NRCS, USDA Conservation Innovation Grants (CIG)
Final Project Report

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Central Big Sioux River Watershed Water Quality Trading Project:

Covering September 2012 through December 2015

Prepared under funding from
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Deliverables:

A sediment water quality trading credit trading (WQCT) and bacteria payment for ecosystem services (PES) program for the Central Big Sioux River Watershed (CBSRW) located in east-central South Dakota and southwest Minnesota. These were developed through completion of tasks including:

1. Establish Technical Review Team;
2. Conduct a Basic Literature Search for the Central Big Sioux River Water Quality Trading Project;
3. Assess Pollutant suitability for a water-quality credit trading program in the CBSRW;
4. Assess the Financial Attractiveness for a Water Quality Credit Trading Program in the CBSRW;
5. Develop the Market Rules and Infrastructure (CBSRW Sediment WQCT Program Protocols and CBSRW Bacteria PES Program Protocols);
6. Test the Water Quality Trading Program (CBSRW Pilot Programs); and
7. Public outreach meetings, with individual reports summarizing the findings for Tasks 2 through 6 and incorporated into the final sediment water quality credit trading and bacteria payment for ecosystem services trading methods and guidance documents for the CBSRW.

In addition to specific deliverables, grantee provided the following items as deliverables:

a. Semi-annual reports;
b. Supplemental narratives to explain and support payment requests;
c. Final report;
d. Fact sheet;
e. Participated in the National Workshop on Water Quality Markets. Held September 15-17, 2015 in Lincoln, Nebraska.

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Executive Summary

The purpose of this project was to determine the viability of and develop, if appropriate, a water-quality credit trading (WQCT) program for the Central Big Sioux River Watershed (CBSRW). WQCT is a flexible compliance option for the National Pollutant Discharge Elimination System permit program (NPDES permits) governed by the Clean Water Act. An appropriate WQCT program is based on the current best available science regarding the pollutant parameter(s) of concern and the discharger types involved. The most defensible use of trading occurs in programs that blend a combination of load reduction estimation methods with margins of safety, eligibility criteria and other policies which provide assurance that an equal or greater pollutant load reduction takes place. The pollutants of concern in the CBSRW are *Escherichia coli* (*E. coli*) and total suspended solids (TSS). The US EPA has approved two Total Maximum Daily Load (TMDL) studies in the CBSRW, one for each of these pollutant parameters. A WQCT program may not be an appropriate compliance option in every setting. Factors that may limit the use of WQCT include the physical attributes of the watershed, treatment economics and how the pollutant parameter and the sources contribute to the creation of the water quality impairment. WQCT programs developed to date most often address nutrient reduction requirements while a few other programs in the nation address TSS or temperature compliance needs. Therefore, given this watershed has not previously been assessed for the viability of WQCTs and that one of the pollutant parameters of concern is *E. coli,* the project team included a pollutant suitability evaluation and economic viability assessment as part of the project.

Exploring the use of WQCT as a flexible compliance mechanism for TSS and *E. coli* addresses the NRCS CIG (CFDA #10.912) designated priority of Water Quality Credit Trading to stimulate the development, adoption, and evaluation of innovative conservation approaches and technologies related to environmental enhancement and protection in conjunction with agricultural production.

WQCT for TSS is considered to be a viable compliance option, though it was demonstrated that there is not sufficient demand for WQCT in the CBSRW. Documents developed in this project are transferrable to other watersheds in areas where TSS demand and supply would support trading. Likewise, agricultural livestock credit generation for permitted stormwater buyers in WQCT programs for the pollutant parameter of *E. coli* bacteria was identified as not fully equivalent to sources of bacteria and other pathogens commonly present in urban stormwater. However, this study identified that some pathogens entering the streams emitted by livestock do pose a human health risk. In addition, these pathogens are able to survive in the water for substantial distances and periods of time. These sources pose a health risk to people recreating in the waters (partial and full body contact beneficial uses) when the concentration are above the streams' water quality standards. Hence, this project demonstrated the viability and benefits for communities entering into a payment for ecosystem services (PES) when located downstream of high loading agricultural livestock operations which are not large enough to be permitted by the Clean Water Act's authorized National Pollutant Discharge Elimination System (NPDES) permit program.

The watershed setting for the TMDL includes contributing areas from portions of nine South Dakota and two Minnesota counties. Within this contributing area there are two permitted municipal separated stormwater sewer system entities, Sioux Falls and Brookings South Dakota. The environmental market methods developed are transferable to other parts of the Big Sioux River Basin and the region as well. The ultimate goal of this project is to improve the water quality by providing an efficient and cost-effective approach that accelerates implementation throughout the entire Big Sioux River Watershed. Therefore, the project design and implementation must allow funding of activities to cross the state, county and city political boundaries. While some communities can allocate city spending outside of their incorporated areas, most are reluctant to or cannot because of existing ordinances or rules. The City of Sioux Falls entered into a joint powers agreement with Moody County Conservation District. The joint powers agreement approach solidified how city funds may be used when participating in the PES program. The development and use of this agreement allows communities to participate in funding conservation measures on Ag lands in a legal and seamless manner.

The project's scope of work was divided up into seven tasks. The project's first task was to launch an inclusive and transparent review and development format in which multiple interested stakeholders could participate. The next three tasks included benchmarking transferable existing WQCT programs and a non-regulatory Payment for Ecosystem Services (PES) program currently operating in the CBSRW and conducting two market viability evaluations. The last three tasks included constructing the appropriate market mechanism protocols and rules, testing the efficacy and efficiency of the framework and conducting public outreach. More detail for each of the development tasks is provided here:

Task 1 – Establish a Technical Review Team; consisting of federal, state and local regulators, conservation district supervisors, agricultural producers and municipal officials who share an interest that this approach provide cost-effective environmental protection.

Task 2 – Conduct a Basic Literature Search; including six WQCT programs selected from existing national programs that have watershed settings similar to CBSRW, actual trading transactions and a comparable regulatory and local governmental structure/approach.

Task 3 – Assessment of the Pollutant Suitability; evaluating the viability of a market-based program successfully addressing bacteria and sediment pollutants was completed. The pollutant suitability assessment included consideration of each pollutant's fate and transport within the watershed and equivalence of the pollutant forms between sources (e.g., types of pathogens discharged).

Task 4 – Assessment of Financial Attractiveness; WQCT Program or equivalent market based program economic analysis to determine potential cost savings was completed for the CBSRW. The economic analysis compared total costs for a defined unit of load reduction across a twenty year period for urban and agricultural best management practices (BMPs). This allows for BMPs with different practice life and treatment efficiencies to be compared based on the potential cost margins available that will provide cost savings. To provide an objective comparison the process steps included determining a unit load reduction cost for typical BMPs used by each sector. The unit load reduction cost is based on the total annualized cost of capitalization, operation, maintenance and replacement necessary for operation across twenty-years.

Task 5 – CBSRW Sediment WQCT and *E. coli* PES Market Rules and Infrastructure; the market program rules and infrastructure include the necessary policies, design protocols, and load reduction calculator methods as well as definitions for program administrators and participants regarding their roles and responsibilities. Creation of an appropriate framework of rules and infrastructure provide transparent and defensible mechanisms to govern credit transactions which provide cost-effective greater or equal pollutant load reductions.

Task 6 – Central Big Sioux River Watershed (CBSRW) Pilot Programs; the resulting market rules and infrastructure were tested on three pilot projects in the CBSRW. The pilot focused on the resources required to connect buyers with sellers including the staff resources needed for contracting, overseeing, documenting and reporting processes required by the market rules and infrastructure. A feedback loop from market participants was also solicited to provide city officials' and agricultural producers' perceptions regarding using a market based approach.

Task 7 – Public outreach meetings; the team participated in several outreach events to update interested parties on the concept, project status and preliminary findings.

As noted, the ultimate goal of this project was to improve water quality throughout the entire Big Sioux River Watershed, across political boundaries, in the most cost-effective manner. The purpose of the project was to develop a water-quality credit trading (WQCT) program for the Central Big Sioux River Watershed (CBSRW) project area that would facilitate implementation of best management practices for sediment and bacteria. A key preliminary step in setting up a WQCT program is completing a WQCT Feasibility Study for the watershed and pollutant parameters. The feasibility study evaluates many physical and chemical characteristics of the watershed and the pollutants of concern to determine if trading will provide a cost effective alternative. As this report explains, the findings of this project determined that a WQCT program is not a viable option for bacteria in the CBSRW. Because of this, a payment for ecosystem services (PES) program that uses many of the same WQCT program components was tested as an alternative method to meet the ultimate goal of the project. A pilot WQCT program for sediment was developed. However, it was determined, due to limited buyer demand, that this was not a viable option for sediment reduction in the CBSRW.

The project team faced several barriers that prevented the original project concept from being realized. The two major barriers faced were that bacteria is not an acceptable pollutant parameter to use in trading and the National Pollutant Discharge Elimination System (NPDES) permit revision that includes requirements to meet the TSS and bacteria TMDL reduction requirements has not been reissued. Due to the outcome of the Pollutant Suitability Assessment, the project team switched its focus from a pure form of WQCT to using subcomponents of WQCT in a PES program approach. As explained below, the PES approach evaluation found the Seasonal Riparian Area Management (SRAM) and monoslope barn projects to be a very robust and successful group of practices when considering *E. coli* reductions.

The WQCT Feasibility Study included examination of the pollutant characteristics of concern and the CBSRW watershed characteristics. The pollutant characteristics of concern include the type of water quality impact (e.g., acute toxicity or bioaccumulate parameters are considered to be generally ineligible). Watershed characteristics that may limit the use of trading include low credit purchase demand, or inversely the inability to supply credits to meet the demand; the use of trading contributes to or causes water quality violations located between the buyer and the water resource of concern. In addition, site specific economics can prevent or limit the use of environmental markets if the cost of generating a tradable credit exceeds the buyer's willingness to pay for the credit. TSS is the measurement used to evaluate for sediment. In the case of bacteria, the water quality standard applied is a measure of *E. coli* bacteria that is used as a surrogate for all water borne pathogens that affect human health. It was determined that reductions derived from conservation practices that reduce livestock sources of *E. coli* and other pathogens do not result in the same stormwater treatment reductions as the list of critical pathogens in stormwater sources that can impact human health. Likewise, for both sediment and bacteria the CBSR watershed characteristics have a couple of limiting factors that would prevent the CBSRW from being a viable location for a WQCT program approach to be an attractive option. The main limitation facing sediment trading in the CBSRW is the relatively small percent reduction that will be required of Municipal Separate Storm Sewer System (MS4) facilities by the watershed's sediment TMDL. Another limiting characteristic for both bacteria and sediment is that the Corps of Engineers built and operates a diversion structure (see Figure 1) that greatly alters the land cover dominance of CBSR Reach 10 to be mainly permitted MS4 urban land use.

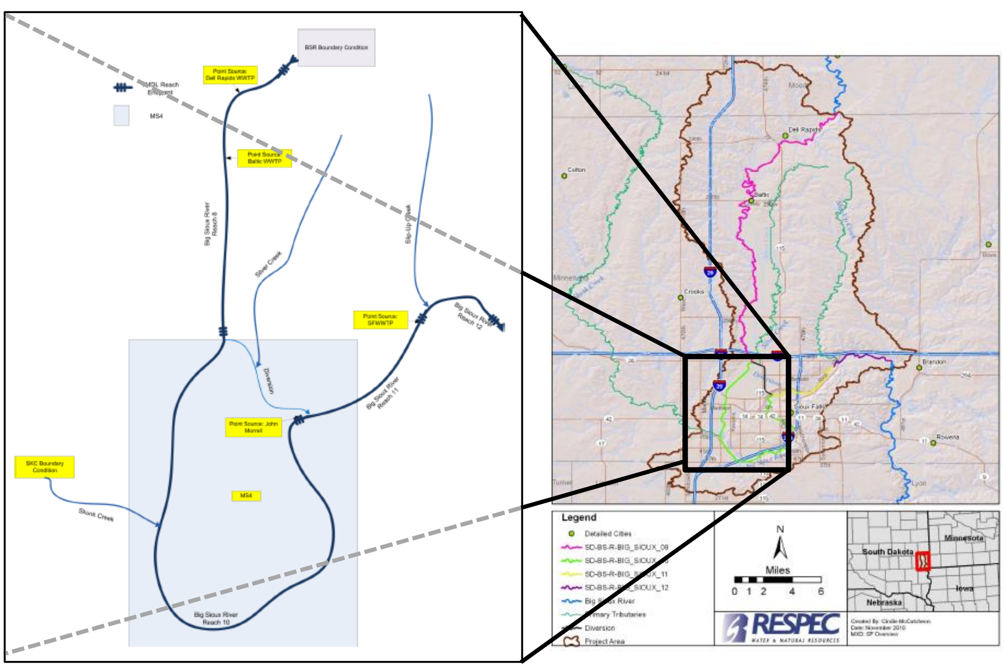

Figure 1. Diagram of the Corps of Engineers diversion structure in Sioux Falls, South Dakota.

However, the project findings and piloting of the PES approach verified how robust and effective funding for bacteria loading reductions can be. This funding mechanism provides early reductions, accelerating the TMDL implementation plan load allocation activities. This provides a quicker increased level of protection, though not full protection, for those citizens using the CBSR for recreational purposes.

In this PES market approach, a buyer (e.g., a stormwater utility) purchases credits for pollutant reduction similar to WQCT programs but with an additional acknowledgement that the resulting bacteria load reduction is not fully equivalent to MS4 urban conservation practices and their associated pathogen protection. As such this is not considered to be a fully functioning flexible compliance approach for NPDES permits. Instead this approach focuses on bacteria reductions in general while urban conservation practice activities are being scheduled and implemented. Urban implementation of conservation practices are often hampered by existing infrastructure and limited available space. A PES program can be implemented alongside conservation practice schedules that sequence water quality implementation with other infrastructure upgrades like road replacement. This provides decision makers an expanded list of possible practices to select, while also providing a cost-effective approach by minimizing duplication of construction activities in the same location for different purposes.

Such a PES program has been implemented by the City of Sioux Falls. Associated stream monitoring was able to document a substantial reduction in potentially harmful bacteria within Skunk Creek. These reductions assist in protecting citizens who take advantage of the water resource's recreational value while the City continues to implement its own conservation measures within the permitted footprint. With added lessons from WQCT attributes, it is also possible to implement a PES program with sufficient funding, documentation and inspections in a manner that can be used to support a permittee's request for a permit variance or longer compliance schedule by demonstrating real reductions will take place during the interim period.

This project developed the marketing framework for both WQCT and PES approaches which can be transferred to interested entities addressing impairments within the region. The project verified the credit estimation methods developed. In addition, a range of administrative structures and documentation forms were developed in order to provide multiple options to address different levels of potential controversy that might arise, if a third party interests question the effectiveness and implementation of WQCT or PES programs.

The project included an economic feasibility assessment that compared the annualized life cycle cost for both agricultural and urban land use best management practices. The results of this total cost comparison indicates that for all evaluated BMPs bacteria cost savings result in a minimum of 96 percent reduction in cost per unit reduced. Likewise, except for animal waste management structures, the TSS reduction costs reduce the total cost per unit of reduction by a minimum of 93 percent. However, as previously indicated the PES program cannot be used to completely offset the necessary urban upgrades.

Table 1. Economic cost comparison table for agricultural best management practices versus urban stormwater retrofit upgrades.

		Sediment Cost Savings			Bacteria Cost Savings		
Urban BMP	**Agricultural BMP**	**2:1 Trade Ratio**	**3:1 Trade Ratio**	**4:1 Trade Ratio**	**2:1 Trade Ratio**	**3:1 Trade Ratio**	**4:1 Trade Ratio**
Retention Pond	*Filter Strips from Heavy Use Area*	98%	97%	96%	100%	100%	100%
	Riparian Area Fencing and Watering Facilities	N/A	N/A	N/A	98%	97%	96%
	Agricultural Waste Management System-Waste Treatment Lagoon	-3,395%	-5,143%	-6,891%	99%	99%	99%
Extended Detention Basin	*Filter Strips from Heavy Use Area*	97%	95%	93%	100%	100%	100%
	Riparian Area Fencing and Watering Facilities	N/A	N/A	N/A	97%	96%	94%
	Agricultural Waste Management System-Waste Treatment Lagoon	-5,947%	-8,971%	-11,994%	99%	99%	98%
Infiltration Basin	*Filter Strips from Heavy Use Area*	96%	94%	92%	100%	100%	100%
	Riparian Area Fencing and Watering Facilities	N/A	N/A	N/A	96%	94%	92%
	Agricultural Waste Management System-Waste Treatment Lagoon	-6,848%	-10,322%	-13,796%	99%	98%	97%

This project tested the PES program on three sites, two which applied Seasonal Riparian Area Management BMPs and one which installed a monoslope barn as an alternative to an on-stream, open feedlot. The process was well accepted by both the program representatives and the Environmental Quality Implementation Program (EQIP) eligible agricultural producers who participated in the pilot testing. The producers involved expressed appreciation for the efficient administrative program elements and agricultural production improvements. In addition, the SRAM practices were proven to be an effective conservation measure that reduces *E. coli* bacteria counts. Monitoring results indicate large reductions in bacteria and some reductions in TSS. The reduction results for TSS were not as dramatic as the reductions produced for bacteria by these practices. SRAM and monoslope barn practices do not address many other sediment sources within the watershed. As such, the TSS reduction goals for TMDL compliance will require a more comprehensive approach.

This CIG project provided and verified a cost-effective implementation option that can benefit regional NPDES permitted stormwater entities and agricultural producers alike. While the project area focused on the City of Sioux Falls setting and immediate contributing area, this process is transferable to other watersheds in South Dakota and Minnesota. In addition, it may also be appropriate in other states like Iowa. However, the transferability of this approach will be dependent on regional land use and regulatory agency discretion. For instance, Iowa is located in a different EPA region.

The project funding was expended as projected. The project team requested and was awarded a short time extension due to the construction scheduling and implementation of the pilot test projects. Similarly, the project team requested the no-cost extension to allow more time for the NPDES permit reissuance process to be completed. Unfortunately the permit reissuance was not initiated within the time extension. If permitting processes were initiated, the City could have chosen to use this project material, if necessary, to leverage more favorable schedules.

