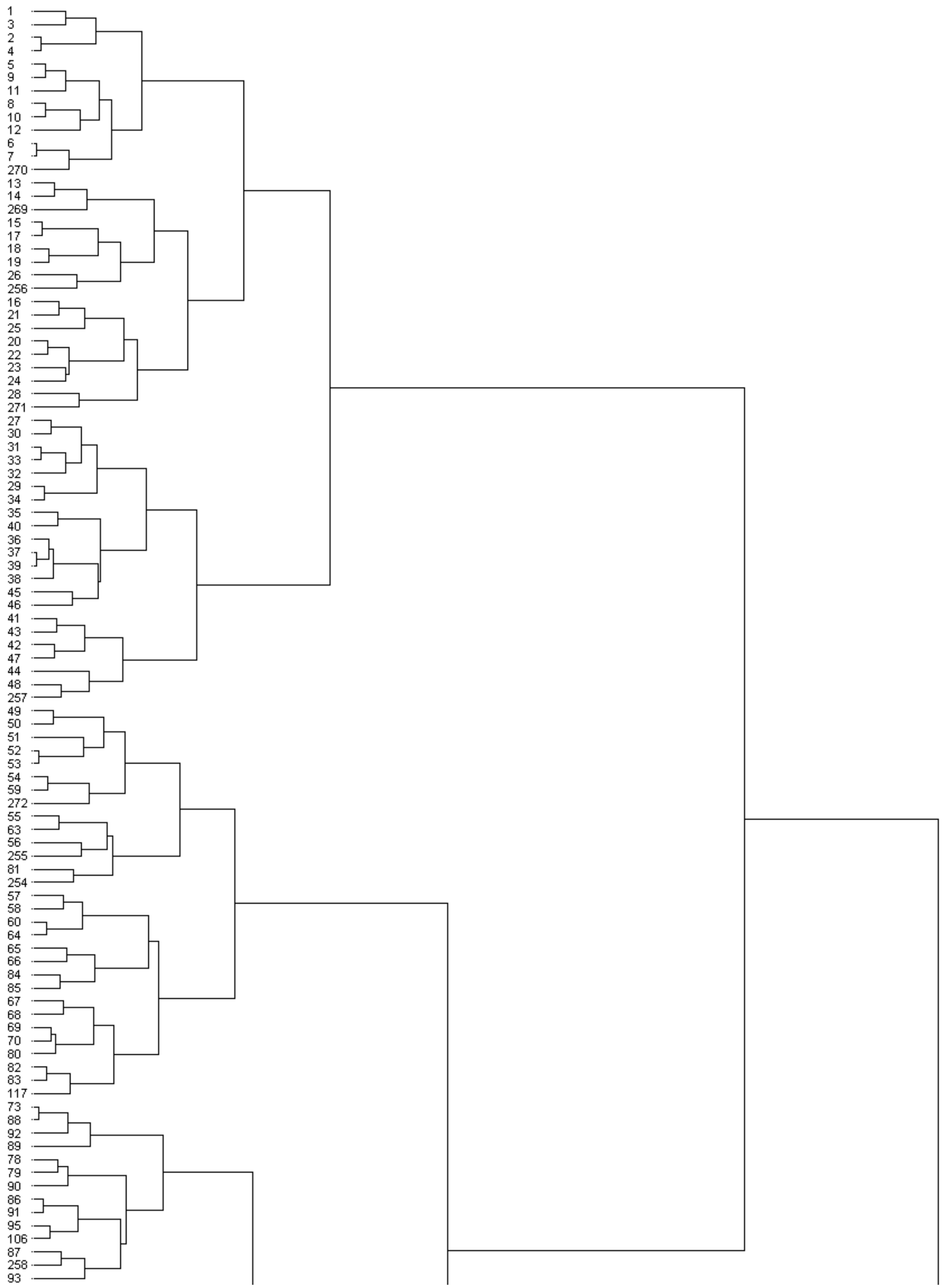
(a) 9 Clusters **(b) 23 Clusters** **(c) 41 Clusters**

