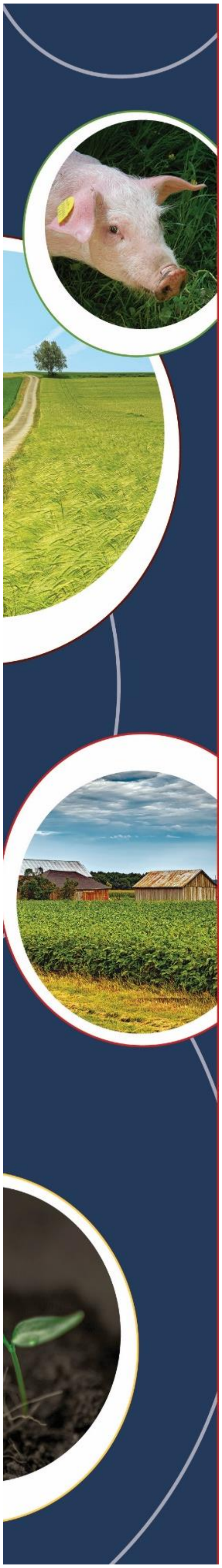

Ecosystem Services Markets Conceived and Designed for Agriculture:

An Assessment of Protocols, Methodologies, Tools and Approaches to Inform ESMC's Integrated, Tiered Ecosystem Services Market Protocol for Working Agricultural Lands

A Technical Brief by the Ecosystem Services Market Consortium (ESMC)

ECOSYSTEM SERVICES MARKET CONSORTIUM

January 2020

Acknowledgments

The Ecosystem Services Market Consortium (ESMC) would like to thank the following organizations for their work on this report: DRD Associates, LLC, which was the lead contractor on ESMC protocol development work during 2018 and 2019, supported by contractors Kieser & Associates, LLC and their subcontractors, Tetra Tech, Inc. and WestWater Research, LLC. For this document, Kieser & Associates led its overall development and was the primary author of the water quality section. Tetra Tech and DRD Associates worked closely to co-author the section on carbon, while WestWater Research developed the section on water quantity. This foundational document, written in 2018, served as the basis of development for an integrated, multi-asset protocol for ESMC, focused on rangeland, grassland, pastureland and cropland systems in the Southern Great Plains. That protocol, completed in December 2018, is currently being field-tested by ESMC and its members and stakeholder collaborators. This technical brief was completed prior to development of that protocol and includes a review of existing protocols in the carbon, water quality, and water quantity market space, and provided rationale for decisions made in advancing select elements of these for the ESMC protocol. Citations for protocol references appear at the end of each section. A comprehensive cross-cut analysis of the assessed protocols is provided in tabular form under separate cover as a companion to this technical brief.

Appreciation is also extended to the members of the 2018 ESMC Steering Committee for the review of this work, including: Bill Buckner, Chad Ellis, Jimmy Emmons, Wayne Honeycutt, Kris Johnson, Bruce Knight, Jerry Lynch, Tim Palmer, Gary Price, Debbie Reed and Steve Rowe.

Executive Summary

This Technical Brief preceded the development of the Ecosystem Services Market Consortium (ESMC) integrated protocol for working agricultural lands intended to generate soil carbon, net greenhouse gases (GHG), water quality, and water quantity credits or assets for sale in ESMC's national market. The first generation ESMC protocol, developed for use in rangeland, grassland, pastureland and cropping systems in the Southern Great Plains, is currently being pilot tested. The brief examines existing soil carbon, water quality, and water quantity protocols, and summarizes findings which include the state of the science underlying the relationships between ecosystem services and soil health in the context of markets for carbon, water quality, and water quantity. The main objective of this assessment was to provide a foundational reference to support and inform the development of ESMC's integrated, modular protocols. The brief and all compiled materials also served to forecast opportunities and challenges anticipated when developing ESMCs integrated ecosystem services protocol.

The technical brief summarizes the following for carbon, water quality, and water quantity:

1) state of science between each ecosystem services and soil health;

2) findings for protocol components (data collection and management, quantification tools, aggregation methods, monitoring, reporting, and verification);

3) findings for priority elements (scalability, scientifically rigorous, transparency, standards-based, farmer-facing, and legal considerations); and

4) research needs and data gaps.

A "Master Protocol Assessment Table" is provided under separate cover that serves as a detailed compilation of important protocol elements examined in this technical brief. We summarize here general findings in these regards.

Carbon

The assessment of existing soil carbon protocols and the science relating soil carbon to soil health is the most straightforward and well-documented of the ecosystem service protocols reviewed. The understanding of the relationship and principles between soil carbon and soil health are well understood and the protocols align well with existing corporate social responsibility standards. Although a number of protocols have been developed to quantify carbon emissions from agricultural practices, the majority of the reviewed protocols are developed for particular conservation practices. These vary in the complexity of their protocol components, with the level of complexity for scenario quantification carrying into the other monitoring, reporting, and verification elements. Some elements of these independent protocols have informed development of the ESMC protocol in rangelands and grasslands of the Southern Great Plains. The considerations are presented in *Section A. Assessment of Existing Carbon Protocols*.

Water Quality

The tools to connect soil health and water quality do not yet exist. However, there are reliable quantitative tools for connecting conservation practices and their impacts on water quality. Even though hundreds of conservation practices are identified as providing water quality benefits, only a few of those are being promoted for soil health. ESMC's development of a water quality modular protocol utilizes the existing science and tools for conservation practices linked to both soil health and water quality benefits. Existing process-based tools such as the Nutrient Tracking Tool/Agricultural Policy Environmental eXtender (NTT/APEX) are sufficiently robust to model benefits from conservation practices that improve soil health and predict concomitant water quality outcomes. The assessment of existing water quality protocols describes the different options towards quantification.

Compliance-driven water quality market applications typically exhibit the highest levels of rigor around water quality benefit quantification and documentation. Voluntary supply chain or corporate sustainability programs for water quality are beginning to mirror such rigor in certification and verification, though not necessarily in quantification of water quality benefits. These types of programs may lend themselves to examining various levels or tiers of marketable water quality credits. Notably, the tools used to compute water quality benefits as load reductions in regulated markets may not be necessary for supply chain or corporate sustainability investments where social context, as compared to compliance markets, is a more prominent interest tied to water quality benefits. In these instances, more qualitative tools such as indices may be used. Such approaches could potentially be correlated to a yet-to-be devised, unique 'soil health credit' where in some circumstances, load reductions are an insufficient metric. Relevant details are discussed in *Section B. Assessment of Existing Water Quality Protocols*.

Water Quantity

The science describing the relationship between soil health and water quantity is well-documented, though water quantity credits are likely the most nuanced of the three ecosystem services under assessment. The distinction between on-farm and off-farm beneficiaries provides a key step in placing the development of a water quantity protocol in context. The water quantity focus of the ESMC program will be on the off-farm beneficiaries as these are considered marketable credits. The focus within off-farm beneficiaries should be on continued development of Flood Reduction Credits, Water Conservation Credits, and Water Efficiency Credits. Each category of credits has varying degrees of precedent and existing protocols. These vary greatly from existing literature support and precedence to a credit type with a substantial emphasis and legal/policy considerations. Due to the more nuanced nature of water quantity credits, the water quantity protocol assessment is better reflected in *Section C. Assessment of Existing Water Quantity Protocol* than in the master protocol assessment table separately accompanying this document.