The PES program selected BMPs could be introduced into farm bill programs such as the EQIP practice standards. In addition, the Clean Water Act driven NPDES program could consider using this type of approach when working with enforcement penalties when the permittee settlement negotiation elects to implement water quality improvements instead of paying fines to the delegated authority's general fund.

A summary of the salient findings from this project are:

- This project provides forms and protocols that can be used to implement transparent and defensible environmental market based programs for water quality protection. These protocols and forms can be used in total or only on selected components for the site specific program.
- Animal livestock can be the source of several pathogens that both present a health risk to humans and persist in rivers and streams once they have entered into the water resources.
- Reductions in animal livestock pathogen sources do not provide an equivalent reduction for many human generated pathogens that can be found in urban stormwater systems.
- The economic assessment determined substantial cost benefits exist when comparing the cost margins between agricultural and urban retrofit settings. While these cost benefits are not universal for all Ag practices (e.g. offsetting TSS with animal waste control lagoons) for several identified best management practices the total cost of an offset including the trade ratio is pennies on the dollar.
- The PES program conservation measures tested have proven to provide a substantial water quality protection benefit.

- A WQCT flexible compliance approach for TSS is available for use in the region, although it was determined to be unnecessary for compliance purposes for the City of Sioux Falls at this time.
- The participating farmer viewpoints towards participation in the market based programs are all based on a very strong appreciation for the program and one commented that he recognized a production benefit in the form of a calf rate of gain increase when implementing the SRAM BMP.

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Introduction

This project was conceived to bring a cost-effective implementation process to the CBSRW Total Maximum Daily Loads (TMDLs) for bacteria and TSS. The project concept was an extension of the team realization that environmental market based conservation programs could offer both permitted Municipal Stormwater Separated Sewer System (MS4) entities and agricultural producers a method to advance conservation. While the original project focus was on WQCT, this flexible compliance approach was found to work only for TSS. Addressing bacteria reduction goals by only treating pathogens from animal livestock is not considered to be equivalent to urban sources. Untreated urban stormwater has the potential to contain several types of pathogens not common to animal livestock sources. The use of WQCT in this watershed was also limited by the watershed's TSS Total Maximum Daily Load reduction goals. The project findings indicate that the required MS4 permitted stormwater reductions are not sufficient to justify implementation of a WQCT program.

However, a different market based compliance approach was found to be very beneficial. A payment for ecosystem services (PES) program for bacteria reductions was already being implemented in the watershed. This CIG project built on the existing efforts which targeted animal livestock sources of *E. coli*. The project developed a range of possible documentation forms, credit estimation tools and policies to allow a National Pollutant Discharge Elimination System (NPDES) permitted entity to select an appropriate level of rigor necessary to address questions, comments and challenges that may arise during a permit reissuance period. PES programs provide cost effective offsets that a permittee can use to leverage more flexible compliance schedules and/or permit variances necessary to work through common implementation challenges when working in high density built up areas. The recommended PES approach is to assist permittees by providing an immediate cost-effective decrease in bacterial loading, while the permittee works on implementing easy to retrofit sites and begins the daunting challenges commonly faced when addressing bacteria issues in the high density impervious surface urban land use zones. The recommendation further entails a strategic implementation of urban MS4 stormwater upgrades over time associated with reduced expenditures on PES program sites over the same time frame.

The project was conceived by several collaborators that were engaged in previous watershed studies and implementation efforts to address known impairments within the CBSRW. Specifically the list of representatives and their affiliations is as follows:

- Mr. Robert Kappel City of Sioux Falls–Environmental Division Environmental Manager
- Mr. Sol Brich Central Big Sioux River Watershed Implementation Project–Watershed Coordinator
- Mr. Pete Jahraus South Dakota Department of Environment and Natural Resources–Nonpoint Source Coordinator
- Mr. Chuck Regan Minnesota Pollution Control Agency

- Mr. Jeff Vanderwilt South Dakota Natural Resources Conservation Service–Assistant State Conservationist for Programs

After the award of the CIG, RE/SPEC engineering and Kieser & Associates, LLC (K&A) consulting firms were contracted to provide technical assistance with the completion of the WQCT viability assessment and development of the market based systems. RESPEC provides watershed management assessments throughout many states in the upper Midwest and are well regarded for their team of Hydrologic Simulation Program FORTRAN (HSPF) modelers who provided key understanding to this project regarding loading and persistence estimates. K&A was contracted to provide their technical expertise and understanding of WQCT and other environmental market options. K&A has market development experience in over 23 states and internationally. Together the list of collaborators provided a strong experience base and skill set that was used to assess options and tailor a complete environmental market program for use in this region.

Background

The Big Sioux River Watershed encompasses approximately 9,570 square miles. From the headwaters near Summit, South Dakota, the Big Sioux River flows 420 miles south until it meets the Missouri River in Sioux City, Iowa. The watershed covers area in three states: 1,436 square miles within Iowa, 1,531 square miles within Minnesota, and 6,603 square miles within South Dakota. There are impaired waters within each of these states that have historically been addressed by each state somewhat independently through subwatershed based approaches. The Central Big Sioux River Watershed Project has taken a proactive approach to enhancing water quality within its watershed. The project began with two TMDL assessment studies that addressed the pollutants identified on the SD DENR 303(d) list for waterbodies in the Central Big Sioux River (December 2004) and the north-central Big Sioux River/East Oakwood Lake (December 2005). A total of 29 TMDLs were approved by the EPA from a result of these studies.

More recently, a bacteria and sediment TMDL study was conducted on the four reaches of the Big Sioux River above, adjacent to, and below the city of Sioux Falls. The City of Sioux Falls is a Phase I MS4 community within the watershed. The draft TMDL documents, which have gone through a presubmittal review process with the EPA and should be issued for public notice soon, indicate that the loadings originating from the City of Sioux Falls National Pollutant Discharge Elimination System (NPDES) permitted stormwater system and those originating from the agricultural lands in the watershed must both be managed to meet the goals of the TMDL. In response to this information, stakeholders in the group formed the Central Big Sioux River Watershed Implementation Project (CBSRWIP) Steering Committee. The Steering Committee is comprised of representatives from all four conservation districts in the area, East Dakota Water Development District (EDWDD), South Dakota Association of Conservation Districts, SD DENR, and the City of Sioux Falls. The responsibility of the Steering Committee is to prioritize the application of Best Management Practices (BMPs) targeting sediment erosion and bacteria reductions, and to restore water quality of the Big Sioux River and its tributaries to reach the TMDL targets established.

Traditionally across the nation MS4 entities facing more restrictive permit requirements to comply with the TMDL reduction goals work through the manageable list of urban sites and BMP installations. However, at some point the costs associated with working in high density built up areas become exorbitant due to the lack of open space, complex mix of other utilities and commercial buildings. When faced with these challenging barriers often times the rate of previous progress being achieved drastically declines. In these settings the use of market based approaches like WQCT and PES programs can provide a level of protection, giving permitted entities the necessary time to plan and implement water quality BMPs in sequence with other infrastructure upgrade projects. This flexible timing allows urban BMPs implementation to be accommodated in a cost-effective manner.

In the CBSRW livestock producers and row crop producers may benefit by implementing their desired list of BMPs that treat TSS and/or bacteria if the market assessment determines the programs to be viable. Without using these market programs in viable settings, delays in providing adequate protection for water quality beneficial uses and public health can occur.

In this context, the project team set about to determine the viability of and develop a WQCT and PES program for the CBSRW.

Review of methods

The following section describes the physical and analytic activities that took place during the course of the project. These activities are those undertaken in completion of the tasks introduced above including:

- Task 1 – Establish Technical Review Team
- Task 2 – Conduct a Basic Literature Search for the Central Big Sioux River Water Quality Trading Project
- Task 3 – Assess Pollutant suitability for a water-quality credit trading program in the Central Big Sioux River Watershed (CBSRW)
- Task 4 – Assess the Financial Attractiveness for a Water Quality Credit Trading Program in the CBSRW
- Task 5 – Develop the Market Rules and Infrastructure (Central Big Sioux River Watershed Sediment WQCT Program Protocols)
- Task 6 – Test the Water Quality Trading Program (Central Big Sioux River Watershed Pilot Programs)
- Task 7 – Public outreach meetings

Each of the later activities was overseen by the Technical Review Team (TRT) which was assembled as the first task of the project and included diverse stakeholders with a vested interest in the successful implementation of the program. TRT members included watershed managers and field-scale conservation technical providers, urban and agricultural interests, potential buyers and sellers, and academic, public and private sector representatives.

Program Innovation

The CBSRW WQCT program development process included an assessment of the ability to address conventional trading guidance and policy recommendations to fulfill the Clean Water Act (CWA) provisions for National Pollutant Discharge Elimination System (NPDES) permits. Many trading programs across the nation have successfully addressed the CWA obligations when using nutrient and sediment trading between wastewater treatment plants and other point sources and/or nonpoint sources. However, the CBSRW program also focused on the unique issues surrounding the suitability of using a bacteria trading approach. While bacteria trading potentially could be allowed in existing legal frameworks in several states, appropriate examples of actual bacteria trades do not exist. Similarly, until recently the use of trading to fulfill permitted stormwater obligations was identified as an option in many state rules and/or policies but at the time of this project's review of these programs no available documentation on the approach for stormwater trading was found. However, currently these types of stormwater related trades are starting to emerge. Table 2 divides the trading elements of this project based on whether they are common to earlier programs or relatively new and emerging, exemplifying attention in new and innovative areas.

Table 2. Water Quality Credit Trading program design elements.

Elements Common to Earlier Trading Programs	Emerging Elements in Trading Programs
Sediment as a pollutant of concern	Stormwater permittee participation
Credit supply and demand evaluations	Bacteria as a pollutant of concern
Sediment credit estimation methodology	Bacteria credit estimation methodology
Trade Ratios accounting for: • Calculating and monitoring uncertainty • Location (attenuation) • Pollutant equivalence between sources • Retirement of a fraction of each trade	Bacteria trade ratio considerations: • Uncertainty • Equivalence between sources
Eligibility criteria	Bacteria eligibility criteria
Baseline determination	Bacteria baseline determination
Trade transaction forms and protocols	
Program administration, organizational design	
Technical support for Ag at the local level	

As part of Task 2 - Conduct a Basic Literature Search for the Central Big Sioux River Water Quality Trading Project, the project team screened available materials on at least 48 existing WQCT programs with the goal of selecting six programs for more in-depth assessment. Six programs that were most applicable to the CBSRW setting based on specific elements including nonpoint source credit generation, trade activity volume and geographic similarities to the CBSRW were selected and reviewed. Each program was specifically assessed for the following considerations:

- Number of approved trade transactions
- Regional proximity
- Watershed characteristics
- Pollutant parameters of concern
- Source types buying and selling credits
- Administrative and organizational frameworks
- Local service providers supporting the program

The six programs chosen for further intensive literature search and review were from the following states: Minnesota, Wisconsin, Ohio, Colorado, Virginia and Pennsylvania. In addition, Wisconsin and Colorado programs were selected for further evaluation through interviews with program facilitators.

The specific characteristics of each WQCT program will influence how trading occurs. In addition, all trading programs must be designed to comply with the provisions of the federal Clean Water Act (CWA). WQCT programs must include several basic requirements. Trading programs must prevent discharges from causing or contributing to a water resource impairment (e.g., creating or contributing to a local "hot spot"). The program also must comply with anti-degradation requirements and approved Total Maximum Daily Load (TMDL) studies in the reach of concern, as well as every reach between the buyer and seller. These provisions are structured to protect existing beneficial uses of water resources. The CWA also includes permit anti-backsliding provisions that require maintaining treatment levels for existing effluent limits where the previous effluent limits have been attained in the past.

The U.S.EPA's 2003 Water Quality Trading Policy addresses necessary WQCT program considerations to ensure relevant CWA provisions are addressed. The trading program administrative framework will determine the type of credit transactions, the entities involved, basic eligibility requirements for participants and how credits are calculated. Common elements that are incorporated in other programs to appropriately address these issues include:

> <u>Baselines</u> (for a seller) – A minimum performance requirement for credit generators to participate in a trading program and the initial point used for calculating the quantity of reduction credits eligible for sale.
>
> <u>Certification</u> – The formal approval process signifying that all the required trading policies and protocols have been accurately completed. This includes the CWA delegated authority's oversight of credit transaction provisions, verification processes, eligibility and baseline policies that are necessary in order to comply with CWA provisions.

Legal Framework – The mechanisms necessary for implementing a WQCT process. Approaches include: state policy established to support the NPDES permit process, formal trading rules and trades within individual NPDES permits.

Program Structure – The administrative framework that determines the trading program design and how transactions are implemented. Program structures vary in their efficiency and resources necessary to implement trading. Therefore, an appropriate structure should be selected based on the expected scale of trading program activities. If a high volume of trade transactions is expected, a clearinghouse structure might be most efficient. (A clearinghouse acts as an intermediary to buy credits from sellers and re-sell them to participating buyers. Such structures might also use aggregators that combine credits from multiple sources.) An expected low volume of transactions might best be accommodated by individual permits and bilateral trades at a reduced program investment cost.

Trade Ratios – A fixed multiplier or combination of discount factors that is applied to the overall pollution reduction achieved by a source. The ratio or discount factors account for uncertainty, differences in pollutant attenuation between buyers and sellers, and/or adjustments necessary to ensure pollutant equivalency between sources. Applying these considerations is necessary in order for trade transactions to provide equal or greater pollutant reductions than would be expected with traditional command and control approaches (e.g., NPDES permit limits and conventional point source treatment upgrades).

Trade Registry – A publically accessible database used to post a predetermined amount of information for each credit transaction. Registries promote trading program transparency and accountability goals. Registries commonly include site information such as the reduction measure applied, subwatershed location, credit life start and end dates and quantity of credits generated. However, for privacy concerns, this database might not include personal information such as price, name and/or specific site location (i.e., latitude and longitude of credit generators). [Note: some state trading rules and/or policies require the NPDES permit process to contain some personal information regarding the credit generation site.]

Verification – The process by which an administrative authority ensures that the credit generating practice has been installed as designed and therefore is performing as expected. This process often includes BMP definitions and design standards, site inspections during construction and operation, record keeping and reporting protocols.

Each of the selected programs were reviewed regarding the above requirements and key comparisons to the CBSRW, particularly in terms of watershed characteristics, program legal framework and administrative structure.

Comparison to Existing Practices

Several important characteristics were examined from the six trading programs from the Chesapeake Bay (Virginia and Pennsylvania), the Upper Midwest (Ohio, Minnesota and Wisconsin) and the Western United States (Colorado) for a cross-cut analysis supporting CBSRW trading program development. K&A applied past project experience to gleaning the relevant elements that would assist the CBSRW project, such as stormwater buyer participation, inclusion of sediment and bacteria pollutants of concern, extensive corn production, soybean and livestock production and a high level understanding of watershed loading and difficulties encountered when establishing buyer baselines and participant eligibility criteria. The project team and the Technical Review Team identified the following program features as being most relevant to the CBSRW effort: proximity; watershed characteristics; approved trades and future potential trades; local service provider involvement; source types participating in trading; and program framework elements. This section summarizes the evaluation of these program elements.

One of the features found to be of key importance for relevant comparisons was proximity to the CBSRW. The proximity evaluation considered geographic location and EPA Region as highly relevant to CBSRW applications. Other programs in the same EPA Region as the CBSRW are more applicable, given differences in how each regional office interprets trading policy. The most relevant programs based on geographic considerations appear to be Minnesota, Wisconsin, Ohio and Colorado. This is due to permittee oversight coming from the same EPA Regional office and possibly similar local socio-political influences on eligibility and baseline policies.

Table 3. Proximity in relation to CBSRW.

State	Proximity
Minnesota	Part of CBSRW
Wisconsin	Adjacent to MN; EPA Region 5, same as MN
Ohio	EPA Region 5, same as MN
Colorado	EPA Region 8, same as SD
Pennsylvania	Distant; Chesapeake Bay, EPA Region 3
Virginia	Distant; Chesapeake Bay, EPA Region 3

Note: Programs that provide the most relevant attribute to the CBSRW WQCT program development process are shaded in light blue.

Watershed characteristics are relevant to the types of crediting transactions that are likely to occur. Trading programs from watersheds with similar characteristics can be used to inform WQCT program development regarding crediting equation methods, eligibility criteria and baseline policies. This particular evaluation considered land use, dominant crops, pollutant sources and climate. The programs with the most similar watershed characteristics appear to be Minnesota, which is part of the CBSRW, and Wisconsin and Ohio with similar crops, more precipitation, smaller farm size and the addition of more dairy farms in Wisconsin. Colorado trading areas were found to have more urban land uses, semi-arid conditions and a warmer climate. Watershed characteristics in Pennsylvania and Virginia included substantial urban areas, livestock-heavy agriculture, smaller farm size, and much wetter conditions with a much warmer climate in Virginia as well.

The number of approved point source-nonpoint source trades can be used as an indicator of successful WQCT program establishment and program functionality. Regarding approved trades and future potential trades, most programs have experienced a low number of trades thus far, with a few exceptions. However, almost all of the evaluated programs have a high or moderate potential for future trading, with the exception of Colorado. The programs with the highest likelihood of transferring relevant information into the CBSRW WQCT program development based on this indicator appear to be Minnesota, Ohio and Pennsylvania.

Evaluation of the six selected trading programs included consideration of involvement of local agricultural technical service providers that also exist in the CBSRW. Programs that use these professionals in some capacity in the program structure can inform decisions regarding roles and responsibilities in the CBSRW WQCT program structure. The programs with the highest degree of similarity in local program professionals appear to be Minnesota, Ohio and Pennsylvania. Minnesota involves engineers, CCC, or other licensed professionals, including NRCS and SWCD staff working under the NRCS State Engineer’s license in their program. Ohio includes qualified soil & water conservation professionals in their WQCT program structure, while Pennsylvania involves aggregators consisting of nutrient management planners or agricultural consultants.

Programs with similar entities participating as buyers and/or sellers in trading can be used to provide input on effective program structures, baselines and eligibility criteria. The primary buyers identified in the CBSRW setting would be MS4 permittees. Not all of the benchmarked programs allowed participation by stormwater permittees. The programs with the highest potential to provide relevant information according to this indicator appear to be Minnesota, Wisconsin, Pennsylvania and Virginia, as other programs are more focused on WWTPs.