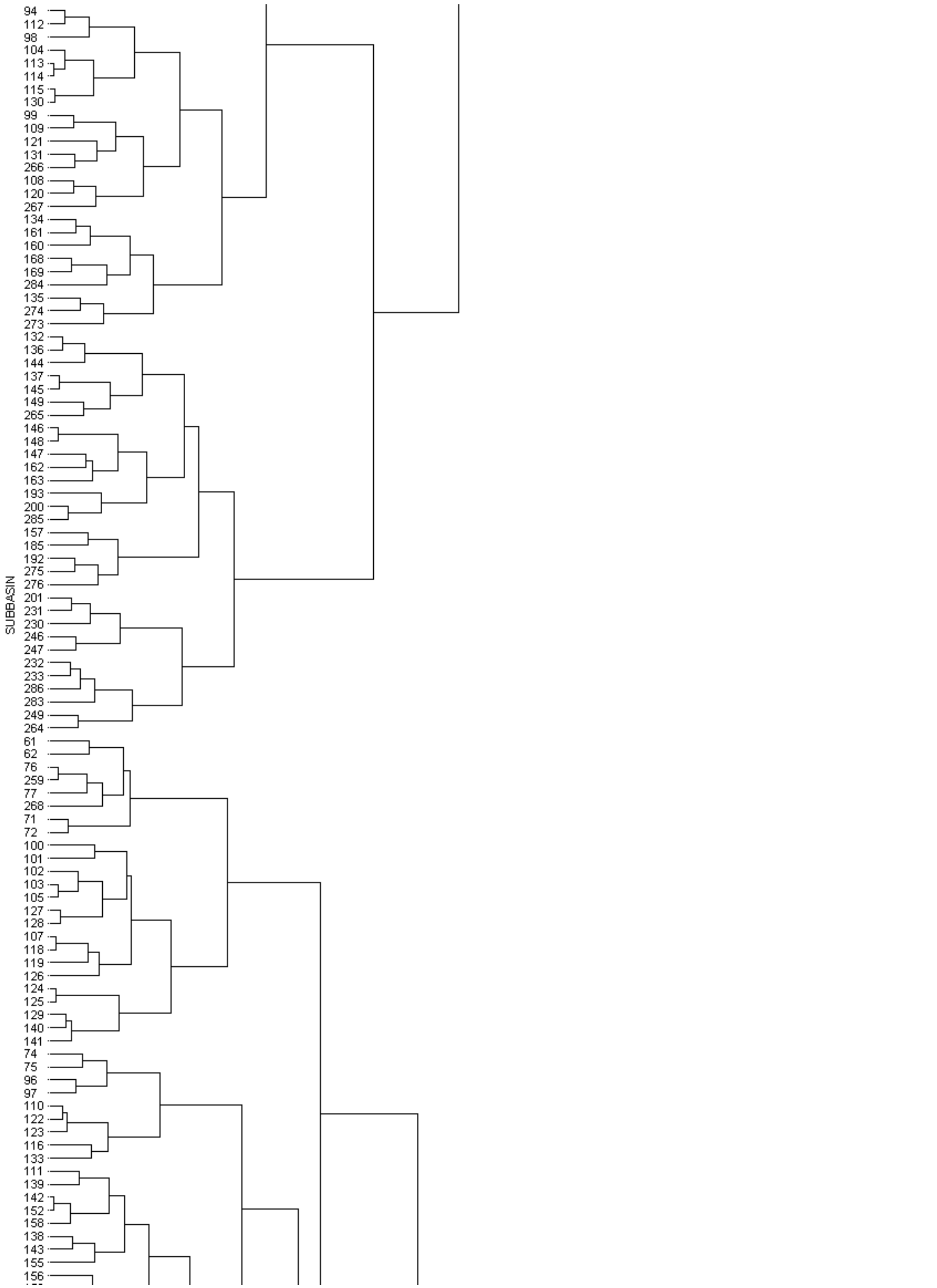
Figure H-1 SAS Cluster Analysis Results:

The SAS TREE procedure produces a tree diagram, also known as a dendrogram or phenogram, using a dataset created by the SAS CLUSTER procedure (SAS Institute Inc., 2004). The tree diagram contains all scenarios at left of vertical axis, and the horizontal axis presents the R^2 values. The diagram shows a continuous view for any two smaller clusters (leave) mere into a new one (branch) until become one and only one stem on the right of diagram. Therefore, it is possible to set a specific cluster levels to group whole scenarios by reading the tree diagram with the number of the vertical lines. Figure H-2 illustrates the tree diagram of the cluster analysis in TN and TP load reduction in this study.

Table H-1 Cluster Generation History Based on TN and TP Load Reduction for S7-S32

NCL	Clusters Joined		FREQ	SPRSQ	RSQ	ERSQ	CCC	PSF	PST2
50	CL73	CL105	11	0.0003	0.989	0.987	2.91	428	8
49	CL80	CL114	8	0.0003	0.989	0.986	2.96	427	7.6
48	CL82	CL93	11	0.0003	0.988	0.986	3.02	427	9.2
47	CL71	CL143	12	0.0003	0.988	0.986	3.05	426	9.6
46	CL120	CL86	7	0.0004	0.988	0.985	3.07	425	9.3
45	CL55	CL137	9	0.0004	0.987	0.985	3.1	423	6.6
44	CL65	CL110	9	0.0004	0.987	0.984	3.12	422	7.7
43	CL98	CL70	11	0.0004	0.986	0.984	3.16	421	10.2
42	CL92	CL68	13	0.0004	0.986	0.983	3.18	420	10.6
41	CL89	CL57	13	0.0005	0.986	0.983	3.18	418	10.3
40	CL102	CL100	9	0.0005	0.985	0.982	3.19	417	16
39	CL90	CL83	15	0.0005	0.985	0.981	3.23	416	14.9
38	CL125	CL95	8	0.0005	0.984	0.981	3.28	415	16.9
37	CL107	CL109	6	0.0005	0.984	0.98	3.37	415	13
36	CL99	CL75	10	0.0005	0.983	0.979	3.45	416	12.8
35	CL113	CL59	9	0.0005	0.983	0.979	3.54	416	9.7
34	CL63	CL79	16	0.0006	0.982	0.978	3.64	417	12.1
33	CL38	CL66	16	0.0006	0.981	0.977	3.69	416	9.3
32	CL116	CL46	11	0.0007	0.981	0.976	3.74	416	9.9
31	CL103	CL53	14	0.0007	0.98	0.975	3.83	416	12
30	CL60	CL51	16	0.0007	0.979	0.974	3.93	417	13.4
29	CL77	CL62	11	0.0008	0.978	0.973	4.03	417	15.2
28	CL52	CL49	15	0.0008	0.978	0.972	4.14	418	11.5
27	CL61	CL48	17	0.0009	0.977	0.97	4.26	420	14.1
26	CL47	CL76	19	0.0009	0.976	0.969	4.4	421	17.4
25	CL41	CL115	15	0.0009	0.975	0.968	4.56	423	12.1
24	CL54	CL67	14	0.001	0.974	0.966	4.76	426	13.6
23	CL28	CL81	20	0.0012	0.973	0.964	4.84	427	11.6
22	CL35	CL45	18	0.0015	0.971	0.962	4.82	424	14.4
21	CL50	CL43	22	0.0015	0.97	0.96	4.89	424	22.5
20	CL39	CL56	22	0.002	0.968	0.958	4.76	419	32.3
19	CL32	CL37	17	0.0022	0.965	0.955	4.67	415	16.7
18	CL30	CL44	25	0.0023	0.963	0.952	4.65	413	23.3
17	CL64	CL34	24	0.0023	0.961	0.949	4.73	413	31.4
16	CL23	CL29	31	0.0033	0.958	0.946	4.54	407	21.6
15	CL40	CL26	28	0.0033	0.954	0.941	4.52	404	34.5
14	CL24	CL33	30	0.0034	0.951	0.937	4.66	406	27.1
13	CL42	CL22	31	0.0043	0.947	0.931	4.64	404	30.8
12	CL31	CL18	39	0.0051	0.942	0.925	4.61	401	32.1
11	CL25	CL27	32	0.0054	0.936	0.918	4.78	403	43.5
10	CL19	CL21	39	0.006	0.93	0.909	5.09	408	31.7
9	CL15	CL36	38	0.0074	0.923	0.898	5.41	414	40.3
8	CL17	CL9	62	0.0141	0.909	0.884	4.68	395	47.2
7	CL13	CL20	53	0.0156	0.893	0.866	4.46	388	68.2
6	CL12	CL16	70	0.024	0.869	0.843	3.78	372	87.3
5	CL8	CL10	101	0.0378	0.831	0.81	2.58	346	83.1
4	CL14	CL6	100	0.04	0.791	0.761	3.22	356	79.3
3	CL5	CL11	133	0.1398	0.652	0.678	-2.1	265	199
2	CL7	CL4	153	0.2698	0.382	0.456	-3.9	175	349
1	CL2	CL3	286	0.3817	0	0	0	.	175