Table of Contents

List of Tables

List of Figures

Existing Protocols

The U.S. Department of Agriculture has defined soil health as “the continued capacity of a soil to function as a vital, living ecosystem that sustains plants, animals, and humans” (USDA 2018). The agency also presents four principles, seen in Figure II-1, that can be used to guide soil health improvements (see inset), including:

- Maximizing soil cover;
- Minimizing soil disturbance;
- Increasing plant diversity; and
- Maintaining continuous living roots.

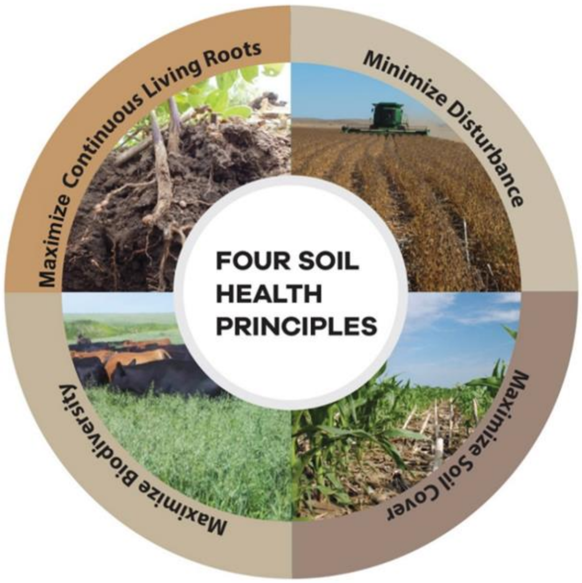

Figure 1. Soil health principles. (Source: USDA 2018)

In the context of rangelands management, Derner et al. (2016) and Ellis (2013) present similar principles for building soil health and add a fifth principle: integrating livestock grazing. The benefits associated with activities that improve soil health also extend to ecosystem services such as carbon, water quality, and water quantity that have established environmental markets. Although the computational tools do not exist yet to equate changes in carbon, water quantity, and water quality directly to soil health, there are tools and methodologies to quantify the carbon, water quality, and water quantity benefits associated with the implementation of conservation practices that benefit soil health. To gain a better understanding of how to develop an integrated protocol that effectively quantifies and monetizes the carbon, water quality, and water quantity benefits associated with soil health improving activities, an evaluation of existing protocols was conducted.

A protocol describes the processes that turn the implementation of a conservation practice into the generation of an environmental asset (a monetizable unit of ecosystem service to be transacted, traded, or sold). Environmental assets generated from existing protocols serve a variety of purposes, including formally tracked pollution reductions, certified credits for corporate social responsibility, and credits for use in satisfying compliance requirements with environmental standards and regulations. Table II-1 summarizes the existing protocols assessed and the variety of environmental assets generated from these protocols.

Table 1. Environmental Assets Generated from Existing Carbon, Water Quality, and Water Quantity Protocols

Protocol	Type of Environmental Asset Generated	Type of Ecosystem Service Credit/Certification Generated
Carbon Protocols		
Reduction of N2O emissions from use of Nitrogen Use Efficient (NUE) seeds that require less fertilizer application --- Version 2.0 ***(Clean Development Mechanism)***	Compliance Market Credit	GHG: N_20
Adoption of Sustainable Agricultural Land Management (SALM) ***(Verified Carbon Standard)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
Quantification protocol for conservation cropping (Version 1.0) ***(Alberta)***	Compliance Market Credit	GHG: CO_2, CH_4, N_20
Grassland Project Protocol ***(Climate Action Reserve)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
Grazing Lands & Livestock Management ***(American Carbon Registry)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
Compost Additions to Grazed Grasslands ***(American Carbon Registry)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
Avoided Conversion of Grasslands & Shrublands ***(American Carbon Registry)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
Nitrogen Management Project Protocol ***(Climate Action Reserve)***	Voluntary Market Credit	GHG: CO_2, N_20
Methodology for N2O Emissions Reductions from Changes in Fertilizer Management ***(American Carbon Registry)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
Methodology for Quantifying Nitrous Oxide (N2O) Emissions Reductions from Reduced Use of Nitrogen Fertilizer on Agricultural Crops ***(American Carbon Registry)***	Voluntary Market Credit	GHG: N_20
Agricultural Land Management, Soil Carbon Quantification Methodology ***(Verified Carbon Standard)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
Increasing Soil Carbon Through Improved Tillage Practices ***(Gold Standard)***	Voluntary Market Credit	GHG: CO_2
Avoidance of methane emissions through composting ***(Clean Development Mechanism)***	Compliance Market Credit	GHG: CH_4
Offsetting of synthetic nitrogen fertilizers by inoculant application in legumes-grass rotations on acidic soils on existing cropland ***(Clean Development Mechanism)***	Compliance Market Credit	GHG: N_20
VM0009 Methodology for Avoided Ecosystem Conversion ***(Verified Carbon Standard)***	Voluntary Market Credit	GHG: CO_2

Protocol	Type of Environmental Asset Generated	Type of Ecosystem Service Credit/Certification Generated
VM0022 Quantifying N2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction ***(Verified Carbon Standard)***	Voluntary Market Credit	GHG: N_20
VM0026 Methodology for Sustainable Grassland Management ***(Verified Carbon Standard)***	Voluntary Market Credit	GHG: CO_2, CH_4, N_20
VM0032 Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing ***(Verified Carbon Standard)***	Voluntary Market Credit	GHG: CO_2, CH_4
Water Quality Protocols		
Ohio River Basin Trading Pilot	Voluntary Market Credit; Compliance Market Credit	Nitrogen, Phosphorus
Pennsylvania NPS Nutrient Credit Trading Program	Compliance Market Credit	Nitrogen, Phosphorus, Sediment
Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program	Compliance Market Credit	Nitrogen, Phosphorus
Wisconsin Water Quality Trading Program	Compliance Market Credit	Phosphorus, Sediment
West Virginia Nutrient Credit Trading Program	Compliance Market Credit	Nitrogen, Phosphorus, Sediment
Great Miami River Watershed Water Quality Credit Trading Program	Compliance Market Credit	Nitrogen, Phosphorus
South Nation River Watershed Water Quality Trading Program	Compliance Market Credit	Phosphorus
Lake Simcoe Phosphorus Offset Program	Compliance Market Credit/ Offset	Phosphorus
Oregon Water Quality Trading Program	Compliance Market Credit	Temperature, BOD, Ammonia, Nutrients, Sediment & Suspended Solids
Vermont Phosphorus Protocol	Compliance Market Credit	Phosphorus
Maryland Nutrient Trading Program	Compliance Market Credit	Nitrogen, Phosphorus, Sediment
Iowa Nutrient Reduction Exchange	Formally Tracked Pollutant Reduction; Compliance Market Credit	Nitrogen, Phosphorus
Field Stewards Program	Certification; Certificate sales as corporate sustainability program	Phosphorus, Nitrogen
Laguna de Santa Rosa Watershed Water Quality Trading Program	Nutrient Offset Credits	Phosphorus (Nitrogen Pending)
Western Lake Erie Basin Water Quality Trading Program	Compliance Market Credit; Voluntary Market Credit (stewardship credit)	Phosphorus
Water Quantity Protocols		
Water Restoration Credits	Voluntary Market Credit	Increases in Streamflows

Although carbon, water quality, and water quantity protocols are not perfectly analogous due to the nuances in the science, technologies, markets, regulations and standards associated with all three ecosystem services, there are parallel processes and protocol components that are mirrored across these services. Protocols typically include the project implementation process and administrative processes of both the project developers, program administrators, and any third-party verification entity as components, including eligibility criteria and restrictions, baseline scenarios, quantification of impacts from the conservation practice, associated data collection and management, monitoring requirements, and verification. Protocol components that are comparable across carbon, water quality, and water quantity protocols are summarized in the Master Protocol Assessment Crosscut Table.