The programs selected for comparison provided a wide variation in key program elements. Differences exist in the legal frameworks used to authorize WQCT, administrative program structures, trade ratios and baselines. Each of the programs can provide relevant information to design protocols and policies in the CBSRW WQCT program development phase. Table 4 summarizes these key trading program elements. This table presents the most pertinent information gleaned from the evaluation of the six trading programs.

Table 4. Summary of salient WQCT program elements.

State	Legal Framework	Nonpoint Source Trading Program Structure	Trade Ratios[1]	Nonpoint Source Baselines
Minnesota	Rules pending	One-off permits with bilateral trading	Phosphorus 2.5 : 1 All other pollutants consider LF, UF, EQ and NB	• Compliance requirements • Pre-existing conditions • TMDL load allocations • TMDL interim milestones
Wisconsin	Rules promulgated, guidance pending	Flexible: includes brokers and bilateral trading	LF, UF, EQ, NB, HF	Modeled compliance requirements • Ag – SNAP-Plus & P-Index • Urban -- SLAMM & P8 Allows interim and final crediting (under review)
Ohio	State rules	Clearinghouse	2 : 1 w/o TMDL 3 :1 w TMDL	Pre-existing conditions
Colorado	State policy	Clearinghouse	2:1	• Measured non-permitted sources • Modeled permitted MS4 & Ag at BMP requirement levels
Pennsylvania	State rules	Clearinghouse	LF, EQ	Ag baselines -- Requirements for: • Soil erosion • Nutrient management • CAFO state requirements Ag threshold – Min 30 ft buffer
Virginia	State Rules	Broker	2 : 1 (Under review)	List of BMPs: • Nutrient management • Soil erosion control ("T") • Cover Crops • Livestock exclusion • Riparian buffer

[1] Trade Ratio Legend:
LF = Location Factor
UF = Uncertainty Factor
EQ = Equivalence factor
NB = Net Benefit factor for water resource
DS = Downstream factor
HF = Habitat factor

CBSRW Trading Considerations

The programs selected provided CBSRW stakeholders with relevant information on multiple program elements that was used to inform the WQCT program development process. Each program proved useful to the project, albeit to varying degrees, because each developed unique combinations of program structure, legal authority, local professional involvement, credit estimation methods, baselines and policies. The following discussions describe K&A's Task 2 recommendations that guided the incorporation of observations gathered during the literature review into the CBSRW WQCT design process. The considerations focus on credit estimation methods, baselines, trade ratios, minimizing permitting and legal challenges and program structure.

Crediting Estimation

The six programs selected for the review predominantly involve nutrient and sediment credits. This is an indicator that innovative approaches were needed to develop an adequate credit estimation methodology for bacteria loading. However, many of the existing programs have the ability to calculate sediment reductions either for direct application in sediment trading or indirectly as part of the nutrient calculations related to sediment attached nutrients. Minnesota and Ohio both rely on relatively simple adaptations of the RUSLE2 model by associating appropriate enrichment algorithms and delivery ratios for their respective program structure. In contrast, Wisconsin and Pennsylvania are implementing the use of several credit estimation tools that are more sophisticated and therefore are more data intensive.

Robust credit estimation methods are vital for a credible trading program, as the credit calculations are a primary framework element. The crediting method has a ripple effect throughout other program elements, contributing to the uncertainty factors in the trade ratio and ultimately affecting credit price. Credit calculations commonly are based on mechanistic or empirical models. Both types of models used for trading typically predict nonpoint source loadings at the edge-of-field for the pollutant parameter of concern. However, the scientific support for bacteria loading estimation is not as well understood as that for sediment and nutrient estimation. For bacteria, different sources of information can be found that are contradictory. Without appropriately addressing this issue, a bacteria credit estimation methodology is likely to result in an increased amount of introduced uncertainty. This uncertainty can be addressed by using conservative assumptions and methods, as well as setting an appropriate margin of safety (the uncertainty factor) in the trade ratio. See the following section on Pollutant Suitability for further discussion of how this concern was addressed.

Baselines

The six programs each have different methods of determining baselines. Each baseline option was selected by the program managers presumably to be an equitable policy used to advance water quality compliance goals. Depending on the unique needs of the watershed, baselines can range from the high reduction baselines typically applied in the Chesapeake Bay watershed to interim baselines, such as those seen in the Minnesota and Wisconsin examples, to the less restrictive baseline requirements, such as those in Ohio. Overall, following EPA guidance, and considering local socio-political perspectives on equity, stewardship expectations and consideration of TMDL goals was important for establishing defensible baseline policies.

Trade Ratio Determination

The applied trade ratio has direct implications for program success with regard to credit cost, credit availability and public acceptance. The six programs evaluated were equally split between a fixed trade ratio (Colorado, Ohio and Virginia) and more nuanced trade ratios based on various biophysical and program factors. Both fixed ratios and those based on individual components are structured to increase program credibility by accounting for uncertainty, equivalency between different forms of the same pollutant, fate and transport variability between different source locations and load retirement benefits for the water resource. Any trading ratio option should be evaluated for its ability to appropriately address the trading program needs. TRT, expert and EPA guidance were considered during later trade ratio discussions.

Minimizing Permitting and Legal Challenges

The project team needed to be aware of and acknowledge the EPA federal and regional staff concerns regarding contemporaneous offsets and work to address these issues up front. EPA and state CWA delegated authorities have substantial discretion regarding interpretations of a trading program's ability to comply with the CWA requirements. It was recommended that the project team engage in frequent communications with EPA Regions 8 and 5, South Dakota Department of Environment and Natural Resources (SD DENR) and Minnesota Pollution Control Agency (MPCA) to successfully identify critical issues and concerns in order to achieve acceptable solutions.

In addition, the threat of legal challenges exists if the program structure and crediting estimation methods are not considered rigorous or based on the best available science. Adequate verification and documentation protocols are necessary for the certification process. The program is more defensible when it includes effective protocols that explain verification procedures and document results. Likewise, the final program structure likely will consist of many protocols, policies and transparency attributes that can be used to provide confidence in the program and justify the decisions made. The program would benefit from gathering recent peer-reviewed literature regarding BMPs and nonpoint source reduction studies, collecting monitoring data and applying an adaptive management strategy to encourage continuous program improvements. However, as expressed in stakeholder comments to the Virginia Nutrient Act, buyers will be concerned that investments in current projects be honored. In addition, stakeholders expressed concern that program changes are to be applied to future transactions and not the existing credits which were purchased in good faith with best available science used to calculate credits at the time of purchase.

Program Structure

The CBSRW project benefited from studying the example program structures assessed in the literature review and represented in the benchmarking process. Some attributes from each of the six programs discussed contributed to the final design of the pilot programs in the CBSRW. Evaluating and selecting a preliminary program structure early in the development process eased the ability to communicate how the other program elements fit together. Five primary considerations are critical when selecting the appropriate program structure:

- Level of involvement of the permitting authority (i.e., DENR and/or MPCA)
- Public and CWA authority acceptance of the program structure regarding the administrative functions being operated with integrity and impartial judgments
- Local office capacity and capability
- Number of potential credit buyers and their cost-benefits of using trading as a compliance mechanism
- Ability for the program to become self-sustaining

The local socio-political setting in the CBSRW was considered regarding equity and objective oversight. These considerations were combined with an understanding of the capacity and capabilities of local offices participating in the environmental market program administration. In addition, the ability to create a program structure that could become self-sustainable was considered. In short, the project team considered how the program administration would be funded.

Many of the benchmarked programs are receiving state government support, grants and/or leveraging existing offices that have similar missions. Other funding streams can come from service fees and/or application costs collected to support the program service providers. These funding methods can be combined to spread program overhead costs across multiple entities and accelerate the process of becoming a stable enterprise in a shorter time frame.

Fundamentally, this information was used as a starting point for trading framework development in the CBSRW. Where tested trading program elements could be readily derived from other existing programs, resources and expertise was then targeted towards more challenging issues. For the CBSRW, these challenges have been: 1) calculating and crediting bacterial loads; 2) contemporaneous discharge issues raised by EPA Region 5; 3) a multi-state watershed where MN has draft trading rules; and, 4) establishing appropriate trading mechanisms to facilitate participation of permitted stormwater entities as credit buyers. These challenges have been addressed in part through the development of a Pollutant Suitability Evaluation and an Assessment of Financial Attractiveness for a WQCT Program in the CBSRW, which are described in the following section.

Analysis of Potential Market: Pollutant Suitability Evaluation

This project completed a Pollutant Suitability Evaluation for bacteria (represented by *E. coli* and fecal coliform) and for sediment (represented by TSS) as part of the analysis of the potential market for WQCT. A pollutant suitability evaluation considers whether or not WQCT is an appropriate alternative compliance option to help achieve water-quality goals. To qualify as an appropriate option, trading must fit with established policies and regulations. Therefore, trades must fit with the U.S. Environmental Protection Agency (EPA) policy and comply with Clean Water Act (CWA) requirements. The CWA-based Code of Federal Regulations (CFR) states that permitted discharges must not cause or contribute to water-quality violations. Trading programs designed to help an entity meet permit obligations must also adhere to this requirement. The pollutant characteristics and local watershed setting were evaluated to determine whether or not this requirement could be met.

The pollutant suitability assessment first identified which pollutants can be traded based on existing policy and the pollutants contributing to water-quality impairments (EPA, 2004b). The assessment also evaluated pollutant characteristics, as well as the quantity and spatial distribution of potential supply and demand. In addition, the environmental impacts of each pollutant form were assessed to determine if equivalencies can be established. Pollutant equivalencies account for differences in environmental impacts associated with different forms of the same pollutant. A trade ratio is a multiplier that is used to help ensure the desired environmental objectives are met by incorporating considerations such as pollutant equivalency, location, uncertainty, and/or policy goals. Trade ratio components are discussed in more detail later in this report.

Pollutant Suitability Evaluation Method

Water-quality improvements in the CBSRW are needed per the *E. coli* and TSS TMDLs (McCutcheon et al., 2012) and master plan (Oswald et al., 2013) for the Central Big Sioux River (CBSR). Achieving water-quality-based effluent limits can necessitate extensive and costly infrastructure upgrades and best management practices (BMPs) depending on the requirements and treatment technology in place.

Bacteria pose a unique challenge for determining pollutant suitability given potential differences in human health risks associated with pathogen contamination from various sources and a lack of information to fully evaluate such differences. Waterborne pathogens in the CBSRW originate from both human and other animal sources. In urban areas, pathogen sources commonly are the result of stormwater coming in contact with sources of human sewage, as well as pet and wildlife excretions. In rural areas, the sources typically are livestock, wildlife, and failing septic systems. Sufficient concentrations of pathogens in water and human exposure through recreational contact can lead to outbreaks of disease. Table 5 summarizes the major illnesses associated with exposure to waterborne pathogens.

Table 5. Pathogens and Related Symptoms

Illness	Cause (Pathogen)	Symptoms	Common Sources	Transmission
Cryptosporidiosis	*Cryptosporidium*	• Prolonged diarrhea • Vomiting • Stomach cramps • Appetite loss • Weight loss • Mild fever Can be asymptomatic	Humans Animals	Released in stool of infected human/animal; ingestion of oocysts in soil, food, or water contaminated with fecal matter
E. coli	*E. coli* O157 (several pathogenic strains exist)	• Stomach cramps • Diarrhea • Vomiting • Mild fever	Humans Animals	Ingestion of food or water contaminated with pathogenic *E. coli* bacteria
Hemolytic Uremic Syndrome	Bacteria (often *E. coli*) that expresses verotoxin	• Vomiting • Diarrhea • Low urine output • Bloody stool • Fever • Lethargy • Weakness	Humans Animals	Ingestion of food or water contaminated with *E. coli* or other bacteria
Giardiasis	*Giardia*	• Diarrhea • Gas • Floating, greasy stool • Stomach cramps • Nausea • Dehydration Can be asymptomatic	Humans Animals	Ingestion of food or water containing fecal matter from infected human/animal
Norovirus	Norwalk virus, calicivirus	• Diarrhea • Vomiting • Nausea • Stomach cramps • Fever • Headache • Body aches	Humans	Contact with infected individual, ingestion of contaminated food or water
Shigellosis	*Shigella*	• Diarrhea • Fever • Stomach cramps	Humans	Contact with infected individual, ingestion of contaminated food, ingestion of water contaminated with sewage

The EPA recommends that states use numeric criteria for *E. coli* to protect human health in waters designated for primary contact recreational use. *E. coli* sources in the CBSRW originate from livestock, humans, wildlife, and pets. *E. coli* was selected as the appropriate trading parameter to address the *E. coli* WLAs in the CBSRW bacteria TMDLs. *E. coli* is used as a proxy to indicate the presence of fecal contamination in surface waters, *E. coli* loading goals are set forth in the CBSRW bacteria TMDLs, and *E. coli* is a quantifiable pollutant (Table 6).

The primary sources of sediment in the Big Sioux River are land surface erosion, bed and bank erosion, and stormwater runoff. Loading is dominated by nonpoint sources, which contribute sediment through wash-off outside of the permitted areas and through bed and bank erosion. Cropland erosion represents a main component of the load delivered through wash-off. TSS was selected as the appropriate trading parameter to address the sediment wasteload allocations in the CBSRW TSS TMDLs (Table 7).

Table 6. *E. coli* Numeric Criteria in South Dakota and Minnesota.

State	Beneficial Use	Applicable Season	Applicable Waterbody	Numeric Criteria (org/100 mL)	Special Conditions	State Rules Section
SD	Limited contact recreation	May 1–Sep 30	Big Sioux River reaches upstream of reach 8, Skunk Creek	≤ 630	30-day mean[a]	ARSD 74:51:01:51
				≤ 1178	Individual exceedance	
	Immersion recreation	May 1–Sep 30	Big Sioux River reaches 8, 10, 11, 12; Pipestone Creek; Split Rock Creek	≤ 126	30-day mean[a]	ARSD 74:51:01:50
				≤ 235	Individual exceedance	
MN	Limited resource value (Class 7 waters)	May 1–Oct 31	Assessment unit identifications (AUIDs) 10170203-516 (portion of Flandreau Creek), 10170203-543 (Unnamed Creek), 10170203-544 (Unnamed Ditch)	≤ 630	Monthly mean[b]	MN Rule 7050.0227 Subp. 2
				≤ 1260	Individual exceedance[c]	
	Aquatic life and recreation (Class 2B waters: primary and secondary body contact)	Apr 1–Oct 31	All other streams that are surface waters of the state	≤ 126	Monthly mean[b]	MN Rule 7050.0222 Subp. 4
				≤ 1,260	Individual exceedance[c]	

(a) Geometric mean based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period.
(b) Geometric mean of ≥ 5 samples per calendar month (April–October).
(c) 10% of all samples per month (April–October) must be in violation of criterion for waterbody to be considered impaired.

Table 7. Total Suspended Solids and Turbidity Numeric Criteria in South Dakota and Minnesota.

State	Parameter	Beneficial Use	Applicable Season	Applicable Waterbody	Criteria (org/100 mL)	Units	Special Conditions	State Rules Section
SD	TSS	Warm water semipermanent fish life propagation	Year-round	BS-1 through BS-12, Pipestone Creek, Split Rock Creek	≤ 90	mg/L	30-day mean[a]	74:51:01:48
					≤ 158	mg/L	Daily maximum	
		Warm water marginal fish life propagation	Year-round	Skunk Creek	≤ 150	mg/L	30-day mean[a]	74:51:01:49
					≤ 263	mg/L	Daily maximum	
MN	Turbidity	Aquatic life and recreation (Class 2B waters: cool or warm water fish and associated aquatic life)	Year-round	All streams that are surface waters of the state	25	NTU[c]	Individual observation[b]	7050.0222 Subp. 4

(a) 30-day average of at least three consecutive grab or composite samples taken in separate weeks.
(b) At least 3 observations and 10% of observations must be in violation of criterion for waterbody to be considered impaired. (c) Nephelometric Turbidity Units.

To better understand the sources of bacteria and sediment and predict regional loadings within the Big Sioux River watershed, a mechanistic watershed model application was developed using the Hydrologic Simulation Program-Fortran (HSPF). A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate naturally occurring, land-based processes over an extended period of time; in this case, hydrology, bacteria loading, and sediment loading were simulated. The Central Big Sioux River Watershed HSPF model application was developed and calibrated based on historical data (meteorological time series, streamflow, land use, and water quality) gathered from agencies, including the U.S. Geological Survey (USGS), East Dakota Water Development District (EDWDD), South Dakota Department of Environment and Natural Resources (SD DENR), the City of Sioux Falls, and High Plains Regional Climate Center (HPRCC). The model was then used as a tool to simulate and predict impacts on water quality throughout the system as described in the Discussion of Quality Assurance section below. The CBSRW HSPF model was originally developed in 2010 as part of the Sioux Falls TMDL project by the SD DENR and has since been expanded for all tributaries to the South Dakota portion of the Big Sioux River.

The focus in this analysis was on the load reductions needed in stormwater runoff for the City of Sioux Falls to meet their wasteload allocations (WLAs). The city's MS4 program received WLAs for *E. coli* and TSS for two impaired reaches: SD-BS-R-BIG_SIOUX_10 (referred to here as BS-10) and SD-BS-R-

BIG_SIOUX_11 (referred to here as BS-11). These are depicted in Figure 2. Impaired Reaches Within the City of Sioux Falls. BS-10 extends from I-90 to the diversion return, and BS-11 extends from the diversion return to the Sioux Falls Waste Water Treatment Plant (WWTP). These TMDLs were approved by the EPA in December 2012 for TSS and in September 2012 for *E. coli*. BS-10 and BS-11, the reaches within Sioux Falls, were considered as options for focus reaches to optimize WQCT benefits. A trading program focused on the optimal reach would provide environmental protection associated with reducing pollutant loadings, generate nonpoint-source reductions of other pollutants, and promote cost-effective projects.