1
3
2
4
5
9
11
8
10
12
6
7
270
13
14
269
15
17
18
19
26
256
16
21
25
20
22
23
24
28
271
27
30
31
33
32
29
34
35
40
36
37
39
38
45
46
41
43
42
47
44
48
257
49
50
51
52
53
54
59
272
55
63
56
255
81
254
57
58
60
64
65
66
84
85
67
68
69
70
80
82
83
117
73
88
92
89
78
79
90
86
91
95
106
87
258
93


SUBBASIN
94
112
98
104
113
114
115
130
99
109
121
131
266
108
120
267
134
161
160
168
169
284
135
274
273
132
136
144
137
145
149
265
146
148
147
162
163
193
200
285
157
185
192
275
276
201
231
230
246
247
232
233
286
283
249
264
61
62
76
259
77
268
71
72
100
101
102
103
105
127
128
107
118
119
126
124
125
129
140
141
74
75
96
97
110
122
123
116
133
111
139
142
152
158
138
143
155
156

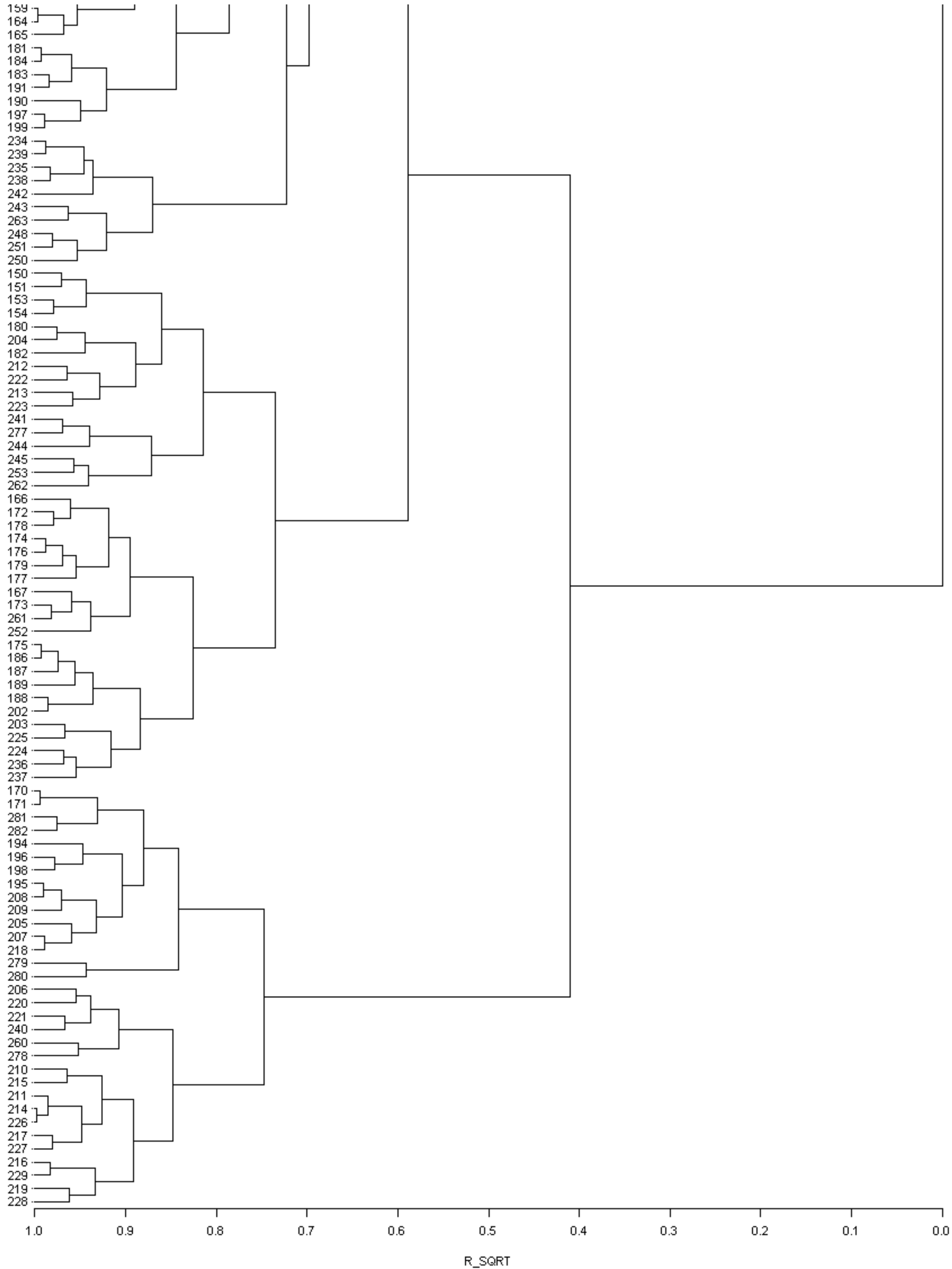


Figure H-2 Overview of the Tree Diagram for Cluster Analysis in TN and TP Load

Appendix I WQTIPS Geospatial Data Model

Based on the design criteria of the geospatial data model, a conceptual design of WQT geospatial data model (WQTGDM) was developed. As described in Section: 5.3.1, the conceptual design was based on the data requirements of modeling inputs, post analyses, and data visualizations. To distinguish data sources and an easy to maintain database, WQTGDM used ten major categories, each based on its role and purpose in WQTGDM. Basic information about watershed physical properties such as “Topography,” “Soil,” “Landuse,” and “Hydrology” was added; model settings and their parameters were stored in either “Watershed Model” or “Economic Model” categories. For modeling simulations, historical climate data like precipitation or temperature were listed in “Monitoring,” and potential trading information was classified in “Pollution Source.” Modeling results were then stored in “Estimation.” For WQTIPS, “Basic Map” was added to enhance data visualization and presentation. This conceptual design of WQTGDM provides the broad direction of geodatabase design in WQT. Moreover, all listed datasets can be replaced by any equivalent or newer sources of the same thematic information in the required data structures.

Water Quality Trading Geospatial Data Model Conceptual Diagram

This diagram describes the essential feature datasets, class schema, and data model elements that needed to implement Water Quality Trading (WQT) program geodatabase. This data model diagram is a conceptual design and still under-updated. For more details, please contact the author: Ming-chieh Lee (mclee@ksu.edu).

Geodatabase Water Quality Trading Geospatial Data Model (WQTGDM)

Date generated August 11, 2009

Geodatabase Summary

A Geodatabase Structural Summary of WQTGDM.