There are also distinct differences between the protocols. Some differences represent small variations in protocol components from one ecosystem service protocol to another. For example, data collection needs in a water quality context typically entail cropping and management data for establishing eligibility and identifying baseline attainment. Credit quantification model inputs often require site-specific soils data while program requirements typically require site inspections for ongoing verification of conservation or Best Management Practices (BMPs) maintenance or effectiveness.

Because most of the existing water quality protocols were established for compliance trading, establishing eligibility is a core component of initial data collection. Demonstrating compliance with appropriate regulations has typically been a prerequisite to entering a water quality trading program. If a farm is meeting local, state or federally applicable requirements, they can generally enter a trading program. Baseline requirements in a trading program may then stipulate technology or performance thresholds representing a required action level for existing pollutant loads. Practices or performance beyond the baseline with additional conservation practices can generate credits. Here again, site-specific data are necessary to establish baseline conditions. Although many of these data requirement needs are found across both water quality and carbon protocols, carbon protocols largely produce voluntary market credits and thus do not generally require demonstrating compliance as part of establishing eligibility and baselines as in water quality trading programs.

Some differences between protocols are substantial and are not necessarily fully captured in the Master Protocol Assessment Crosscut Table. Differences that could not be captured in this table, such as the assessment of water quantity protocols, are reflected in the *Section C* narratives. A very clear example in this technical brief is how different the processes involved in generating environmental assets for water quantity are from carbon and water quality protocols. Due to the formal nature of carbon and water quality markets, these protocols tend to be more formalized and structured. However, water quantity has three entirely separate environmental assets (Flood Reduction Credit, Water Conservation Credit, and Water Efficiency Credit as noted below) that have very different precedents and procedures as will be discussed further herein.

References for Existing Protocols

Derner, J.D., C. Stanley, and C. Ellis. 2016. Usable science: Soil health. *Rangelands* 38(2): 64-67. https://doi.org/10.1016/j.rala.2015.10.010

Ellis, C. 2013. Five basic principles increase soil health. Ag News and Views. October 1, 2013. https://www.noble.org/news/publications/ag-news-and-views/2013/october/five-basic-principles-increase-soil-health/

Section A. Assessment of Existing Carbon Protocols

1) Summary of the Relationship Between Carbon, Soil Health, and Ecosystem Service Markets

The U.S. Department of Agriculture-Natural Resources Conservation Service (USDA) (2018) states that "the most practical way to enhance soil health today is to promote better management of soil organic matter or carbon." The USDA (2018) also states "organic matter enhances water and nutrient holding capacity and improves soil structure, managing for soil carbon can enhance productivity and environmental quality, and can reduce the severity and costs of natural phenomena, such as drought, flood, and disease. In addition, increasing soil organic matter levels can reduce atmospheric CO_2 levels that contribute to climate change." The current literature provides a variety of information on the effect of soil carbon on single or multiple soil property variables such as soil structure and water holding capacity but do not typically evaluate soil health in a comprehensive way (USDA 2015b). There is no available single measurement that allows for an overall evaluation of soil health; however, soil organic carbon is often used to represent changes in the soil condition commensurate with improved soil health. The NRCS (USDA 2015c) identifies 17 indicators that can be used to assess soil health, including bulk density, soil pH, total organic carbon.

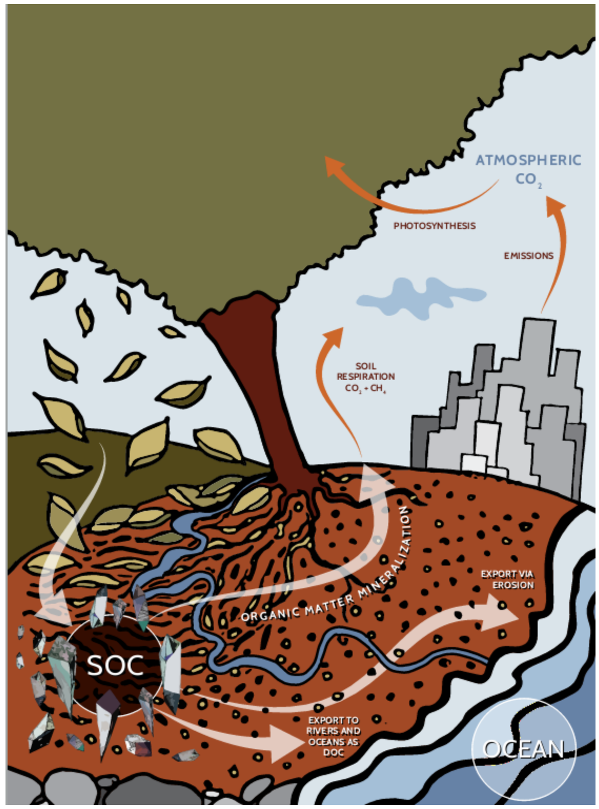

Figure A-1. SOC in the global carbon cycle. (Source: FAO 2017)

What is Soil Organic Carbon?

Soil organic carbon (SOC) is a major component of the global carbon cycle (Figure A-1) and the primary component of soil organic matter (SOM) serving as the primary energy source for soil microorganisms (Lal 2016). SOC provides many benefits to overall soil health and can contribute to soil biogeochemical processes and soil physical properties, and also impact soil microbial communities.

There are three forms of SOC differentiated by their physical and chemical stability: labile (active), intermediate, and refractory (stable). Labile SOC is newly added carbon from biomass and is subject to decomposition (Johns 2017). Intermediate SOC is microbially-processed organic carbon that is somewhat stabilized on mineral surfaces or sequestered in aggregates (Johns 2017). Refractory SOC is very stable and can be hundreds to thousands of years old (Johns 2017). Carbon cycles between the three pools (labile, intermediate, and refractory) within the global carbon cycle including the soil, atmosphere, oceans, and plants.