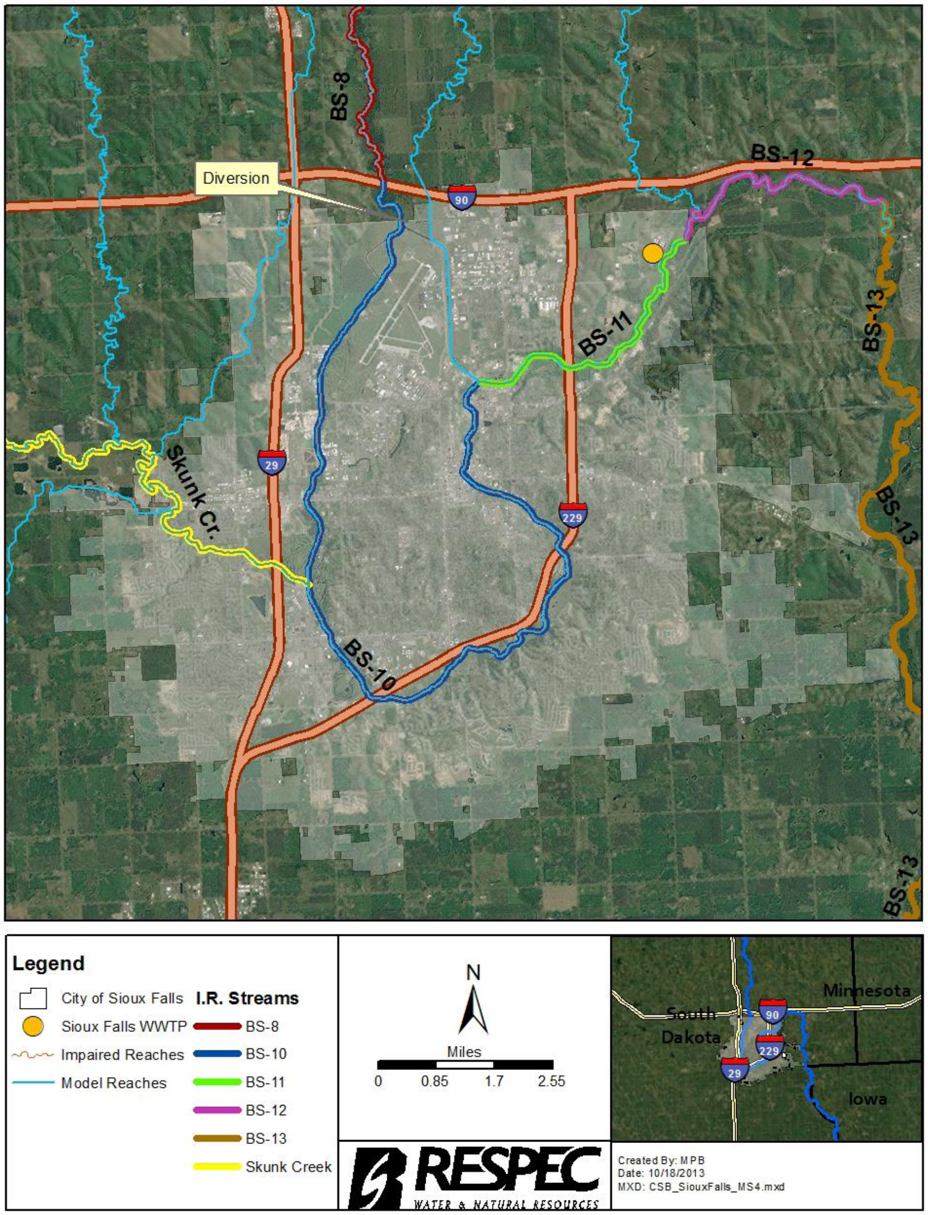

Figure 2. Impaired Reaches Within the City of Sioux Falls.

The model findings indicated that in Upper BS-10 during dry years, *E. coli* concentrations persist well past the hydrograph peak of storm events, because the flows are unable to flush pollutants downstream. During wet years, compliance with the 30-day standard is achieved during most of the recreation season. However, even with higher flushing in wet years, the daily maximum standard is exceeded during the storm event and is driven by city loading. In Lower BS-10, flushing was higher because Skunk Creek added flows, and exceedances of the daily maximum standard were driven by city loading and limited to the storm period. Exceedances of the 30-day standard were driven by noncity loading. Similar patterns were observed in BS-11. Findings could be impacted in BS-10 by use of the diversion channel.

BS-11 best optimizes the benefits of a WQCT program. Its watershed includes the majority of the city of Sioux Falls, and the protection of BS-11 would not cause or contribute to exceedances of standards in other reaches. Even though full compliance with *E. coli* standards in BS-10 and BS-11 using WQCT is not possible, WQCT can be used to accelerate progress toward attaining standards. It was also noted that, though attenuation factors limit program cost effectiveness for an additional reach, any trades that offset city loading for either BS-10 or BS-11 would also reduce loading in BS-12, just east of the city.

E. coli is sufficiently persistent to support a trading program in the CBSRW. Persistence estimates from a water quality credit-generating project to BS-11 were used to develop location factors. For example, 55 percent of the *E. coli* in Skunk Creek just west of the Sioux Falls city boundary persist to BS-11 during the recreational season.

In BS-11, on average, there is enough supply to meet the (daily maximum) *E. coli* demand during all flow intervals. There is more supply relative to demand in the lower flow intervals; in the high and moist intervals, there is just enough supply to meet the demand on average. On average, there is enough supply to meet the (daily maximum) demand during all months.

Figure 3 depicts the hydrograph and source loading as estimated by the HSPF model simulation for BS-11 and graphically illustrates one of the key difficulties with guaranteeing pollutant equivalency, as equivalency appears fairly good for the July 2009 storm events, when city (orange) and non-city (black) are elevated together, but not as good for the August or September events, when city *E. coli* spikes without a corresponding non-city concentration.

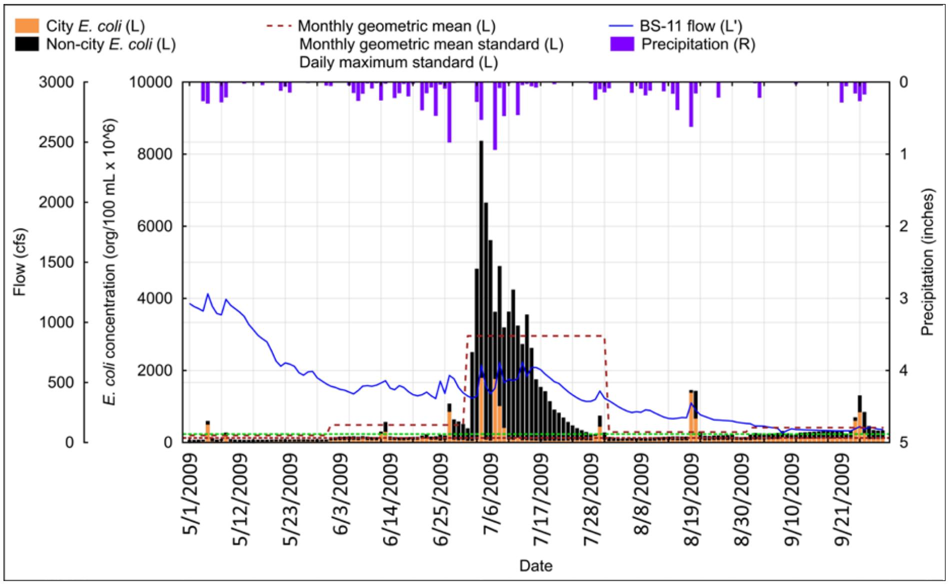

Figure 3. BS-11 E. coli Concentrations for the 2009 Recreational Season.

During the pollutant suitability analysis, a set of critical issues associated with implementing a WQCT program in the CBSRW were identified. Approaches for mitigating these hurdles were considered when evaluating possibility of a trading program being applied to help reduce bacteria loading in the CBSRW. The following are the critical issues:

1. Market approaches alone will not be sufficient to achieve compliance goals. The recommended trading approach is to establish interim trading options, not to use trading as a full compliance solution. Trading would likely be phased out over time as the city implements sufficient urban stormwater BMPs.
2. Agricultural and urban sources do not discharge equivalent forms of pathogens.
   a. Agricultural livestock runoff does contain pathogens that pose a human health risk, and, therefore, reductions in agricultural loading will provide water-quality benefits.
   b. Urban stormwater has been documented in national studies to frequently come in contact with human wastewater and contain pathogens from human sources.
   c. Human pathogens have the potential to increase the human health risks associated with recreational contact.
   d. Human sources of pathogens will be the highest priority and trading will not be an option for these sources.
   e. The current level of understanding makes it challenging to establish a robust equivalence factor for every type of pathogen associated with each source type.
   f. A conservative equivalence factor, supported by justification and appropriate for the recommended approach, can be established in a future project phase when the WQCT framework is completed.

3. *E. coli* bacteria have a limited persistence in CBSR channel.
   a. Persistence affects downstream water-quality concentrations more during high flow regimes, because the pathogens will be transported further during their life cycle.
4. The diversion structure increases the complexity of establishing trade ratios during low and moderate flow periods.
5. For key reaches, the model simulations indicate that bacteria are not fully flushed out of the source reach and adjacent downstream reaches during low flow events.
6. The daily maximum *E. coli* standard is often exceeded in BS-10 and BS-11 when the HSPF model simulations indicate that the source of loading is substantially dominated by urban runoff.
7. Upper BS-10 and the unnamed tributary to Skunk Creek pass through the northwest corner of Sioux Falls and have limited potential for offsetting local stormwater loading with agricultural-generated credits.
8. Upper BS-10 low flow has extended durations of exceedance periods that could be benefited by adding more flow from the diversion structure during dry-to-moderate periods.

To address these issues, an environmental market framework could use watershed-specific program elements during the early periods of the TMDL implementation period. Such elements include trade ratios, watershed management policies, and eligibility criteria. In this way, uncertainty could be managed appropriately while accelerating loading reductions and the achievement of water-quality standards. The program framework could address the issue concerning limited pollutant persistence. In addition, there would be adequate ability to provide a credit supply for a portion of city stormwater loading that would result in an accelerated reduction in loading.

An appropriate approach would take into account each source type, timing, and spatial characteristics. This approach would emphasize implementing critical activities for both urban and rural sources. Urban pathogen loading would be divided into two categories—human waste and animal sources. Human waste sources would be a higher priority to be addressed by traditional stormwater BMPs and preventative measures. The animal sources could be addressed by traditional measures and/or trading. The activities to manage human and animal sources could be incorporated into an implementation schedule that included measurable milestones along the way to full compliance through traditional stormwater BMPs. As the project progressed, it was determined that human and animal sources were even less equivalent than originally assessed in this Pollutant Suitability Evaluation.

Pollutant Suitability Findings

Based on the critical issues identified above and further considered over the course of the project, it was recommended that a Payment for Ecosystems Services (PES) program be pursued as an alternative method to reduce sediment and bacteria. The PES approach uses many of the same components as WQCT, and can be made robust by applying lessons learned from WQCT programs, but does not provide a full compliance offset. The previously existing CBSRW PES approach did not take advantage of elements of WQCT that allow for transparency and quantifiable reductions in bacteria and/or sediments.

This project was able to suggest a WQCT-informed PES program administrative structure that could maximize defensibility.

To address the complications associated with trading bacteria, it was recommended that TMDL compliance activities in the CBSRW incorporate a tiered approach that prioritizes addressing human health risk. Activities to reduce pathogen load would include both urban retrofit projects and agriculture PES projects. The recommended PES program reduces the *E. coli* loading but could be only used in a regulatory manner for leveraging longer compliance schedules and/or applying for a variance. Such longer compliance schedules could be used to allow time for MS4 permitees to schedule retrofits in a more cost-effective manner by sequencing these with other utility upgrades (like road replacement). PES projects would be evaluated based on human health risks, expense, and overall improvements in water-quality conditions. Approved projects would be less expensive off-site BMPs, allowing time for financing on-site BMPs and technology controls to be phased in through the infrastructure planning process. PES would not be applied to human sources of pathogens. However, including the PES option for nonhuman sources would enable accelerated water-quality improvements by providing more cost-effective load reduction options early in the implementation process.

The proposed strategy would involve a three-phased implementation process (Figure 4). In the first phase, high-priority urban stormwater activities would be implemented to address human sources of pathogen loading. PES would be used to offset a portion of the sediment and bacteria loads. The second and third phases would involve expanding the extent of urban BMP coverage, and result in further pollutant loading reductions. However, without addressing the dominance of stormwater loading during precipitation events and the heightened risk to human health from potential intermingling of wastewater with stormwater, trading was not anticipated to be an acceptable, long-term approach for complying with bacteria load reduction requirements. Therefore, the proposed strategy would phase out the PES program to meet bacterial and sediment loading over time. In this type of strategy, PES activities over a longer-term would be replaced by on-site urban BMPs and technology controls that are more difficult to implement.

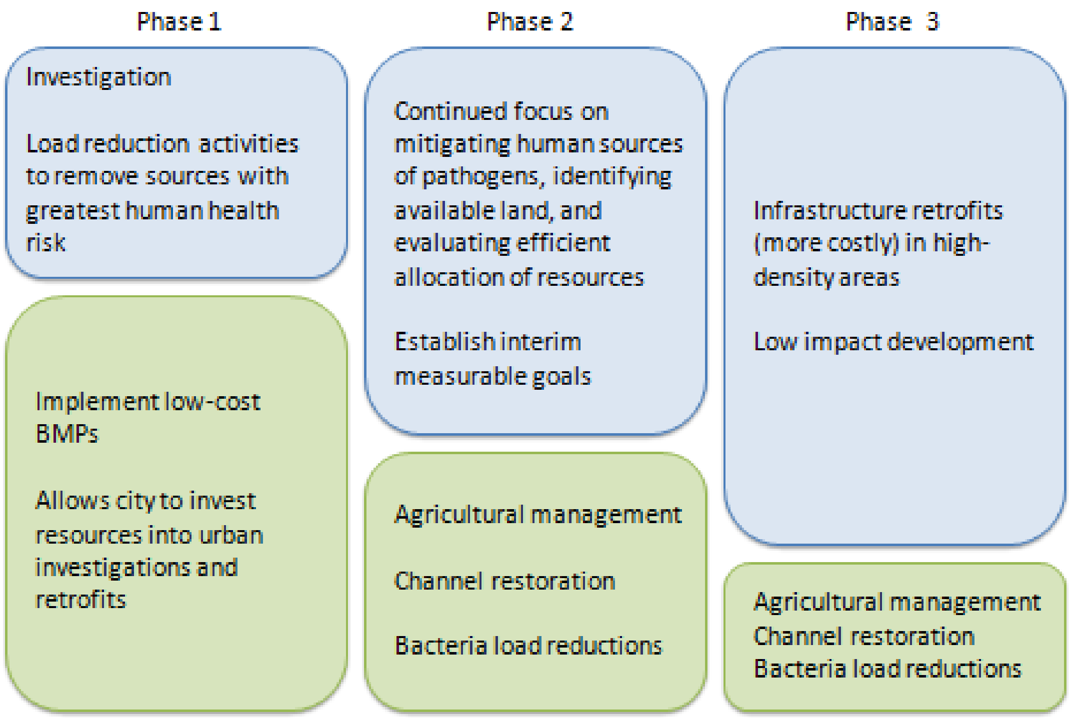

Figure 4. Recommended Phased Approach.

Land use in the CBSRW includes substantial agricultural activities, including livestock operations. Runoff from livestock manure has been identified as a major source of pathogen contamination. Some pathogens that originate in livestock can cause disease in humans, and others do not pose a human health risk. For bacteria to be suitable for trading, pathogens originating from livestock sources must be equivalent to pathogens originating from other watershed sources. However, there is insufficient data to establish a specific equivalency relationship and for this project it was determined that nonhuman and human sources could not be considered equivalent. Despite this lack of equivalency, reducing pathogen loading from livestock sources can still contribute to water-quality improvements and reduce human health risks.

The findings of this evaluation indicated that TSS can be a suitable parameter for trading. TSS is included in other WQCT programs across the U.S. Developing a trading program for TSS will apply the methods explained in trading guidance documents issued by the EPA. These methods provide assurance that the established program is suitable for addressing watershed management goals and NPDES permit requirements associated with reducing TSS loading.

Given the challenges associated with incorporating bacteria into a trading program and concerns raised by the WQCT staff in the Washington, DC EPA office, another market based approach, PES, was recommended. This PES system is based on the existing Seasonal Riparian Area Management (SRAM) program, which has been proven to serve the City of Sioux Falls well. In addition, appropriate source reduction BMPs can be developed with the support of the PES program. The PES program recommendations create a standardized and formalized program that includes:

- Public transparency
- Third party checks and balances
- Application and/or request for projects windows (e.g., open windows, reverse auctions, etc.)
- Cost-effective site selection

Program transparency and third party oversight will strengthen support when requesting longer permit compliance schedules and/or a variance. The potential market and costs of implementing such practices are further evaluated in the Economic Feasibility portion of this project.

Analysis of Potential Market: Economic Feasibility

The economic feasibility of trading was also evaluated. WQCT and PES programs are market-based options to help meet environmental protection objectives. If trading does not provide a cost-effective alternative to traditional treatment approaches, it will not be selected. Achieving water quality-based effluent limits can require extensive and costly infrastructure upgrades and best management practices (BMPs). A thorough Assessment of Financial Attractiveness for a Water Quality Credit Trading Program in the CBSRW was conducted to determine whether environmental markets can help achieve equivalent or greater water quality protection at an overall lower cost.

Assessment of Financial Attractiveness

For WQCT and PES programs to be viable, they must achieve equal or greater pollutant reductions compared to traditional methods, while also providing cost savings. While both environmental and economic considerations are taken into account when evaluating the feasibility of trading, the environmental factor takes precedence. As seen above, both *E. coli* and TSS trading may be helpful to meet pollution reduction goals in the CBSRW. A trading program will be cost-effective where trading can reduce the total cost of complying with water quality goals. For example, trading reduces overall compliance costs when a permittee can purchase reduction credits at a lower price compared to implementing traditional technology upgrades. This cost savings provides an economic incentive to participate in trading and improves the economic efficiency of achieving environmental protection. It should be emphasized that economic efficiency can help drive participation in a trading program, but environmental protection is the primary goal.