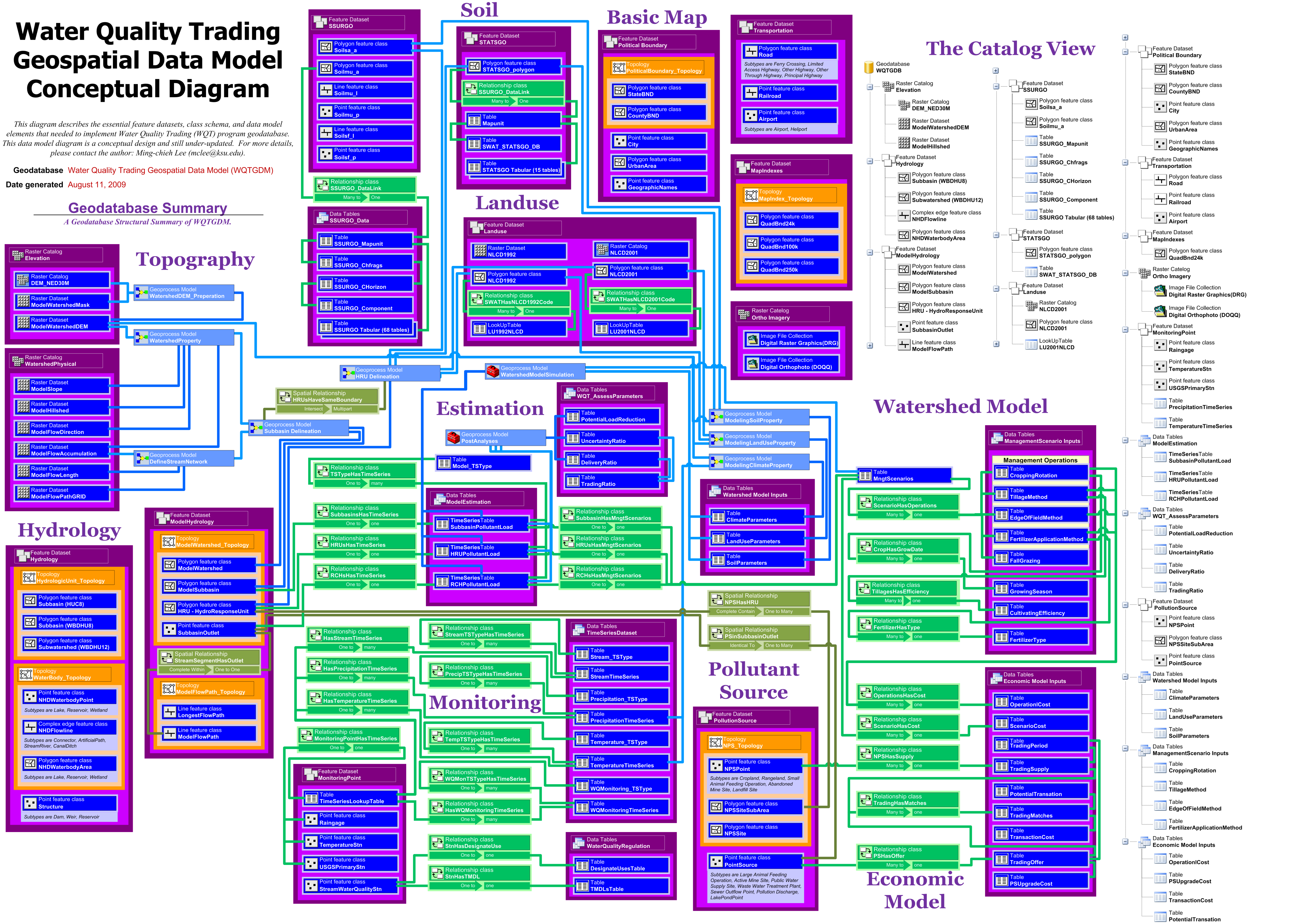


Figure I-1 Summary of the Conceptual Diagram for Water Quality Trading Geospatial Data Model (WQTGDM)