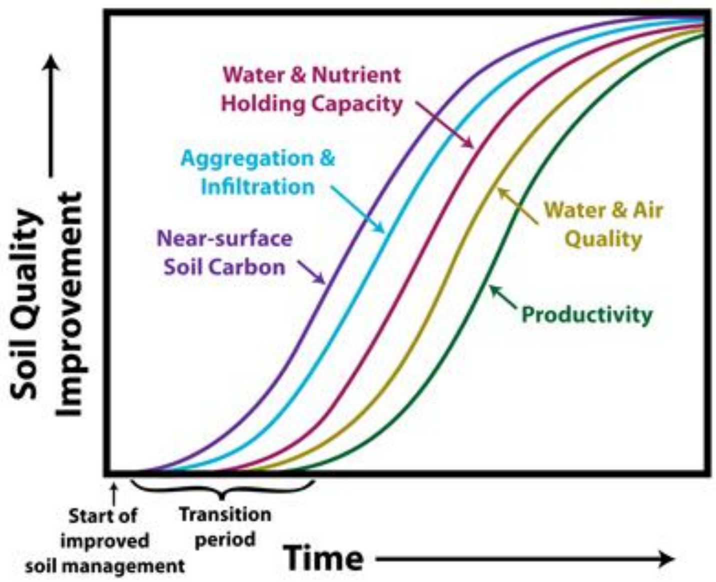

Figure A-2. Role of Soil Organic Matter. (Source: NRCS 2018)

SOM is comprised of organic matter residue and microbial biomass, labile SOM, and stable (or refractory) SOM (Lal 2016). The different organic matter (carbon) pools play different roles in soil health. While particulate organic carbon (POC) is important for providing soil stability and structure, refractory carbon provides little benefit to this parameter. Humus, the partially decomposed organic matter, varies in its ability to provide soil structure but is key to water retention and cation exchange. Both POC and humus are important sources of food and energy for microbial populations.

What Are the Effects of SOC/SOM?

SOC increases soil aggregation (physical stability), reduces the likelihood of soil compaction, and increases water retention capacity (Blanco-Canqui et al. 2013). Improved aggregate stability can in turn impact soil processes including splash detachment, surface sealing, and crusting which can have an impact on infiltration and runoff capacity of the soil. Soils that have lower surface sealing will allow for infiltration during rainfall events (Johns 2017). Improved stability also increases soil aeration, drainage, and water retention, and reduces the amount of carbon loss to the atmosphere via carbon dioxide formation (Cornell University Cooperative Extension 2016). Lado et al. (2004) found higher saturated hydraulic conductivity in aggregate soils and attributed this to higher organic carbon levels.

While more stable soils can prevent nutrient loss through reduced erosion, increased amounts of SOC also reduce nutrient leaching. Stable SOC has been shown to be the primary SOC contributor to soil nutrient retention capacity (Johns 2017). In addition, reactive carbon, the mineral fraction of carbon that is easily decomposed by microorganisms, has been shown to be strongly related to the filtration, buffering, degradation, and detoxification of organic and inorganic materials in soil (USDA 2015a). To a lesser extent, it is related to biological diversity, activity and productivity, and physical stability of the soil (USDA 2015a). Declines in reactive carbon can signal soil health issues as it is typically only in the soil for 2-5 years and could indicate a lack of SOM (USDA 2014).

Microbes are responsible for the conversion of dead organic matter into soil organic matter and as such are an important component of soil health. SOC drives the soil microbial community composition by providing an energy supply. Huang (2004 as cited in Murphy 2014) found that soil microbes are associated with soil colloids and the amount of organic matter determines the ability of these organisms to bind to the surface of colloids. The colloidal environment provides the microbial population with ions, water, nutrients, and organic matter (Huang 2004 as cited in Murphy 2014). Carbon additions to the rhizosphere create a more active and diverse microbial population. This diversity of microbes can influence root morphology, the rate of trace element uptake, affect symbiotic relationships with Rhizobia and Mycorrhiza, and detoxify the soils (Murphy 2014).

How Can Agricultural Practices Improve SOC/SOM?

As provided in USDA 2016a, numerous studies have documented increases in SOM or SOC as a result of various agricultural practices including residue management and tillage systems, fertilizer/manure management, cover crops, various crop rotations, mulching and compost amendments, and grazing management (Bowman et al. 1999; Bowman and Anderson 2002; Bremer et al. 2011; D'Hose et al. 2014; Franzluebbers and Stuedemann 2015; Havlin et al. 1990, Hubbard et al. 2013; Kahlon et al. 2013; Olson et al. 2014; Schillinger et al. 2007; Wang et al. 2015;). For example, D'Hose et al. (2014) found that crop yields were increased, a direct result of large increases in SOC and total nitrogen that occurred following long-term farm compost soil amendments. Most of the literature also evaluates other indicators of soil health such as available water capacity and infiltration and when taken together, form the basis of the link between certain agricultural practices and improved soil health. It is important to note that many of the impacts on soil health are dependent on the soil type, crops, and setting and can be compounded or reduced depending on other land management practices.

The USDA has conducted extensive literature reviews on various agricultural practices and their effects on soil health (USDA, 2015b, 2016b, 2018). Potential effects on SOC/SOM from these practices are provided in Table A-1. There are limited studies specific to rangeland and pasture management practices. The USDA NRCS literature reviews stress that often it is a combination or system of practices that achieve the SOC/SOM benefits. In addition, the type of crop, rotation, climate, fertilizer application, etc. all influence the effectiveness of the agricultural practice as it relates to soil health.

Table A-1. SOC/SOM Benefits from Agricultural Practices (USDA 2015b, 2016b, 2018)

Agricultural Practice	SOC or SOM Benefit
No-till systems	Study results are mixed, but tend towards increases in SOM.
Reduced till	No studies that evaluated SOC/SOM under reduced tillage scenario.
Mulching	No studies that evaluated changes in SOC/SOM as a result of mulching.
Other organic matter additions	Increased SOC was typical with organic matter additions.
Conservation crop rotations	Studies show higher SOC, however study fields typically included other conservation practices (e.g., no till) in addition to crop rotations.
Forage and biomass planting	Increases in SOC/SOM common.
Cover crops	Most studies showed increase in SOM and SOC. Several studies noted the potential negative effects of nitrogen uptake and water loss as a result of cover crops.

Nutrient management plan	Specific to manure – increased SOC was common. No studies that evaluated changes in SOC/SOM as a result of commercial fertilizer application.
Subsoiling or deep tillage	No studies that evaluated SOC/SOM as a result of subsoiling or deep tillage.

2) Summary of Findings for Protocol Components

Due to the success of carbon finance for forestry and industrial (e.g., landfill gas) project types, greenhouse gas (GHG) markets have been seen as a way to incentivize the adoption of sustainable agriculture as well. While there have been a variety of published and peer-reviewed carbon protocols that are relevant to grasslands and pastures, very few projects have been implemented and even fewer credits registered. The majority of GHG programs have adopted methodologies for the agricultural-based project activities that have established science behind them, creating an unwieldy list of existing protocols with much redundancy.

In lieu of outlining the pros and cons of each protocol, this section identifies the existing project types and highlights innovative aspects of existing methodologies, what has been successful, and hindrances for widespread adoption. The project types for which there are existing protocols include: avoided conversion of native ecosystems; conservation tillage or no till; compost additions; whole farm methodologies; and nitrogen management practices. At this time, it is unclear that there is a direct relationship between nitrogen fertilizer management alone and improved soil health (Eagle et al. 2012). This relationship needs to be further studied to understand if this project activity is applicable to the current scope of the ESMC program, but for now those protocols are included. As the focus of this exercise was limited to improved soil health primarily in the Southern Great Plains, non-relevant project types such as rice management systems and inactive protocols have been excluded from discussion herein.