The financial attractiveness of trading is evaluated by comparing the costs associated with various options of pollutant reduction BMPs. For the CBSRW, trading would be an economically viable option if other, non-regulated pollutant sources in the watershed can reduce loading at a lower cost than reductions achieved in the permitted MS4 footprint. This economic evaluation compared the costs of agricultural BMPs with the costs of urban stormwater treatment practices and the potential cost savings associated with implementing the more cost-effective options. The total costs, annual costs, and unit costs of both urban and agricultural BMPs were evaluated to determine whether WQCT or PES is economically viable in the CBSRW. This analysis generated an equivalent annual cost associated with each selected BMP. A lifecycle cost analysis (LCCA) was conducted to enable a comparison of the relative cost-effectiveness of BMPs with different costs and replacement cycles. This is a standard economic approach for comparing the financial impacts of different projects. Federal regulations mandate that any federal agency evaluating the cost-effectiveness of energy and water conservation projects, as well as renewable energy projects, follow the federal lifecycle costing rules published in the Code of Federal Regulations (US DoE, 1996). An LCCA involves first calculating the total cost of each BMP for the full lifetime of the practice. The total cost then is annualized to determine an estimated cost per year. The annual costs associated with different BMPs can be compared to evaluate which BMPs can be implemented at the lowest cost. In its trading handbook, the U.S. Environmental Protection Agency (US EPA) recommends calculating annualized costs associated with pollutant control options for assessing the economic feasibility of WQCT (US EPA, 2004 & 2011).

The total costs, annual costs, and unit costs of both urban and agricultural BMPs were evaluated to determine whether WQCT or PES is economically feasible for the CBSRW. A LCCA was conducted to provide a meaningful comparison of BMPs with different initial capital costs, operations and maintenance costs, and lifespans. This analysis provided an equivalent annual cost for each selected BMP based on example practice designs. The load reductions achieved by each treatment option then were incorporated into the cost assessment to determine a unit cost of pollutant reduction. These unit costs enable the relative cost-effectiveness of each BMP to be assessed. Finally, example trade ratios were applied to the unit costs of the agricultural BMPs to illustrate possible credit prices. The urban BMPs examined were extended detention basins, retention ponds, infiltration basins, vegetative buffers and bioswales. The agricultural BMPs used for comparison included: riparian area fencing and watering facilities, filter strips, riparian herbaceous cover, prescribed grazing management, streambank stabilization, and agricultural waste management systems including waste storage stacking facilities, vegetated treatment systems, and waste treatment lagoons.

The unit costs of urban and agricultural BMPs can be compared to determine if WQCT or PES can provide a cost-effective alternative to help the City of Sioux Falls achieve load reduction goals. In almost all cases, the agricultural BMPs are more cost-effective than the urban BMPs. The exceptions are the three agricultural waste management systems. These practices were more cost-effective than urban treatment options for bacteria reductions, but were more expensive for sediment reductions. Even when a conservative trade ratio of 4:1 is applied, all of the agricultural BMPs (with the exception of the Ag waste management systems) remain more cost-effective than the urban BMPs.

The potential cost savings associated with applying load reduction offsets was evaluated by comparing the unit costs of selected agricultural BMPs and urban BMPs. The three least expensive urban BMPs were selected, based on the lowest unit costs for bacteria reductions. Agricultural BMPs were selected to reflect a range of unit costs associated with bacteria reductions. Filter strips treating runoff from heavy use areas represented the least-cost agricultural BMP, riparian area fencing and watering facilities represented mid-range unit costs, and the waste treatment lagoon represented the highest cost agricultural BMP. The percent cost savings associated with each combination is presented in Table 8. These values were derived by calculating the percent difference in unit costs between the selected urban and agricultural BMPs under three different trade ratios. The most cost-effective options are highlighted in green (cost savings greater than 90-percent) and options that would result in an economic loss are highlighted in pink.

Table 8. Percent cost savings comparison between urban and agricultural BMPs.

		Sediment Cost Savings			Bacteria Cost Savings		
Urban BMP	**Agricultural BMP**	**2:1 Trade Ratio**	**3:1 Trade Ratio**	**4:1 Trade Ratio**	**2:1 Trade Ratio**	**3:1 Trade Ratio**	**4:1 Trade Ratio**
Retention Pond	*Filter Strips from Heavy Use Area*	98%	97%	96%	100%	100%	100%
	Riparian Area Fencing and Watering Facilities	N/A	N/A	N/A	98%	97%	96%
	Agricultural Waste Management System- Waste Treatment Lagoon	-3,395%	-5,143%	-6,891%	99%	99%	99%
Extended Detention Basin	*Filter Strips from Heavy Use Area*	97%	95%	93%	100%	100%	100%
	Riparian Area Fencing and Watering Facilities	N/A	N/A	N/A	97%	96%	94%
	Agricultural Waste Management System- Waste Treatment Lagoon	-5,947%	-8,971%	-11,994%	99%	99%	98%
Infiltration Basin	*Filter Strips from Heavy Use Area*	96%	94%	92%	100%	100%	100%
	Riparian Area Fencing and Watering Facilities	N/A	N/A	N/A	96%	94%	92%
	Agricultural Waste Management System- Waste Treatment Lagoon	-6,848%	-10,322%	-13,796%	99%	98%	97%

Note RE: N/A Sediment load reductions associated with riparian area fencing and watering facilities were not calculated given the lack of data necessary to estimate livestock-based erosion.

Many other agricultural BMPs were found to be cost-effective for both bacteria and sediment; Table 8 reflects only a portion of the results. Of the BMPs included in the analysis, all agricultural BMPs were more cost-effective than urban treatment practices for bacteria reductions and were recommended for consideration for PES program inclusion. For WQCT, the agricultural BMPs determined to be cost effective for sediment at all example trade ratios were:

- Filter strips treating runoff from rangeland
- Filter strips treating runoff from cropland
- Filter strips treating runoff from heavy use areas
- Riparian herbaceous cover treating runoff from rangeland
- Riparian herbaceous cover treating runoff from cropland
- Riparian herbaceous cover treating runoff from heavy use areas
- Streambank stabilization

Combinations of credit-generating BMPs could be implemented to achieve overall greater water quality benefits at a lower cost compared to only implementing urban stormwater treatment practices.

The cost differential between urban and agricultural treatment practices creates an economic incentive for generating pollutant load reductions in agricultural areas of the watershed. A trading program where agricultural reduction credits are applied to MS4 load requirements could be used to assist municipalities, such as the City of Sioux Falls, with achieving water quality goals at a lower cost. In many cases, the cost savings to the municipalities could be substantial.

These pollutant suitability and cost-effectiveness findings were used to inform the development of example WQCT and PES implementation frameworks and schedules. These schedules reflected the acceleration in water-quality protection activities when using WQCT and PES in a pragmatic and targeted manner.

Pilot Program

The activities of the participating EQIP eligible producers were impacted by participation in the pilot program and adherence to the WQCT and PES implementation frameworks and schedules. This section presents two preliminary frameworks for testing the sediment water quality credit trading (WQCT) pilot program and the bacteria Payment for Ecosystem Services (PES) pilot program in the Central Big Sioux River Watershed (CBSRW). The frameworks provide the basic requirements and organizational structures for operating the programs during the pilot stage of the project.

The program requirements were created to provide clear definitions for program operations, enhance stakeholder support, and provide guidance for program development to ensure water quality protection objectives were achieved. Concise program requirements allow for evaluating and judging administrative and environmental performance against the intended outcomes. The proposed program organizational structures reflect how the requirements will be carried out through program operational activities. The specific steps and details associated with carrying out transactions are addressed, outlining the requirements for agricultural producers to participate in the WQCT and PES programs as credit generators. In addition, the section reviews the requirements for other program roles, including MS4 permitees, who participate as purchasers, program administrator staff, and third party verifiers.

It is necessary for both the WQCT and PES programs to have clear, well-developed requirements to guide program development and operations. These requirements help ensure water quality protection objectives are achieved. In addition, concise requirements assist with minimizing program risks and maximizing program outcomes. The requirements applied to the sediment WQCT and bacteria PES programs will differ based on the level of rigor needed for each program.

A WQCT program is designed to address regulatory compliance with National Pollutant Discharge Elimination System (NPDES) permits. A WQCT program must ensure Clean Water Act (CWA) requirements are achieved in order for trading to be used as a flexible compliance tool for NPDES permittees. As such, the policies associated with the trading program provide for a robust approach necessary to provide and document water quality protection. This includes ensuring the trading program fits with EPA policy and complies with the CWA requirement that permitted discharges must not cause or contribute to water quality violations. WQCT program design elements help ensure the program is sufficiently robust to meet federal water quality protection requirements but can result in a fairly complex program. This level of rigor is necessary when addressing regulatory compliance needs.

However, an alternative approach, such as a PES structure, can be designed that incorporates trading principles but is more flexible and less complex. Such an approach would be appropriate for a program that is not being used to meet permit requirements but where watershed managers still desire a credible, defensible mechanism for tracking and demonstrating progress toward achieving water quality protection goals. A PES program is designed as a supplemental activity to help accelerate water quality improvements. Most PES program activities occur outside of NPDES permit programs; however, PES activities can be considered during decision-making intervals regarding flexible NPDES permit options, such as length of compliance schedules and/or variances. For example, a permittee could leverage its participation in a PES program to justify a longer compliance schedule.

No existing WQCT programs currently trade for bacteria reductions, although some state agencies have promulgated rules that allow for later discussions where bacteria trading will be considered if proposed.[1] EPA policy does not specifically identify bacteria as a water quality parameter that is appropriate for trading (US EPA, 2003). Based on this policy, additional justification is necessary in order to trade pollutant parameters such as bacteria. The pollutant suitability evaluation conducted by the project team and discussed above concluded no such justification can be made in the CBSRW case. For this setting it was determined that urban and agricultural bacteria sources are not equivalent, and equivalence is a necessary component of a viable WQCT program. To address bacteria loading, an alternative, PES-style approach was proposed given the unique challenges associated with developing a crediting process for bacteria reductions.

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[1]A Wisconsin WQT framework document states that “Notwithstanding the restrictions presented in Section 2.2 of this report and excluding bioaccumulative chemicals of concern (BCCs) as identified in ch. NR 105, Wis. Adm. Code, the DNR will consider any pollutant parameter including bacteria for water quality trading.” (WI DNR, 2011, p. 9)

The bacteria PES program for the CBSRW will generate load reductions that are counted toward overall environmental and water quality goals, as opposed to compliance requirements. This program will build upon the Seasonal Riparian Area Management (SRAM) program currently operating in the watershed. However, the PES program will incorporate additional elements that enhance the ability for watershed managers to demonstrate progress toward water quality goals. The PES pilots provided testing of the methods to record and communicate implementation activities in a manner that allows for enhanced interaction with stakeholders while using repeatable decision processes. Such processes optimize expenditures to accelerate bacteria reductions.

The PES and WQCT program requirements selected were derived from a review of options used in existing programs combined with locally tailored elements that built on the successes of the Seasonal Riparian Area Management program and incorporated salient components from existing trading programs in similar settings. The pilot program testing period was used to test the program materials for ease-of-use and goodness of fit with the local program intent. The pilot period of this project enabled stakeholders to become familiar with the protocols and forms and provide meaningful feedback for adjustments based on long-term goals and the desired program scale in the future.

Figure 5 illustrates a simplified picture of the overall program framework structure. As depicted in this figure, the major components are similar for both the PES and WQCT programs. In the application of these major components through detailed steps, the PES and WQCT programs do differ and further discussion will support the rationale for the differences.

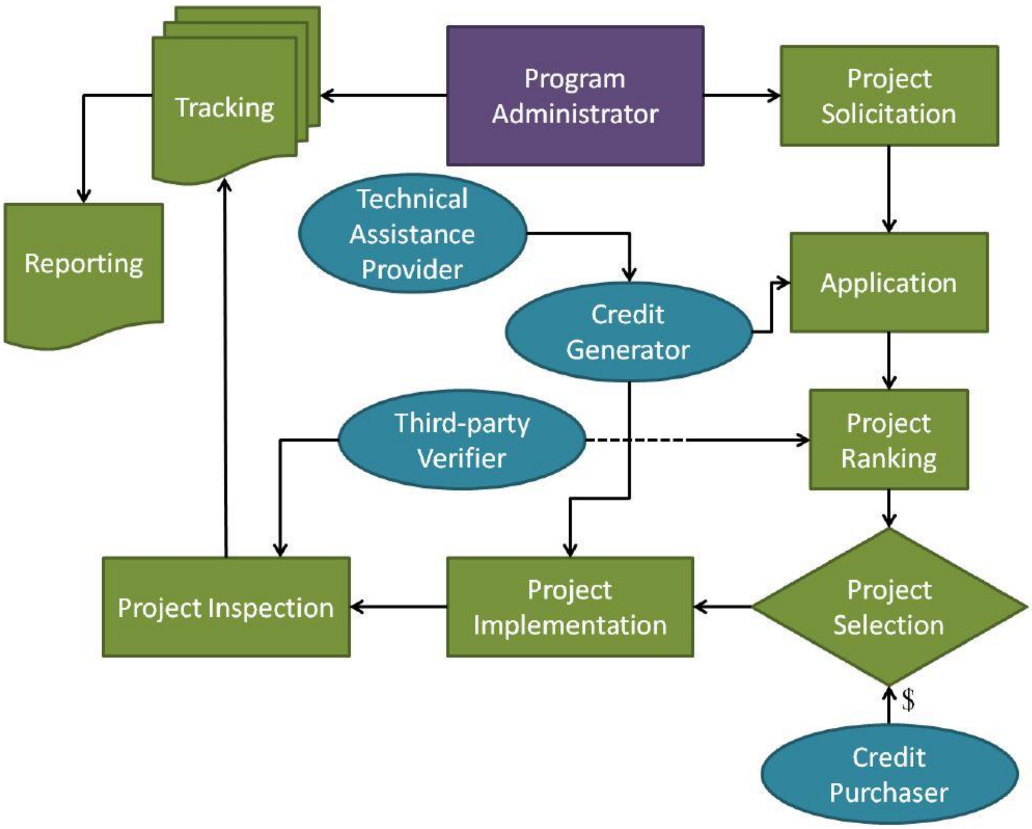

Figure 5. Simplified overall framework diagram for the bacteria PES pilot program and sediment WQCT pilot program.

A notable difference between the WQCT program and PES program is the application of the term "credit". In the sediment WQCT program, a credit is based on the annual tons of sediment reduced at the credit generating site. This estimate is adjusted to account for the introduced estimation uncertainty, equivalence between sources of sediment, and attenuation factors. In the bacteria PES program, the term "credit" is not applied in order to avoid confusion and distinguish this approach from a typical WQCT program. (This difference in terminology is reflected in the PES program protocol document where "bacteria reduction" is used instead of credits; however, for simplicity, this document still uses the term "credit" when referring to both programs generally.) The PES program will use an index that reflects bacteria reductions generated based on a set of bacteria source load index calculations. The index calculator will be run twice, first to reflect conditions before the BMP and second to reflect conditions after BMP implementation. The difference in the index value between the before and after conditions will represent the bacteria reductions generated by the BMP. An index is used in the PES program due to the inherent limitations in estimation given the variability in bacterial counts, pathogen longevity, and equivalent forms.

Sediment Water Quality Credit Trading (WQCT) Pilot Program Participation

Several fundamental trading components must be defined in order to develop an approvable trading program for NPDES-permitted MS4s. US EPA policy indicates that trading can only be a compliance option for addressing new Water Quality Based Effluent Limits (WQBELs). Therefore, a trading program for MS4s must first define the Technology-Based Effluent Limit (TBEL) that establishes the permittee's baseline, or expected level of performance that must be achieved on site prior to using credits for remaining compliance needs. For the CBSRW WQCT program, an MS4 baseline is considered to be the permit's TBEL.

The TBEL is defined as the most recently approved Stormwater Pollution Prevention Plan (SWPPP) prior to the establishment of a TMDL WLA objective. This SWPPP reflects the maximum extent practicable of stormwater control an entity can accomplish (absent an effluent requirement) that achieves the specific need of a water resource.

The MS4 permittee can determine its demand for purchasing reduction credits through the WQCT program based on the level of additional stormwater BMP implementation that will be described in the future SWPPP. The demand will represent the gap between the SWPPP level of protection and the TMDL WLA requirements. The SWPPP and NPDES permit that will comply with a new TMDL can be written to: a) describe the environmental protection as a list of BMPs, or b) as numeric effluent limits. Whichever is the case, the WQCT demand assessment will require a quantified loading estimate to compare against the WQCT credit supply in order to ensure equal or greater environmental protection is achieved when using trading.

Urban stormwater modeling will be used to quantify the nonpoint source sediment loading, current BMP efficiency and the treatment efficiencies of proposed BMPs. The SD DENR and staff permit writer have direct authority to issue approvals regarding model selection, adequate calibration, and the final SWPPP. Thus, the eligibility of an MS4 permittee and how the specific demand is determined is negotiated between the SD DENR and permit representatives.

Bacteria Payment For Ecosystem Services (PES) Pilot Program Scale

The requirements for a bacteria PES pilot program are based on the desired role of the program. If the PES program is a voluntary, standalone initiative not integrated into a compliance program, the requirements can be tailored to fit localized management goals. However, if the PES program is created to support another initiative, the program requirements must address the relevant needs of that initiative. For example, the PES program could be used as leverage to justify a longer permit compliance schedule or demonstrate achievements associated with grant program awards. In these cases, the PES program requirements must be sufficiently robust to fit the requirements of the associated activities.

The scale and purpose of the program also will influence the level of rigor associated with the PES program. For instance, if the expected transaction volume for the PES program is relatively small, then the program requirements should minimize undue overhead, for example if the few participants are well versed in the program. Likewise, the program requirements will consider the overall program purpose. For instance, if intent is to provide public transparency, bolster public awareness, and enhance recognition, then the program should incorporate a level of tracking and reporting that is sufficient to meet this goal.

Sediment WQCT and Bacteria PES Pilot Program Comparison

Table 9 provides a side by side comparison of the program requirements of the Sediment WQCT and the Bacteria PES Pilot Programs. The comparison includes requirements for participation for credit purchasers and credit generators, responsibilities of program administrators, the definition and longevity of a credit/bacteria reduction, and additional regulatory and BMP notes.