Avoided conversion of grasslands: This project type involves the avoided conversion of a native ecosystem such as a grassland to cropland typically through conservation easements. Projects have used both the Climate Action Reserve (CAR) and American Carbon Registry (ACR) grasslands protocols and recent updates (the ACR update is still pending) have been made to streamline the additionality approaches and quantification methodology. In particular, the CAR *Grassland Project Protocol* includes an innovative approach to quantification while the Verified Carbon Standard (VCS) *Methodology for Avoided Ecosystem Conversion* (VM0009) is a bit broader in its scope as it also includes the avoided conversion of forest to non-forest. The latter has not yet been used to develop a project.

Conservation tillage or no till: This project type includes either improved tillage management or no tilling by enhancing soil carbon stocks through this practice change. While the Gold Standard published the *Increasing Soil Carbon Through Improved Tillage Practices* methodology in March 2015, no projects have been implemented using this methodology which is at Version 0.9 until “road testing” has been completed. The most widely used protocol for this project type, however, is Alberta’s *Quantification Protocol for Conservation Cropping* (formerly Tillage System Management) which accounts for the majority of agricultural offsets issued in the Alberta compliance market. The protocol employs a performance-based standard and allows early adopters to participate without penalty or demonstrating field-specific additionality.

Compost additions: This project type includes the land application of manure as compost. There are two published methodologies that exclusively credit this project activity: CDM’s AMS-III.F, *Avoidance of Methane Emissions through Composting* and ACR’s *Compost Additions to*

Grazed Grasslands. Neither has been used to develop a project. Of note, between the two methodologies is the primary crediting mechanism - CDM credits the avoidance of methane released from anaerobic processes that would have otherwise taken place where ACR credits the enhanced below ground carbon stocks (i.e., increased soil carbon).

Whole farm approaches: These projects typically account for the most significant GHG emissions from all farm or ranch operations including soil carbon, enteric emissions, manure management, and above ground carbon stocks. These methodologies are typically written in such a way that allows for the necessary flexibility for project developers to establish emission reducing practice or technological changes such as the Verra VM0017 *Sustainable Agricultural Land Management* (SALM) or the ACR *Grazing Lands and Livestock Management* (GLLM) methodologies.

Nitrogen management practices: This project type includes any change in nitrogen management that reduces the nitrous oxide vented to the atmosphere. Between CDM, CAR, ACR and Verra, there are five published methodologies. One has been used (the ACR *Reduced Use of Nitrogen Fertilizer on Agricultural Crops*) for a Delta Institute NRCS Conservation Innovation Grant (CIG), *Bringing Greenhouse Gas Benefits to Market: Nutrient Management for Nitrous Oxide Reductions* project that registered two tCO2e in 2014 as a proof of concept.

The following sections detail the summary of findings for protocol components but also look at the program-level requirements that dictate aspects of project development, such as aggregation and verification, when applicable.

i. Findings for Data Collection & Management

Specifications for the management of data (i.e., records retention) are provided in some of the reviewed protocols but are typically provided at the program level. Details generally include the length of time that data need to be stored by the project developer and/or the verifying entity [e.g., *Grassland Project Protocol* (Climate Action Reserve) and *Avoided Conversion of Grasslands & Shrublands* (American Carbon Registry)]. How records and data are managed is determined by the project developer. There are very few requirements set at the protocol level, and therefore there is no specific recommendation on data collection or management as they relate to records retention based on existing protocols. It will be beneficial to provide guidance in the protocol on records retention and data management needed to comply with the ESMC program, taking into consideration the water quality and quantity protocol needs and the role that the future MRV (Monitoring, Reporting, and Verification) Platform will provide for the ESMC.

ii. Findings for Quantification Methods

The level of complexity used to quantify the baseline and project scenarios varies in terms of calculation approaches and required input data. The quantification approaches in carbon protocols include both empirical models and process-based models. The first section of the Master Protocol Assessment Crosscut Table summarizes many of the carbon models currently in use in existing carbon markets.

Scenario quantification parameters range from readily available Intergovernmental Panel on Climate Change (IPCC) default Tier II emission factors (e.g., *Grazing Lands and Livestock Management* for micro-impacts <5,000 tCO_2-e/yr [ACR]), to parameters used in models [e.g., DeNitrification-DeComposition (DNDC) used in *Methodology for N_2O Emissions Reductions from Changes in Fertilizer Management* (ACR)], to direct field measurements of either participating projects or representative projects.

Estimates of GHG emission reductions and/or carbon sequestration in soils are typically based on a combination of default emission factors from sources like the IPCC as well as modelling to develop a set of prescribed equations. The latter allows the project developer to calculate the emission reductions and enhancements based on the requisite inputs. Model inputs can include management records that are producer-specific, regional averages (e.g., county-level fertilizer application records published by USDA NASS), or can require in-field data collection in certain cases (e.g. ACR's *Compost Additions to Grazed Grasslands*).

In general, modeling approaches can be broken down into the following categories:

- Prescribed models to be used by the project developer: The DNDC model, for example, must be used for *Methodology for N_2O Emissions Reductions from Changes in Fertilizer Management* (ACR). Use of a single model allows for uniformity in quantification approaches and increased surety that credits issued from one project to the next are likely to be calculated in a standardized manner.
- Models selected by project proponents: A proponent chooses a model that is sufficiently accurate for the project type and is validated and calibrated for the production system and region, e.g., *Compost Additions to Grazed Grasslands* (ACR). Both this and the first option allow for the most accurate calculation of emissions as they're both based on field-specific calibrations. However, this approach cannot ensure that modeled outputs are calculated in precisely the same fashion from one model to the next.
- Modeling conducted as part of protocol development: This approach creates a set of static, uniform emission factors that are based on standardized parameters for the applicable practice changes and used accordingly by the project developer. This probabilistic modeling approach (e.g., the protocol developers used DayCent to model the results provided in the protocol) assumes there is a certain probability that the land will be managed in a variety of ways as described in the *Grassland Project Protocol* (CAR). This option provides a streamlined quantification approach and thereby condenses the verification scope by removing the requirement that the project developer run the model or that those model runs be verified.
- Mix of approaches: *Grazing Land and Livestock Management* (ACR) increases the quantification rigor based on the size of the project using a simplified calculation tool for projects registering 5,000 t CO2e or less annually and ultimately requiring a biogeochemical model for large scale projects.

These four approaches result in the same outcome (i.e., carbon credits) but vary significantly in their required inputs and costs. The intent of the ESMC program is to develop an approach that will minimize the barriers to entry when possible, in order to achieve scale. A tiered, modular integrated protocol is being considered to quantify multiple assets simultaneously to increase income generation potential for farmers and ranchers, and to qualify for multiple (tiered) market opportunities.

For the lower level tiers, the use of emission factors may be a useful alternative approach. Emission factors can be derived from values in peer-reviewed published data or through the use of biogeochemical models developed as part of the protocol (e.g., as conducted as part of the CAR *Grassland Project Protocol).* Depending on the needs and desires of the buyers, either approach could be acceptable. Emission factors can then be used (via the planned platform) to derive quantification needs. A further step for consideration is to create a "calculator" component of the MRV platform that allows producers to input their on-farm monitored parameters that would then automatically calculate the emission reductions, akin to a carbon footprint calculator. This approach would limit costly data collection, a high level of technical assistance on behalf of the project developers, and the scope of verification if a project audit team does not need to validate the model calibration and potentially thousands of model runs.