Table 9. Comparison of Pilot Program Requirements.

Sediment WQCT Pilot Program Requirements	Bacteria PES Pilot Program Requirements
Credit Purchaser Requirements	
Buyers of sediment credits shall be required to purchase an additional ten percent to benefit the CBSRW.	There are no restrictions for purchaser participation.
	The purchaser of credits is responsible for identifying their own credit demand. Credit demand determination guidance is for the purchaser to identify their own balance regarding the purchaser's environmental goals and available resources as achievable within PES program list of eligible BMPs.
Credit Generator Requirements	
Urban stormwater TBELs are assumed to be equivalent to the previously approved SWPPP prior to having identified TMDL WLA goals. The level of stormwater control established through the SWPPP is considered the baseline condition.	The pilot PES program applies select eligibility requirements in order to assure the purchaser that the practice generating bacteria reductions will demonstrate satisfactory performance. PES eligibility requirements include the following considerations: a. Program investments are selected in a manner that optimizes environmental protection. b. Program purchases will increase the level of environmental protection previously occurring on the proposed sites. c. Program investment will be implemented and maintained for the duration of the legally binding agreement. d. Program investments can be selected by their ability to build community relationships.
Credits can be used to comply with the WQBELs associated with TMDL WLA requirements for reductions beyond those achieved through the SWPPP, which is used to define the TBEL requirements.	
The sum of total credits needed to fulfill NPDES permit requirements shall be provided in the permit.	
Upstream credit generation is required to prevent the creation of local water quality violations.	Upstream credit generation is required to prevent the creation of local water quality violations.
Pilot Program Administrator Responsibilities	
	The PES program services will include third party verification and public reporting summaries of the performance and quality of the credits.
	The PES program information will be appropriately managed in a manner that includes discretion and recognition of confidential and sensitive data. Data gathered at sites of any involved parties including those that may be undergoing regulatory enforcement activities will only be released to participating PES program affiliates, until approved for release to others by the entity to whom the private information pertains. Any publicly released data can be in the form of summaries and reports which will not contain identifying information that would disclose either the

	site's location or owner/operator's personal information.
Defining A Credit/Bacteria Reduction	
The credit (unit of exchange) is equal to [tons of sediment reduced yearly X the trade ratio uncertainty factor X the attenuation factor (percentage)].	For purchaser accounting purposes the investments purchased will be provided in Bacteria Source Load Index reduction results. The Bacteria Source Load Index is being developed by the project team and is based on the Bacteria Source Load Calculator (Virginia Tech, 2007) created by the Virginia Tech, Center for TMDLs and Watershed Studies to support bacteria TMDL watershed models by providing inputs.
All sediment load estimation methods shall be selected from the approved list of credit estimation calculators as determined by the WQCT program administrator.	All bacteria load estimation methods will be based on PES program administrator approved methods. For the pilot test period the approved method is the Bacteria Source Load Index.
Currently approved credit estimation method(s) appropriate for the BMP(s) shall be used. The time stamp for determining the currently approved credit estimation method is three months before the date that the legally binding agreement is signed.	
Use of attenuation factors derived by the application of the CBSRW TMDL HSPF model shall address differences in spatial locations.	The approved calculation method includes the use of attenuation factors derived by the application of the CBSRW TMDL HSPF model (SD DENR, 2012). This model assists the program by determining the delivered yield of site reductions to a specified area of interest.
Use of the TMDL modeled attenuation factors shall address sediment equivalency issues. The discharged urban stormwater sediments are considered to be equally offset by the [site load reduction estimate of total sediment X the site location subwatershed's estimated yield downstream]. Reductions in upstream sediments are assumed to have similar particle size distributions to the rest of the basin. As such, the persistence cube accounts for the larger sediment particles being removed for all sources within the Central Big Sioux River Watershed.	
Credit Longevity	
The project life of the credit-generating activity is determined by the length of the legally binding agreement between buyer and seller. The agreement establishes the provisions for implementation and operation of the BMP including the roles and responsibilities of the signatories necessary to assure adequate performance.	The life of a credit-generating project is determined by the length of the legally binding agreement. The agreement establishes the provisions for implementation and operation of the BMP including the roles and responsibilities of the signatories necessary to assure adequate performance.
The "credit generating period" for the sediment WQCT program is defined as one year. The number of credit periods produced by a credit-generating project shall be determined by the duration of the project agreement.	The "credit period" for the bacteria PES program is defined as the five critical months of the year where the water temperature allows for both extended life of bacteria and water recreation beneficial uses (defined

For example, 10 credit periods will be produced by a project with a 10-year legally binding agreement.	as the recreation season May 1 to September 30). The number of credit periods produced by a credit-generating project will be determined by the duration of the project agreement. For example, 10 credit periods will be produced by a project with a 10-year legally binding agreement.
Any project implemented prior to October of a given year or ending after June in a given year shall be considered to generate a half year's amount of credits.	
Contemporaneous trading shall require credits to be generated throughout the year but be used to offset permitted discharges at any time within that same year.	
The approved credit sum shall remain in effect for the term of the legally binding agreement regardless of the approval of an improved credit estimation method for the same BMP(s).	
A legally binding agreement defining project life may be re-signed after successful completion of all requirements of the previous agreement to extend the credit generating period.	Project life as determined by the legally binding agreement may be re-signed after successful completion of past agreement thereby extending the credit generating period.
A 120-day reasonable replacement window shall be allowed to restore credit generating sites identified to have deficiencies, without losing credits or terminating the site approval.	A 120-day reasonable replacement window will be allowed to restore sites identified to have deficiencies, without losing credits or terminating the site approval.
Credit generation shall be eligible after the farmer has complied with the load allocation requirements in the TMDL and/or implementation plan.	
Additional Regulatory and BMP Notes	
Credit generating sites must be in compliance with all applicable Federal, State and local rules and ordinances prior to being able to generate credits.	Credit generating sites must be in compliance, or the PES activities will bring the site into compliance, with all applicable Federal, State and local rules and ordinances.
Standard methods shall be used to design BMPs and create a conservation plan for sites implementing BMPs for credit generation. Standard methods include NRCS practice standards and designs stamped by a professional engineer. In addition, unique requests for consideration of a practice design can be granted when the application submittal provides sufficient descriptions of the design for a pre-approval to be granted by the program administrator. Until design approval is granted by the program administrator, the project is considered ineligible for funding.	Standard methods will be used to design and create a conservation plan for implementation of BMPs. Standard methods include NRCS practice standards and designs signed by a professional engineer. In addition, unique requests for consideration of a practice can be granted when the application submittal provides descriptions of the design sufficient for a pre-approval by the program administrator. Until the Administrator provides approval for a specific deviation from standard methods, the project remains ineligible for funding.
Newly implemented Bacteria Payment for Ecosystem Services projects also having sediment load reductions shall be allowed to generate WQCT credits per these requirements.	
Other ecosystem service marketable credits generated by the BMPs to provide TSS WQCT credits remain under	Other marketable ecosystem service credits generated by the BMPs remain under control of credit generator

control of credit generator and can be sold to other buyers if also appropriate for that ecosystem service program.	and can be sold to other purchasers if also appropriate for that ecosystem service program.

Though there was not enough demand to necessitate a Sediment WQCT program in the CBSRW, the Bacteria PES program requirements were put to the test through application during the 2015 growing season pilot program.

Outcomes of Pilot Program

A pilot program was conducted and outcomes were tracked from May 1, 2015 through September 30, 2015. As noted in the Analysis of Potential Market for Pollutant Suitability, the demand for TSS credits in the CBSRW was not adequate to support a Sediment WQCT program in the CBSRW, so this was not included in the pilot program. The pilot program focused on Bacteria PES, due to ready supply, adequate demand in the CBSRW and clear cost savings from Ag BMPs identified in the Analysis of Potential Market for Economic Feasibility. Three agricultural sites participated in the pilot program, including two Seasonal Riparian Area Management (SRAM) areas and one on-stream, open feedlot being relocated to a monoslope barn.

An estimate of the amount of bacteria reduction realized at Reach 11 of the Big Sioux River (BS-11) was calculated for the three cooperating producer sites from May 1st through September 30th (the contact recreation season in South Dakota), a total duration of 152 days. The number of cattle and total duration they had access to the stream were input into a FLGR4 model, developed by the SD DENR, to produce the on-site total annual load reduction for each lot. The on-site load reduction number was then multiplied by a persistence factor, derived for BS-11 from the calibrated HSPF model for each modeled subwatershed. Figure 6 below displays categories of modeled bacteria persistence for all the subwatersheds modeled.

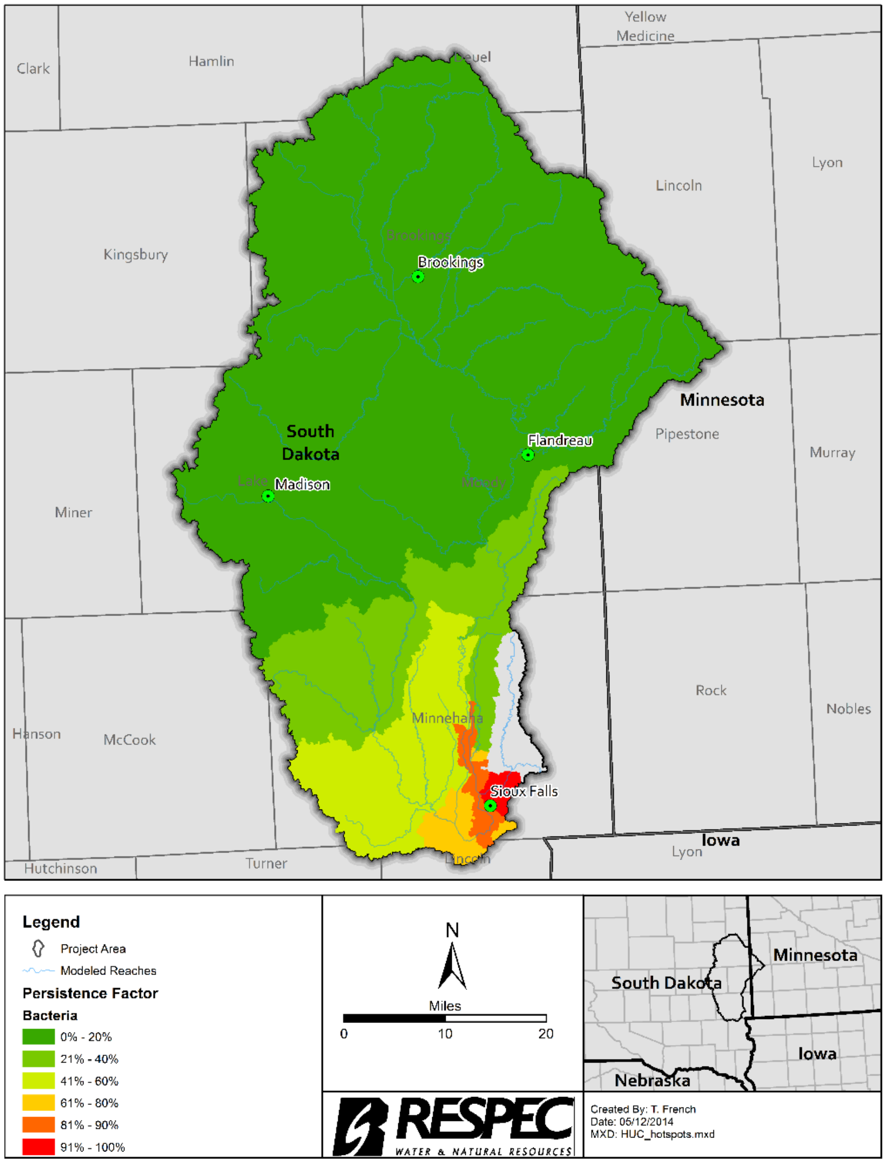

Figure 6. Modeled Bacteria Persistence by Subwatershed.

Both SRAM sites were pastures located on Skunk Creek that contained 70 cow/calf pairs, which as part of the SRAM program are not allowed stream access during the contact recreation season. The FLGR4 spreadsheet model estimated that by eliminating stream access there would be a direct loading reduction of 4.47×10^{12} cfu (colony forming units) per site during this time period. This load reduction number was then multiplied by the BS-11, HSPF derived persistence number for the model subwatersheds they are located, which have a persistence of 16%. This leaves 8.51×10^{11} cfu of bacteria per site remaining at BS-11.

The open feedlot site contained 300 feeder cattle throughout the contact recreation season. The lot was located in the floodplain of a tributary to Skunk Creek prone to flooding events inducing large bacteria loading. The cattle were moved off-site into a monoslope barn with a pit that contained the waste and completely eliminated the bacteria loading to the stream. The FLGR4 spreadsheet model estimated the on-site load reduction from moving the cattle into the monoslope barn to be 2.66×10^{15} cfu. This number was once again multiplied by the persistence factor for the model subwatershed it was located in (25%), leaving 6.64×10^{15} cfu of bacteria remaining and available for potential trading at BS-11.

Through surveys and comments received at public outreach meetings, all producer feedback received involved positive supporting comments for the program. Comments related to innovative program elements, agricultural production improvements, and a renewed sense of value for agricultural contributions. Specifically, producers noted the ease of the contracting process as a positive component. The flexible nature of the seasonal riparian area management (SRAM) PES program received several supporting comments from the program participants. Noted was that the program offered contract flexibility for producers regarding grass species, haying and winter grazing. In addition, production improvements were also noted in that the BMP's increased management systems that fit with production goals. One producer noted that calf rate of gain increased with increased access to clean water due to BMP implementation of program's SRAM, an unanticipated benefit. Another comment received at the public outreach meetings was that the City's participation in the PES program was a welcome sign of partnership. Using an urban-rural partnership brings down the barriers that might be perceived to exist between sectors.

Schedule of Events

The tasks completed for the project are tied to the deliverables provided. A Technical Review Team was established in June 2013 and provided input and direction throughout the project. The Literature Search for the Central Big Sioux River Water Quality Trading Project, which is described in the Comparison to Existing Practices, was also completed in June 2013. The pollutant suitability and the financial attractiveness for a WQCT program in the CBSRW were assessed in January 2014. Market Rules and Infrastructure for CBSRW Sediment WQCT Program Protocols and CBSRW Bacteria PES Program Protocols were fully developed in June 2014. The pilot program began testing the CBSRW Bacteria PES Program Protocols in May 2015 and completed the testing in September 2015 (with a mid-point of July 2015). Public outreach meetings, with individual reports summarizing the findings for each deliverable and incorporated into the final sediment water quality credit trading and bacteria payment for ecosystem services trading methods and guidance documents for the CBSRW were completed throughout the project. The following schedule reflects the project task work as completed.

Table 10. Schedule of Events.

Task ID	Task Name	2013 Q1	2013 Q2	2013 Q3	2013 Q4	2014 Q1	2014 Q2	2014 Q3	2014 Q4	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2016 Q1	2016 Q2
1	**Establish the Technical Review Team**		◆ 6/25/2013												
2	**Conduct a Basic Literature Search**		◆ 6/25/2013												
3	**Assess Pollutant Suitability**					◆ 1/1/2014									
4	**Assess the Financial Attractiveness**					◆ 1/30/2014									
5	**Develop the Market Rules and Infrastructure**						◆ 6/1/2014								
6	**Test the Water-Quality Trading Program**											7/20/2015 ◆			
7	**Public Outreach Meetings/Reports (Throughout)**		▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	
8	Progress Reports to Technical Review Team (Quarterly)	◆	◆		◆		◆		◆				◆		
9	Progress Reports to NRCS (Biannually)		◆		◆		◆		◆		◆		◆		
10	Final Report													3/1/2016 ◆	

Lessons Learned

The CBSRW, located in eastern South Dakota and a portion of south western Minnesota, has a robust blend of progressive communities who are willing to work with the thriving agricultural industry. This partnership has proven very successful to date, as shown by their ability to identify and begin activities to address key water quality impairments in the CBSRW. The collaborators' willingness to engage in flexible implementation activities is evident in their pursuit of this program and earlier creation of the SRAM and monoslope barn funding mechanisms under the joint powers agreement.

This project provided salient findings and verification to this watershed, the upper Midwest region, and indeed, even the nation. The project provided transferrable forms and organizational descriptions, protocols and credit estimation tools that can be used by any watershed management team when considering the use of environmental market based implementation tools. The project developed a comprehensive understanding of vetted tools for TSS WQCT and bacteria PES programs. The economic assessment determined the market based approach is very cost-effective. This determination compared implementation costs for multiple urban and agricultural BMPs using an annualized lifecycle cost to predict a range of total unit costs for both bacteria and TSS. The potential cost savings are substantial. However, the pollutant suitability assessment identified some limitations when using the water quality parameters of TSS and *E. coli* to establish water quality beneficial uses and river and stream criteria. These limitations are exhibited both intrinsically in all water quality settings and are magnified within the altered CBSR channel reaches that meander through the City of Sioux Falls. This project ascertained that:

1. The use of E. coli as a surrogate measure of all water borne pathogens has benefits and drawbacks associated with water quality goals being defined by a "surrogate" and its inherent limitations.

The exorbitant sampling costs associated with measuring all pathogen types prevents a specific water quality criteria from being developed for each pathogen. To date the use of E. coli monitoring plans has proven to be an efficient approach to establishing the current conditions of water resources. However, to fully achieve water quality goals with or without the use of flexible compliance mechanisms like WQCT, managers that has reach assessments of the sources that contribute have a substantial advantage over those who have not or cannot afford such a study. Animal livestock do contribute key pathogen types that both pose a human health risk when present and are persistent in the water media. If animal agriculture is determined to be the dominant source of *E. coli* impairments in a reach then implementation plans can focus on correcting that sector's loading. The inverse is also true for urban sources of pathogens. However, when there exists high loadings from either source then a deeper understanding of the magnitude, frequency and duration will benefit the costly corrective actions planning process. It can be intuitive to some that the development of implementation plans benefit from understanding the magnitude of loading from each source. However, for each reach a deeper understanding of the magnitude of a persisting load that remains within the reach after discharge is equally as important. To accomplish this understanding of the bacteria's assumed decay rate and reach flushing mechanisms is necessary. This project was able to provide the watershed managers a reach by reach assessment that considered the critical period, based on critical flow regimes for both urban and rural sources. This type of assessment provided substantial support that verifies the citizens of Sioux Falls are benefited by PES program activities in many areas of the City. However, the use of a surrogate measure can also increase the uncertainties associated with targeting the correct sources when working without such an assessment. In the end, the citizens of Sioux Falls will not be fully protected when using the river for recreational purposes until all source types are managed adequately. However the pollutant suitability findings provided herein verified more protection is provided sooner for the citizens when using a PES approach.