The ability of the protocol to also address ESMC's proposed tiered and modular protocol framework also needs to be considered. The *GLLM* (ACR) methodology provides an example that includes a tiered approach to quantification based on the projected impact (i.e., tons of CO_2e being registered annually). While this protocol has not been tested in the market, components of it can inform the quantification of baseline and scenarios.

Elements from the CAR *Grassland Project Protocol* and the ACR *GLLM* methodology could potentially inform the need for easier entry into the market by providing flexibility depending on the level of crediting applicable to a purchaser's intended use.

iii. Findings for Aggregation Methods

Aggregation of projects into larger units is allowed under all the protocols examined in this effort. Aggregation is typically structured so that multiple, smaller projects can be combined into a larger project under a single project developer. General rules around aggregation are typically set at the program level and usually can be found in the GHG programs' standards unless there are additional contingencies for an approved methodology, like cooperatives in the Alberta *Quantification Protocol for Conservation Cropping*. The benefits of aggregated projects include streamlined documentation of project data, a single verification of multiple sub-projects, and transaction costs spread across multiple project participants.

In general, there are three types of aggregation: traditional aggregation where all project participants are identified and included in a single project from the project's outset; cooperatives where multiple projects utilize a single project developer to oversee the generation of credits, but each project is still registered separately (e.g., the CAR *Grassland Project Protocol*); and the program of activities or the programmatic development approach which is structured like traditional aggregation, but where project participants can be enrolled on an ongoing basis after the project is successfully validated.

The ESMC program will need to consider if criteria for aggregation should be included, and what those criteria are, depending on the breadth of the role of the project developer and the MRV technology platform.

iv. Findings for Monitoring, Reporting, Verification

GHG programs are tasked with establishing programmatic requirements (e.g., maximum crediting period durations or start date criteria) that are applicable to all project types in a program or standards documents. These are built on the criteria set forth in the international standard, ISO 14064-2:2006 *Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements* (ISO 14064-2). The programs are also responsible for publishing the individual protocols or methodologies that specify the criteria for developing a project for a defined project activity (e.g., the ACR *Compost Additions to Grazed Grasslands* methodology). Typically, monitoring requirements are identified at the protocol level (e.g., CAR *Grassland Project Protocol)* while reporting and verification requirements, such as reporting frequency, are typically found at the program level (e.g., CAR). It should be noted that project developers are responsible for meeting both the programmatic and project level requirements in order to successfully generate carbon offsets.

The protocols that were reviewed are associated with existing GHG programs including the Alberta Emission Offset System (Alberta), American Carbon Registry (ACR), the Climate Action Reserve (CAR), the Gold Standard, the Verified Carbon Standard (VCS) and the United Nation's Clean Development Mechanism (CDM).

Monitoring

Monitoring requirements in the carbon protocols vary in their level of complexity and typically require historical data in addition to parameters that need to be monitored on an ongoing basis during the project's crediting period. Some protocols require only annual management information sourced from producers' records whereas others call for in-depth field analysis of soil and vegetation in addition to management information through soil and plot samples. Almost all of the protocols examined use default emission factors based on published data that can be used in place of field-specific measured parameters, in addition to the on-farm records. Existing protocols can be summarized into three levels of complexity: low, moderate, and high. The following table ranks the protocols based on monitoring requirements provided in the attachment, Master Protocol Assessment Crosscut Table.

Low - No field sample site stratification or field-based monitoring needed. Literature values and agricultural producer-based management information used.
Moderate - Desktop analyses needed to support monitoring requirements (e.g., spatial data, aerial photography).
High - Field-based monitoring requirements (e.g., surveys, soil sampling). Site sampling stratification based on detailed spatial data.

Table A-2: Complexity of Monitoring Required in Carbon Protocols

Protocol	Level of Monitoring Complexity
Reduction of N_2O emissions from use of Nitrogen Use Efficient (NUE) seeds that require less fertilizer application – Version 2.0 *(CDM)*	High
Adoption of Sustainable Agricultural Land Management (SALM) (VCS)	Low
VM0021 Soil Carbon Quantification Methodology *(VCS)*	High
VM0009 Methodology for Avoided Ecosystem Conversion (VCS)	Varies, Moderate-High
VM0022 Quantifying N2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction (VCS)	Low
VM0026 Methodology for Sustainable Grassland Management (VCS)	Low
VM0032 Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing (VCS)	High
Quantification Protocol for Conservation Cropping (version 1.0) *(Alberta)*	Low
Grassland Project Protocol (*CAR)*	Moderate
Grazing Lands and Livestock Management (GLLM) *(ACR)*	High
Compost Additions to Grazed Grasslands *(ACR)*	High
Avoided Conversion of Grasslands & Shrublands (*ACR)*	Varies, Moderate-High
Nitrogen Management Project Protocol *(CAR)*	Moderate
Methodology for N_2O Emissions Reductions from Changes in Fertilizer Management *(ACR)*	Moderate
Methodology for Quantifying Nitrous Oxide (N_2O) Emissions Reductions from Reduced Use of Nitrogen Fertilizer on Agricultural Crops *(ACR)*	Low

Increasing Soil Carbon Through Improved Tillage Practices (Gold Standard)	**Varied, Low-High**
Avoidance of methane emissions through composting (CDM)	Low
Offsetting of synthetic nitrogen fertilizers by inoculant application in legumes-grass rotations on acidic soils on existing cropland (CDM)	Low

Reporting and Verification

Programmatic reporting criteria include high-level requirements for monitoring and documentation, including when and how documentation should be submitted, any required templates, crediting period (CP) constraints, the CP renewal process, reporting intervals, records keeping requirements, and the reporting process. In general, Agriculture, Forestry and Other Land Use types of projects have different timelines than industrial projects like landfill gas or dairy digester projects. Of the GHG programs reviewed, ACR, CAR, and Gold Standard have prescriptive reporting requirements with differing frequencies. Alberta, CDM, and VCS include constraints on the crediting period, but do not require set reporting intervals.

All Validation/Verification Bodies (VVBs) must be approved by the GHG program before they can conduct audits on behalf of the program, and they must also be accredited. Most VVBs are accredited by an accreditation body (i.e., the American National Standards Institute in the United States) to ISO 14065:2013 *Greenhouse gases -- Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition.* In the case of the Alberta and California Air Resources Board (CARB) programs, the GHG program itself accredits both verifiers and verification bodies to conduct audits on the program's behalf.

At the program level, verification criteria lay out the GHG program-specific requirements for approval of VVBs, accreditation requirements, the interval for validation and/or verification (i.e., validation happens once per CP and verification happens once per reporting period) as well as the overarching verification scope and criteria. All of the GHG programs have published validation/verification standards or guidance that outline the underlying expectations and requirements. Several protocols do, however, have additional protocol specific requirements. For instance, in the CAR protocols reviewed (*Nitrogen Management* and *Grassland Project* Protocols), both identify which aspects of the verification can be based on the auditors' judgements and which must be satisfied with empirical evidence.

v. Findings for Registration for Sale

The registration or issuance of credits and the process of transacting these credits are prescribed by the GHG program that the project is listed with. The registry is responsible for the transparent tracking of credits from issuance through retirement but is not privy to the details of the actual transaction (e.g., the price per ton) unless the information is publicly available. Credits are issued to the project's account on the registry after a successful verification, and then one of several transaction approaches can be utilized. Credits can be directly contracted from a project developer by a corporate entity for delivery upon issuance. For example, Ducks Unlimited signed a verified emission reductions purchase agreement with Chevrolet that set the transaction price for credits which were then delivered in 2014 after the successful verification of the project.