2. Channel alteration and resulting stream flow management can unintentionally magnify the magnitude and duration of water quality excursions from stream standards.

   Specifically the Corps of Engineers diversion channel within the City of Sioux Falls historically was managed as a flood protection enhancement. The modeling from this project and previous work verified the water quality protection could be enhanced if low flow regimes were intentionally managed as well. The persistence of E. coli loading from urban stormwater sources can combine with inappropriate low flow management of such diversion structures to result in longer periods of high flow concentrations of bacteria. To state this another way, without the natural channel flow regimes, the original channel received only a little flow while most headwater flow was being diverted through the diversion channel. Without nature's ability to flush the system, higher concentrations of bacteria were allowed to persist in the reach's pools and back waters.

3. EQIP eligible producers appreciated the PES program approach.

   The cooperation and collaboration of both rural and urban managers was truly appreciated by producers who elected to participate in the PES program. All pilot test participants expressed gratitude for the level of contracting, funding option, and site benefits obtained by implementing the PES option. Key SRAM attributes that are attractive include the allowance of haying during the summer, full grazing during the winter and its ability to provide a cleaner water supply. The PES program test of monoslope barns identified EQIP eligible producer's desire to move their herd out of wet and muddy conditions to protect their herd from the many complications that can develop under those conditions. All producers appreciated having an affordable way to implement their production goals in a manner that protects water quality.

4. The SRAM monitoring results indicates that livestock access to streams, combined with intensive grazing practices results in a correctable water quality impact.

   Livestock grazing in riparian areas is often considered to be a cost effective use of the land and water supply with or without intense management. This project identified indicators that livestock health ramifications have sometimes gone unnoticed when producers are making many decisions regarding pasture and livestock management. The indication that one producer witnessed an increase in rate of gain in his calves is an illustration of production opportunities and revenue that are lost because they are not readily identifiable. More education and research may benefit livestock producers who are making these decisions with the full picture of the long-term opportunity costs that may exist.

5. The project team and Technical Advisory Team both experienced key personal retirements during the course of the project.

   Retirement is a fact of life, as are job changes and other influences on institutional knowledge. During this project’s period a substantial number of key personal retired. The ability to maintain institutional knowledge held by critical staff is an investment all management teams should routinely visit. This project witnessed a small but noticeable decline in participants’ passion during these periods of transition. In addition, the cost of bringing replacement staff up to speed is a real life cost that is seldom budgeted for. This period of transition would benefit from briefs or summary write ups that focus on the resulting decisions rather than the list of complexities previously faced. This would allow new personal to participate early while having more time to develop a fuller understanding.

Discussion of Quality Assurance

This project used both monitoring and modeling to assist with determination and verification of pollutant loading, persistence and treatment efficiencies. Models used to determine effectiveness of the projects and their impacts on the lower reaches of the CBSRW were based on scientific models previously developed by the SD DENR (Hydrologic Simulation Program-Fortran Model), and Bacteria Source Load Calculator (SD DENR 2012, Virginia Tech 2007).

Hydrologic Model Calibration/Validation

In the application of the Hydrologic Simulation Program-Fortran (HSPF) to this project, a variety of graphical comparisons and statistical tests were used to assess the performance of the hydrologic model. These procedures were based on data gathered at the points identified in Figure 8, which identifies the location of flow calibration gages and boundary condition for the HSPF modeling domain.

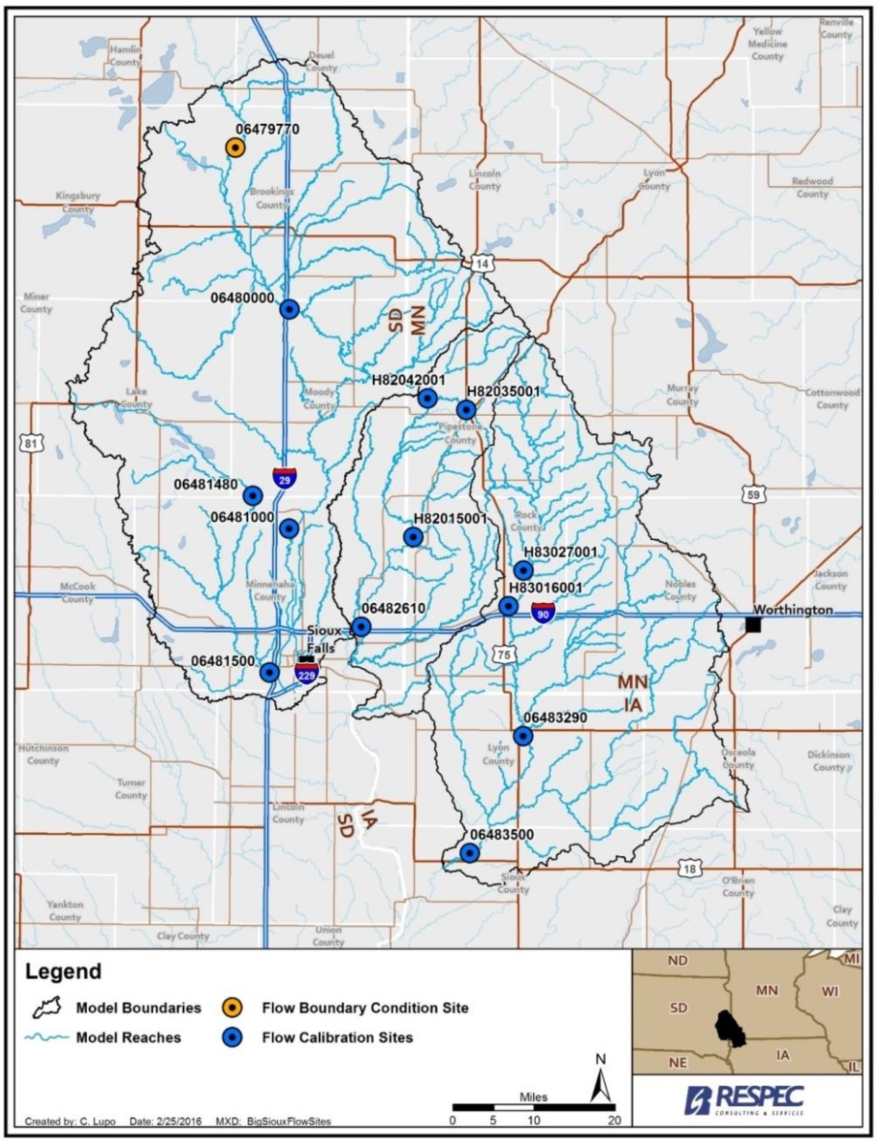

Figure 7. Location of Flow Calibration Gages and Boundary Condition for the HSPF Modeling Domain.

These procedures included flow duration curves, time series plots, error statistics, and correlation coefficients. The graphs and statistics were placed in three categories to provide a systematic approach for calibration: comprehensive, water balance, and event statistics and graphs. The comprehensive category included flow duration curves and coefficients of determination (R^2). The water balance category involved mean total runoff volume percent errors and average annual and monthly runoff errors and graphs. Event statistics included storm runoff plots and hydrograph statistics. This approach provided an increasingly tighter focus on a temporal scale (i.e., annually, seasonally, and monthly) for calibrating hydrology.

A flow duration curve is a graph that depicts flow versus the percent of time that flow is exceeded. This plot represents the hydrologic response of a watershed from base flow to peak flow. The flow duration plots one of the calibration points as illustrated in Figure 9. The *y*-axis for these figures is a log scale of flow in cubic feet per second (cfs) while the *x*-axis represents the percentage of time that the flow is equaled or exceeded. The red, dashed line represents the model-predicted flow duration curve while the blue, solid line represents the flow duration curve for the actual data recorded at the respective sites. This figure illustrates that the model excels at representing flows for all flow regimes throughout the modeling period.

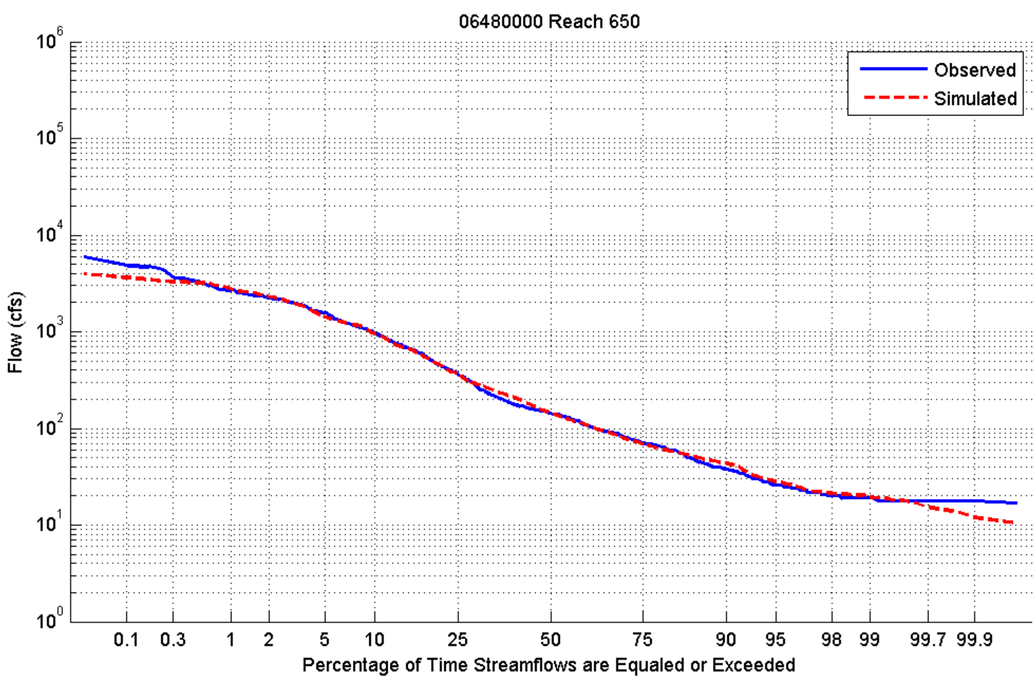

Figure 8. Flow Duration Curve for U.S. Geological Survey Site 06480000 on the Big Sioux River South of Brookings, South Dakota.

The coefficients of determination (R^2) values computed were compared with the criteria in Figure 9 to evaluate the performance of the hydrologic model. Table 11 provides a summary of the R^2 values for daily and monthly time steps as well as the percent volume error for each calibration point throughout the modeling period. At sites with continuous flow data, daily R^2 values ranged from 0.81 to 0.87 while monthly values ranged from 0.92 to 0.94, and this indicates "very good" calibration for both time steps. Because of the lack of continuous flow data at Site 6481480, the daily R^2 was 0.65 and the monthly R^2 was 0.59.

Another statistic used to assess the validity of the modeled flow is the volume percent error. This statistic is determined by dividing the simulated total volume of water that flows past a given point by the measured total volume during the entire modeling period. A negative number indicates that a smaller volume of water was simulated to pass the calibration point than what was measured and vice versa for a positive number. The volume percent error statistics presented in Table 11, were evaluated with the hydrologic performance criteria in Table 12. Again, this statistic indicates that the model is performing in the "very good" category at all calibration sites with continuous data available. Volume percent error does not apply to Site 06481480 because only instantaneous flow measurements are available.

Figure 9. R and R^2 Performance Criteria for Model Calibration and Validation (Bicknell, 2001).

Table 12. Daily R^2, Monthly R^2, and Percent Error of Simulated Flows Compared to Measured Flows at Select Calibration Points.

USGS Gage	HSPF Reach	Daily R^2	Monthly R^2	Volume Error (%)
6480000	650	0.85	0.93	0.46
6481000	30	0.87	0.92	0.49
6481480[(a)]	810	0.65	0.59	N/A
6481500	870	0.81	0.94	0.79

(a) Continuous flow data not available.

Table 13. General Performance Criteria for Model Calibration and Validation (Bicknell, 2001)

	% Difference Between Simulated and Recorded Values		
	Very Good	Good	Fair
Hydrology/Flow	< 10	10–15	15–25

Thus through the variety of methods applied to assess the performance of the hydrologic model, the HSPF model performed very well for this project for the hydrologic flow.

Bacteria Model Calibration/Validation

Calibration of the bacteria model was very similar to the calibration of the hydrologic model. It is an iterative process intended to match simulated bacterial concentrations with observed concentrations by methodically adjusting model parameters. Again, the entire simulation period (October 1, 2005–September 30, 2009) was used in calibrating the model. Twenty water-quality sites within the model boundary were used for calibration. Fecal coliform sample results were converted to *E. coli* using the regression equation. Figure 11 shows the calibration sites used to assess the effectiveness of the bacteria model calibration.

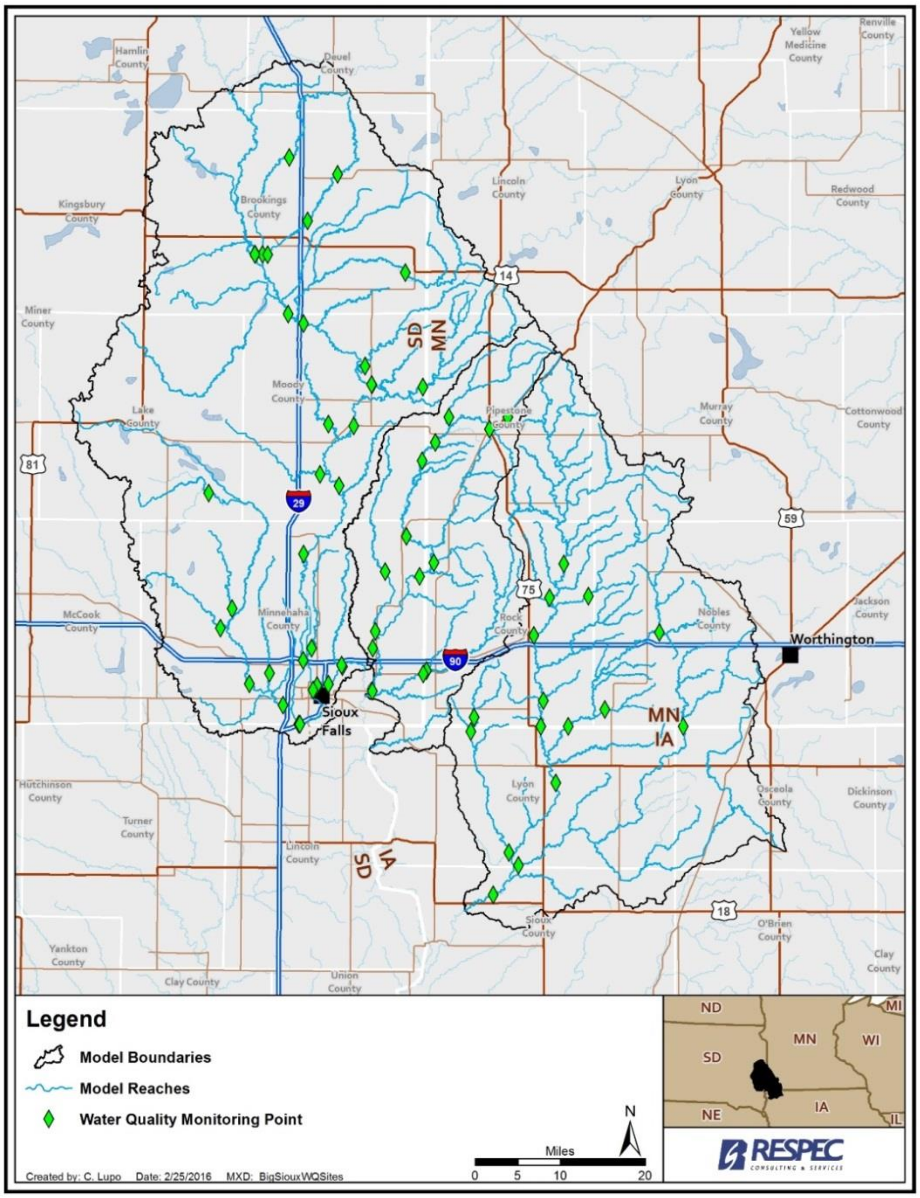

Figure 10. Location of Water-Quality Calibration Points for the HSPF Modeling Domain on the Big Sioux River.

Similar to hydrologic calibration, graphical comparisons of simulated and observed data were completed using bacterial concentration duration curves and time series plots. The graphs represent a comprehensive and storm event approach toward calibrating the pollutant model. Calibration parameters were adjusted to improve the performance of the model until the preferred performance criteria were either met, or no apparent improvement from parameter refinement was noted. Graphical plots were visually evaluated to objectively assess the model performance. It should be noted that the current science available to predict daily E. *coli* concentrations is at best inaccurate (represented by the time series plots), but the goal of the model is to provide a generalized understanding of bacteria trends (represented by the concentration duration curves).

Three parameters were available for refinement during the bacteria calibration: (1) bacterial decay and temperature correction coefficient for instream processes, (2) a multiplication factor for direct stream loading (from the Bacteria Source Load Calculator (BSLC)), and (3) the EMC value applied to each pervious and impervious land segment where the EMC approach was used (Virginia Tech 2007).

The progress of the calibration is assessed visually by comparing observed values to modeled (simulated) values represented on concentration duration curves and time-series plots. The concentration duration curve for site BS-10, which is located on the Big Sioux River just upstream of Sioux Falls, is displayed in Figure 12. The *y*-axis represents concentration (in cfu/100 mL), and the *x*-axis displays the percentage of time concentrations are equaled or exceeded.

The green static line on the graph represents the acute water-quality standard for the beneficial use of immersion recreation, which is 235 cfu/100 mL for *E. coli*. Note that this standard line does not apply to those reaches with a beneficial use of limited contact recreation. The standard line is merely a reference for the antidegradation law, which states that contributing waters with a different beneficial use cannot cause impairment of downstream reaches. The blue line with the blue circles represents the observed data collected in the field, and the solid, pink line represents the continuous data points simulated by the model on an hourly time step. The dashed, red line with the red squares represents the data simulated when a field water-quality sample was collected, and this line provides a more direct comparison of the observed data to the simulated data. Because the pink line represents continuously simulated data, it encompasses a much larger set of data than the observed samples or paired, simulated samples. This sometimes results in a noticeable difference in the pink line when it is compared to the blue and red lines.

The concentration duration plots illustrate how accurate the model is at predicting across the range of concentrations at each site. Ideally, the observed and simulated concentrations will cross the water-quality standard line at the same location. This means that the observed percent of time exceeding is the same as the simulated. These figures show that the model excels at representing the range of concentrations as well as the time exceeding the standard or referenced standard.

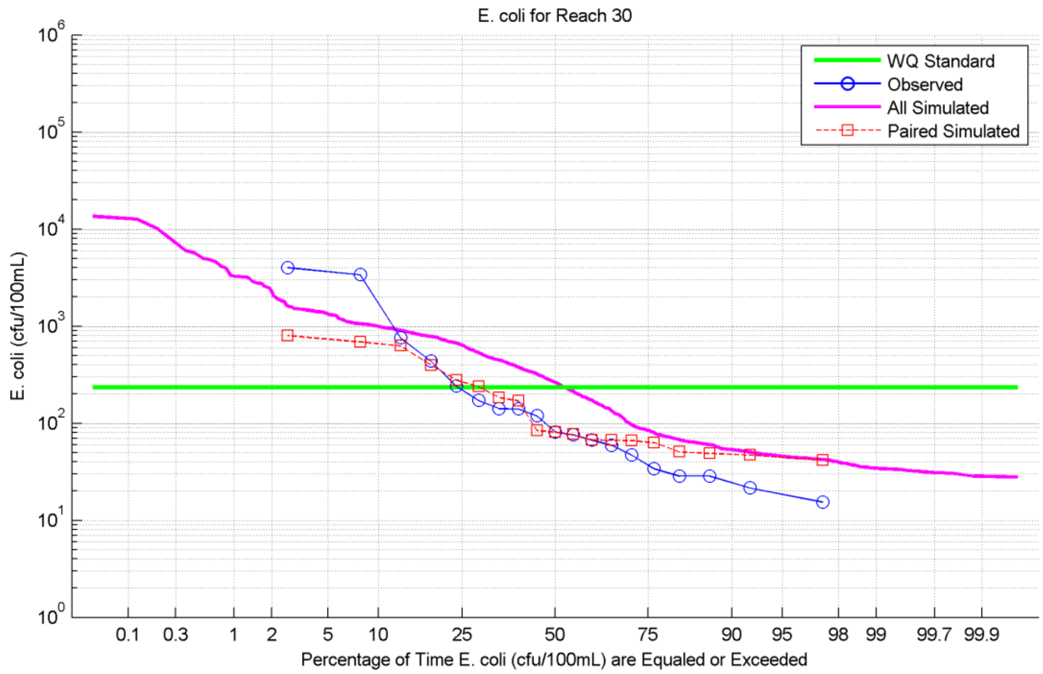

Figure 11. *E. coli* Concentration Duration Curve at BS-10 on the Big Sioux River North of Sioux Falls (the Water-Quality Standard Line is Applicable).

The other graphical representation used to assess model calibration status is the time series plot. Figure 13 illustrates an *E. coli* time-series plot for BS-10. The lower *y*-axis is the log-scale concentration in cfu/100 mL. The upper *y*-axis is flow in cfs and the *x*-axis represents the date throughout the modeling period. In the lower graph, the blue dots symbolize samples collected in the field, and the red line tracks the simulated concentrations on an hourly time step throughout the modeling period. In the upper graph, the dashed, red line represents simulated flow and the blue line represents measured flow, if available. Plotting both concentration and flow over the same time series shows the relationship between flow and concentration. Calibrations of concentrations at low or high flows can be evaluated to better understand whether concentrations are coming from storm events or direct stream loadings. Because of the unpredictable nature of stream bacteria concentrations, it is not assumed that the model will predict the observed concentrations at all times. However, the figure illustrates that the model excels at matching the general trends through the different flow regimes.

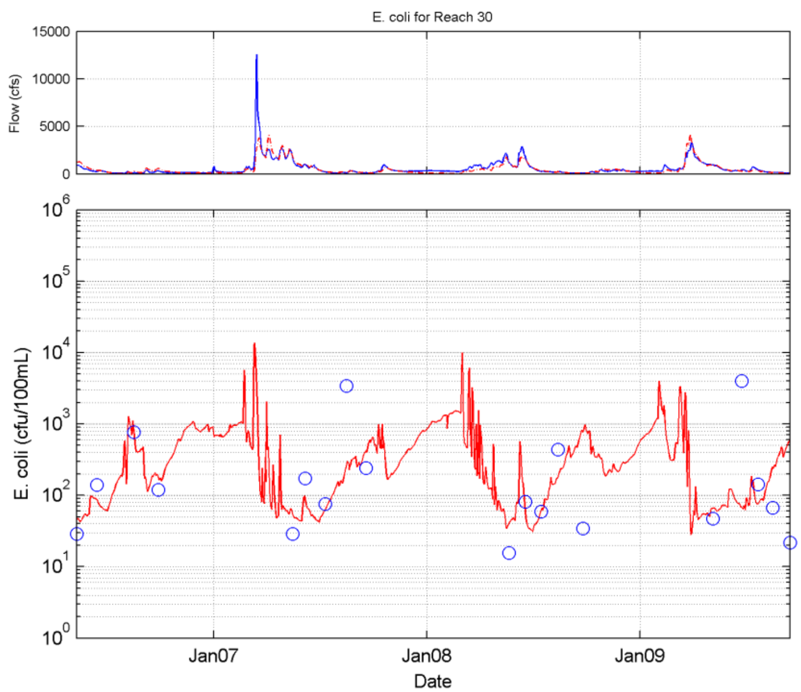

Figure 12. ***E. coli*** **Time Series at BS-10 on the Big Sioux River North of Sioux Falls.**

Sediment Model Calibration/Validation

Calibrating the sediment model incorporated the same general processes as calibration of the bacteria model. Simulated TSS concentrations were matched to observed concentrations through an iterative process. Through the calibration process, graphical comparisons of concentration duration curves and time series plots were evaluated to objectively assess model performance, by comparing the observed values to modeled (simulated) values that were represented. Figures 14 illustrates TSS a concentration duration curve at BS-10 on the Big Sioux River north of Sioux Falls. The *y*-axis represents concentration in mg/L and the *x*-axis displays the percentage of time concentrations that are equaled or exceeded. The green, static line on the graph represents the acute water-quality standard of 158 mg/L for warm-water semipermanent fish life propagation, the designation given to the Big Sioux River. This line is used for reference on all graphs; however, Skunk Creek has a standard of 263 mg/L for warm-water marginal fish life propagation, while neither Colton Creek nor Silver Creek has a fish life propagation designation.

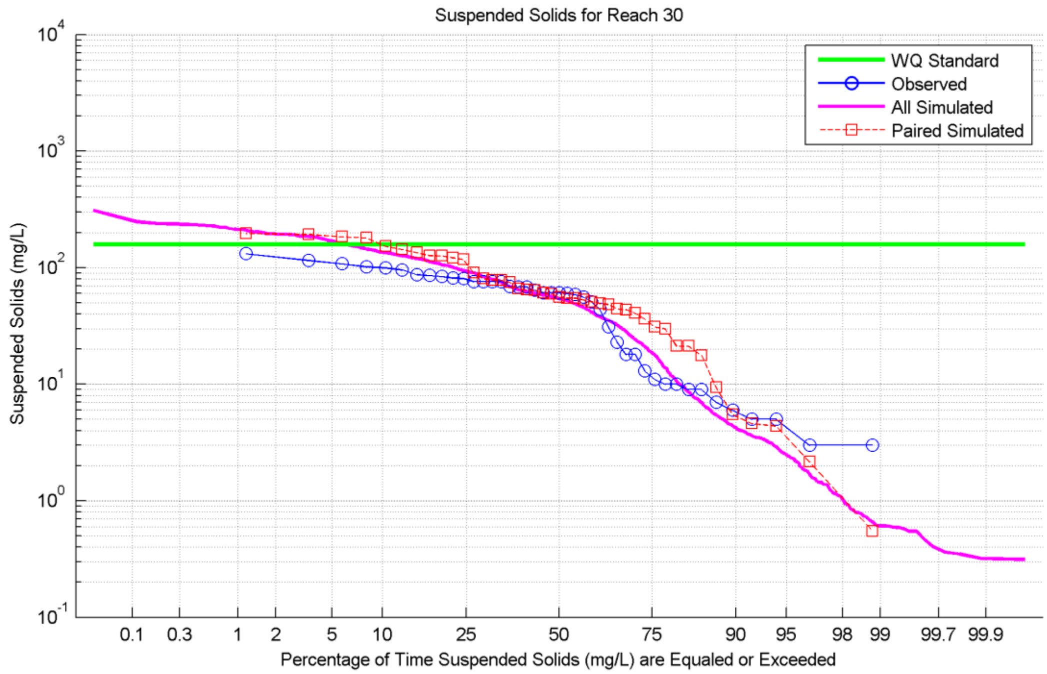

Figure 13. Total Suspended Solids Concentration Duration Curve at BSR 10 on the Big Sioux River North of Sioux Falls (the Water-Quality Standard Line is Applicable).

As with the concentration duration plots for *E. coli*, the blue line with blue circles represents the observed data collected in the field, and the solid, pink line represents the continuous data points simulated by the model on an hourly time step. The dashed, red line with red squares represents the data simulated when a field water-quality sample was collected, and it provides a more direct comparison of the observed data to the simulated data.

The TSS concentration duration plots illustrate how accurately the model is predicting across the range of concentrations at each site. Ideally, the observed and simulated concentrations will cross the water-quality standard line at the same location and indicate that the observed percent of time exceeding is the same as the simulated. The figure illustrates that the model excels at representing the range of concentrations as well as the time exceeding the standard.

Figure 15 below illustrates a TSS time-series plot for BS-10 on the Big Sioux River north of Sioux Falls. The lower *y*-axis is the log-scale concentration in mg/L. The upper *y*-axis is flow in cfs. The *x*-axis represents the date throughout the modeling period. In the lower graph, the blue dots symbolize samples collected in the field, and the red line tracks the simulated concentrations on an hourly time step throughout the modeling period. In the upper graph, the dashed, red line represents simulated flow and the blue line represents observed flow, if available. As with *E. coli*, the sediment model excels at matching general trends throughout the different flow regimes.

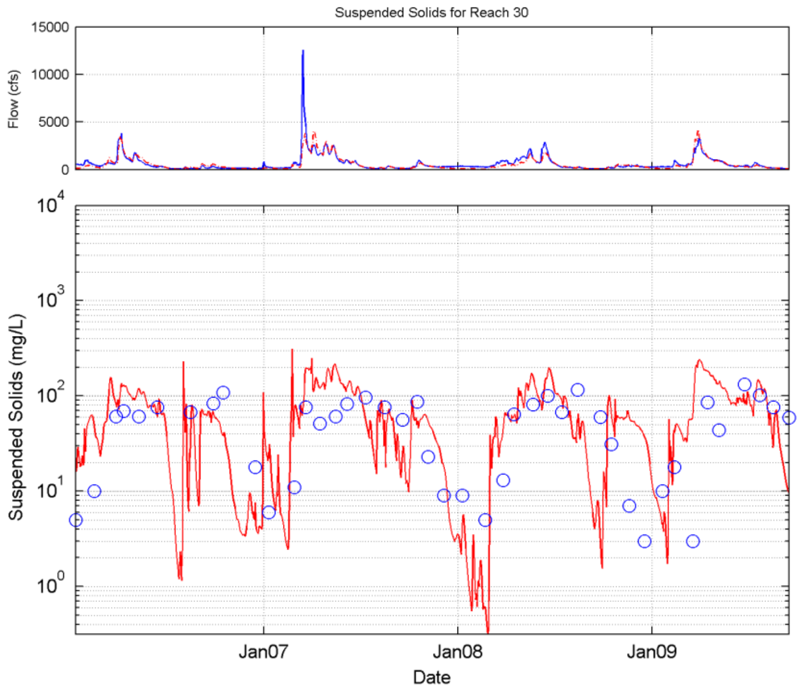

Figure 14. Total Suspended Solids Time Series at BS-10 on the Big Sioux River North of Sioux Falls.

Findings

A summary of the salient physical and economic findings from this project are described below, including some of the findings that did not support the goals of the project.

This project provides forms and protocols that can be used to implement transparent and defensible environmental market based programs for water quality protection. These protocols and forms can be used in total or only on selected components for the site specific program. By providing such modular forms and protocols, the project supports the development and adoption of similar approaches that can be adapted to the unique needs of other locations.

One of the findings that did not support the goal of the project, as initially stated, was that it became clear that WQCT would not be applicable to the CBSRW for this project, due to lack of demand for sediment credits and lack of equivalency for urban and agriculturally sourced bacteria. However, this provided the opportunity to demonstrate that the PES program conservation measures tested have proven to provide a substantial water quality protection benefit for bacteria and an additional water quality protection benefit related to sediment.

In addition, producer attitudes were surveyed and the results indicate participating producers have a very strong appreciation for the program regarding ease of participation and also recognize the production enhancements gained by implementing these BMPs.

Thus, despite not meeting all the initial objectives due to intermediate findings that the initial objectives were not appropriate for the setting, the overall intent of improving water quality was met. These findings provide the basis for the following conclusions and recommendations.

Conclusions and Recommendations

The analysis contained in this report concludes an environmental market approach entitled payments for ecosystems services (PES) is viable for bacteria credits in the CBSRW. Present supply and demand, as well as economic incentives, exist which allow for market based transactions to be effective and efficient. The project team does not believe the same is true for sediment credit trading in the CBSRW. Lacking necessary regulatory demand of credits, the project team believes sediment trading is not viable in the near term. If demand of sediment credits develops in the future, trading may provide an attractive market based option. This report provides a framework for sediment credit trading for regions with more viable trading.

The project team drew numerous conclusions and recommendations for WQCT and PES programs in the CBSRW.

Conclusions

- The findings of this project team are that the PES system is a viable approach for reducing bacteria.
- Supporting materials provided include the forms and protocols necessary to implement transparent and defensible environmental market based programs for water quality protection. These protocols and forms can be used in total or only on selected components for the site specific program.
- Animal livestock can be the source of several pathogens that pose an immediate health risk to humans and can persist in rivers and streams.
- Reductions in animal livestock pathogen sources are not equivalent to reductions of human generated pathogens in urban stormwater systems.
- Favorable cost differentials exist between implementing agricultural control methods and urban retrofits. While these cost benefits are not universal for all agricultural practices (e.g. offsetting TSS with animal waste control lagoons), several practices identified in this report would achieve reductions for pennies on the dollar.
- A strong willingness to collaborate exists between the City of Sioux Falls and the county conservation districts (chaired by Moody County), an attribute not always present among watershed communities. This collaborative approach is a beneficial attribute for effective, long term WQCT and PES programs.
- Without having a regulatory permit driving implementation schedules, the need for a cost effective environmental market program is based solely on the values and objectives of the

watershed community and its desire to protect its citizens. The City of Sioux Falls, South Dakota has demonstrated that for a reasonable investment from moderately sized community great gains in bacteria reduction from livestock operations can benefit both the producer and the community's citizens.

- The conservation practices under this PES program provide substantial water quality protection benefits.

Recommendations for Further Study

- WQT and PES practitioners will continue to benefit from maintaining a current understanding of other advancements and challenges documented by working programs across the United States.
- Continued research to improve watershed manager's understanding of bacteria and pathogen persistence in rivers and streams would benefit both the watershed source load identification and market-based program credit estimation methods.
- Continued research on BMP treatment efficiencies regarding bacteria and pathogen removal will reduce the level of uncertainty currently present when making decisions for watershed management planning and market based program designs.

Promotion of Technology Adoption

- Continued educational programs highlighting the documented success of programs like the CBSRW PES program are necessary to advance the use of environmental markets.
- This project benefited greatly from the high level of cooperation and collaborative nature of both urban and rural representatives that exists in this watershed. Without these attributes the cost-effective and efficient use of market based programs would not be available to accelerate reductions in water quality bacteria counts. Therefore, to successfully transfer this approach to other watersheds, a need for educational materials that place an emphasis on watershed planning methods that use an inclusive list of representatives from the multiple sectors with a cooperative attitude exists.

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Appendix B: Technical Review Team Membership

Name	Organization
Jesse Neyens	City of Sioux Falls
George Azevedo	EPA Region 5
Sandra Spence	EPA Region 8
Brent Truskowski	EPA Region 8
Peter Brumm	EPA Region 8
Matt Drewitz	MN Dept of Ag
Anna Bramblett	MN NRCS
Jack Majeres	Moody County SD Conservation District & Project Sponsor
Bruce Henningsgaard	MPCA
Lyn Kirschner	National NRCS
Ian Cunningham	Pipestone MN Conservation District
Wayne Smith	SD Ag Producer
Barry Berg	SD Association of Conservation Districts
Pete Jahraus	SD DENR
Kelli Buscher	SD DENR
Gerald Jasmer	SD NRCS
Jeff Vander Wilt	SD NRCS

Appendix C (enclosed in packet): Results and Findings of Task 2 – Conduct a Basic Literature Search for the Central Big Sioux River Water Quality Trading Project

Appendix D (enclosed in packet): Results and Findings of Task 3 –Pollutant Suitability Evaluation for a Water-Quality Credit Trading Program in the Central Big Sioux River Watershed

Appendix E (enclosed in packet): Results and Findings of Task 4 – Financial Attractiveness Evaluation for WQCT in the CBSRW

Appendix F (enclosed in packet): Results and Findings of Task 5 – Central Big Sioux River Watershed Water-Quality Trading Pilot Program: Develop Market Rules and Infrastructure