Projects can also be affiliated with brokers who will sell the credits on behalf of the project developer. This approach allows the brokers to provide a range of projects in their portfolios to companies or people who are voluntarily attempting to lower their carbon footprints. An example of this is the option to purchase offset credits to offset GHG emissions associated with air travel, as offered by some airlines when customers purchase airplane tickets.

A third option is when credits from multiple projects are bundled by a broker to meet a minimum amount desired by a buyer. For example, Pacific Gas & Electric typically requests packages of credits in increments of at least 25,000 t CO_2e, in which case brokers aggregate credits from multiple projects with similar characteristics into a single package to meet the desired tonnage sought by the buyer. Credits can also be listed on trading platforms like NYSE Blue or the Carbon Trade Exchange.

3) Summary of Findings for Priority Elements

Protocols for the ESMC will be developed initially for rangelands, grasslands, pastures and crops in the Southern Great Plains to quantify and monetize soil carbon, water quality, and water quantity impacts of activities on working agricultural lands that enhance soil health. Existing protocol methodologies, as provided in the Master Protocol Assessment Crosscut Table and summarized above can inform protocol development for this geographic area. Important for consideration are the types of activities that are anticipated to be encountered in the Southern Great Plains and their potential to enhance SOC/SOM and therefore soil health (see table below). This table is not a comprehensive list of practices that can address GHGs and soil health; these are examples of typical practices being implemented in this geographic region. Many of these identified activities can lead to increased SOC/SOM, either directly (e.g., precision grazing) or indirectly (e.g., fencing).

Table A-3. Conservation Practice Potential to Increase SOC/SOM

Conservation Practice (NRCS Conservation Practice #) *	Potential to Increase SOC/SOM?
Prescribed Grazing (528)	Practice can maintain SOC/SOM, but not increase. Other forms of grazing management may increase SOC/SOM (e.g., adaptive multi-paddock grazing)
Brush Management (314)	Yes, if managed for soil carbon
Range Planting (550)	Yes, if managed for soil carbon
Prescribed Burning (338)	Yes, if managed for soil carbon
Forage and Biomass Planting (512)	Yes, if managed for soil carbon
Fence (382)	Indirectly as relates to grazing management
Nutrient Management (590), Waste Utilization (633)	Yes, if managed for soil carbon
Livestock Water Development (614)	No
Integrated Pest Management (595)/Herbaceous Weed Treatment (315)	Yes, if managed for soil carbon
Forage Harvest Management (511)	Practice can reduce SOC/SOM

* This list is of typical practices in the Southern Great Plains. Additional practices can be used to improve soil health and increase SOC/SOM. Additional practices will also be considered as the ESMC moves into new production systems and geographies

The following sections address several key issues for consideration as they relate to how existing protocols may inform ESM protocol development in the Southern Great Plains.

i. Scalability

Many of the reviewed protocols were developed for a specific type of activity (e.g., avoided conversion of native ecosystems, conservation tillage or no till, compost additions, and nitrogen management practices) and therefore scalability (i.e., adaptability) has been limited for these protocols beyond the specific practices. Methodologies that address the whole farm and more general land management activities and that could be scalable and potentially applicable to the ESM protocol development include:

- VM0017 *Methodology for the Adoption of Sustainable Agricultural Land Management* (SALM) (VCS)
- *Methodology for Grazing Land and Livestock Management* (ACR)
- VM0026 *Methodology for Sustainable Grassland Management* (VCS)
- VM0032 *Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing* (VCS)

The SALM methodology is outcome-based and does not rely on a specific set of land management activities to achieve carbon credits. Sustainable land management is defined as any practice that increases the carbon stocks on the land. Examples of sustainable land management are (but are not limited to) manure management, use of cover crops, and returning composted crop residuals to the field and the introduction of trees into the landscape. The methodology includes a series of modules that are used to step through the protocol, including a detailed field data collection process to measure soil carbon.

This methodology would be scalable; however, the level of effort to develop the necessary documentation for crediting is high. The SALM methodology has successfully been used to register credits for two projects in Africa and three projects in the VCS pipeline (one in New Zealand and two in India). VM0026 has not been used for project implementation, however.

The GLLM protocol can inform ESMC's approach. This protocol does not specify approved practices and therefore allows flexibility on behalf of the project proponent. The GLLM's quantification approach is innovative in that projects registering less than 5,000 tCO2e annually use an Excel spreadsheet published by ACR. The quantification approach increases in rigor as the credits increase, ultimately utilizing a biogeochemical model for large-scale projects (those registering more than 60,000 tCO2e annually). No projects have been implemented using this methodology.

VCS has two additional protocols to note in this category: VM0032 the *Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing* and VM0026 the *Methodology for Sustainable Grassland Management*. VCS currently has only one project underway in Kenya using VM0032, but the methodology aligns well with the practices recommended in the Southern Great Plains and has direct ties to soil health. VM0026 has not been used to develop a project; however, the identified practices include change of grazing regimes such as improved rotational grazing of summer and winter pastures, limiting the timing and number of grazing animals on degraded pastures, and/or the restoration of degraded land through replanting of perennial grasses. These components can thus inform ESMC protocol development.

ii. Scientifically Rigorous

The level of quantification rigor has not yet been decided for the ESMC protocol; however, a tiered approach is being considered. The protocols reviewed met the necessary scientific rigor to generate credits in their respective markets and used the best available science at the time of peer review and/or publishing. In the case of the Alberta program, it should be noted that while the *Quantification Protocol for Conservation Cropping* has been successful in generating credits, emission reductions created under the Alberta scheme do not meet the requirements of the Western Climate Initiative, which resulted in the Alberta program being denied linkage with the California Cap and Trade program.

As described in Scalability [*Section A.3)i* above], the *GLLM* protocol (for voluntary offset markets) addresses a range of scientific rigor and provides an example protocol that potentially addresses multiple tiers of quantification approaches depending on the size of the project. This methodology is structured in a modular way, allowing the project developer to determine the appropriate methods to meet a specific project need. This approach can inform the platform being proposed for the ESMC, eliminating much of the burden on the applicant.

The CAR *Grassland Project Protocol* includes static emission factors developed via DayCent model runs, and thus alleviates the need for the project developer to become a modeling expert or hire a modelling consultant. This approach retains the scientific rigor necessary to produce credits, but reduces the quantification burden, which reduces project development costs.

iii. Transparency

Transparency is a fundamental principal of all carbon offsets in accordance with ISO 14064-2, regardless of the GHG program. The most transparent protocols include detailed methodologies for quantification and monitoring [e.g., *Grazing Lands & Livestock Management* (ACR), *Soil Carbon Quantification Methodology* (VCS0]. Transparency will be critical to ensuring an ESM protocol that is successful while not being overly prescriptive. This will be achieved through detailed documentation.

ACR's *Reduced Use of Nitrogen Fertilizer on Agricultural Crops* methodology credits solely the reduced use of nitrogen fertilizer. This methodology has been used by project developers who find the option of using a Tier 2 emission factor that establishes a direct relationship between N_2O emissions and N application rates to be the most streamlined project development approach due to the reduced quantification and monitoring burdens. The emission factors developed are specific to one region of the U.S. (i.e., the corn belt) and one cropping system (corn) based on data sourced from Michigan State University in partnership with the Electric Power Research Institute (EPRI 2014). Project developers can include other crops but would be required to include a quantification methodology that is validated, which means that all credits from this methodology issued to date have been from corn crops in the corn belt. The performance standard employed to determine additionality in that methodology is no longer relevant as it was published when the baseline scenario assumed that all corn crops use a yield goal approach, whereas the current BMP is for the maximum return to N, creating a negligible delta for credit generation. This protocol includes a high degree of transparency and is also straightforward to apply.

iv. Standards-Based (Regulatory and CRS)

With the exception of the CARB Cap and Trade program, all GHG programs in North America are built on the tenets of ISO 14064-2 and may incorporate components of ISO 14064-1:2006 *Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals* (ISO 14064-2) if including aspects of organizational GHG accounting.

v. *Farmer-Facing*

Project implementation in current carbon markets is generally conducted by project developers/project proponents rather than farmers/producers. The primary responsibilities of the farmer/producer should be providing on-farm records (e.g., fertilizer application rates, acres in a particular practice or crop, etc.).

There are limited farmer-facing issues that need to be addressed. To ensure easy entry in the ESMC program, a simplified platform is needed that will interface with the producers or the project developers and allow for complex modeling and calculations to occur behind the scenes. Limited site-specific data requirements from farmers and ranchers will help to reduce onerous burdens on participants.

A recognized barrier to entry for enhanced soil carbon projects is the permanence requirement as it has been defined and applied by existing GHG programs. For example, CAR's *Grassland Project Protocol* requires project participants to put their land into a permanent easement; the crediting period is 50 years; and monitoring for reversals is required for 100 years after the end of the crediting period. Any one of these requirements is onerous for producers, but collectively, they create significant obstacles for most producers.

vi. *Legal Considerations*

Legal considerations for the ESMC program include issues such as ownership of the GHG attributes and potential invalidation. As the ESMC protocol is designed to improve soil health and enhance SOC sequestration, the ESMC will need to define permanence, establish how to credit producers who do not own the land that they operate on, determine whether a buffer pool for soil carbon enhancements will be established and what the contribution rules are, establish how to deal with fraudulent statements, what the statute of limitations for invalidation may be, etc. Each of the GHG programs approaches legal issues differently. The State of California is the most risk averse in these respects, and their approach has stifled credit generation and buyer interest from the agricultural sector.

The right to claim emission reductions must be clear and uncontestable. This is typically done through contractual agreements with the landowner, the manufacturer, etc. As the ESCM protocol is drafted, a decision on how to define ownership of the GHG emission reductions or enhancements must be established.

Similar considerations will also be needed for permanence as the ESMC will need to ensure that credits issued for enhanced soil carbon are credibly accounted for. This is usually done through the use of a buffer pool, a risk mitigation mechanism for sequestration-based projects whereby projects contribute a portion of the verified credits to a risk pool administered by the GHG program in case of unintentional or intentional reversals. ACR, CAR, Gold Standard, and VCS all require buffer pool contributions based on the risk rating of the project which is generally spelled out in the project-specific risk mitigation agreement. Some of the programs return buffer pool contributions if no reversal occurs after a defined period (e.g., 5 years) and programs like Gold Standard state very clearly that the buffer pool is non-refundable.

4) Research Needs and Data Gaps Relevant for Protocol Development

- Correlation between remote sensing data and soil carbon in the Southern Great Plains and potential for use in protocol [as described in *Soil Carbon Quantification Methodology* (VCS)].

- Additional research on the relationship between nitrogen fertilizer management and soil health.
- Additional research specific to rangeland and grassland management practices and their impact on soil health and soil organic carbon on the Southern Great Plains (specific to the list of practices provided in *Section A.3*).
- Modeling (i.e., DNDC) to produce emission factors or simplified equations for quantification specific to the Southern Great Plains.
- Potential effect of fencing as a conservation practice on soil health.

References for Assessment of Existing Carbon Protocols

Blanco-Canqui, H., C.A. Shapiro, C.S. Wortmann, R.A. Drijber, M. Mamo, T.M. Shaver, and R.B. Ferguson. 2013. Soil organic carbon: The value to soil properties. *Journal of Soil and Water Conservation* 68(5):129A-134A. https://doi.org/10.2489/jswc.68.5.129A

Bowman, R.A., M. F. Vigil, D.C. Nielsen, and R.L. Anderson. 1999. Soil organic matter changes in intensively cropped dryland systems. *Soil Science Society of America Journal* 63:186-191. https://doi.org/10.2136/sssaj1999.03615995006300010026x

Bowman, R.A., and R. L. Anderson. 2002. Conservation Reserve Program: Effects on soil organic carbon and preservation when converting back to cropland in northeastern Colorado. *Journal of Soil and Water Conservation* 57(2): 121-126.

Bremer, E., H.H. Janzen, B.H. Ellert, and R.H. McKenzie. 2011. Carbon, nitrogen, and greenhouse gas balances in an 18-year cropping system study on the northern Great Plains. *Soil Science Society of America Journal* 75:1493-1502. https://doi.org/10.2136/sssaj2010.0326

Cornell University Cooperative Extension. 2016. *The carbon cycle and soil organic carbon*. Fact Sheet 91. Agronomy Fact Sheet Series. Cornell University Cooperative Extension, College of Agriculture and Life Sciences. http://nmsp.cals.cornell.edu/publications/factsheets/factsheet91.pdf

D'Hose, T., M. Cougnon, A. De Vliegher, B. Vandecasteele, N. Viaene, W. Cornelis, E. Van Bockstaele, et al. 2014. The positive relationship between soil quality and crop production: A case study on the effect of farm compost application. *Applied Soil Ecology* 75: 189-198. https://doi.org/10.1016/j.apsoil.2013.11.013

Eagle, A.J., L.P. Olander, L.R. Henry, K. Haugen-Kozyra, N. Millar, and G.P. Robertson. 2012. *Greenhouse gas mitigation potential of agricultural land management in the United States: A synthesis of the literature*. Report NIR 10-04, Third Edition. Durham, NC: Duke University, Nicholas Institute for Environmental Policy Solutions. https://nicholasinstitute.duke.edu/ecosystem/land/TAGGDLitRev

Electric Power Research Institute (EPRI). 2014. *Creating greenhouse gas emissions offsets by reducing nitrous oxide (N_2O) emissions in agricultural crop production: Experience developing and implementing the world's first on-farm N_2O offset project*. Report 1025399. Palo Alto, CA: Electric Power Research Institute. Franzluebbers, A.J. and J.A. Stuedemann. 2015. Does grazing of cover crops impact biologically active soil carbon and nitrogen fractions under inversion or no tillage management? *Journal of Soil and Water Conservation* 70: 365-373. https://doi.org/10.2489/jswc.70.6.365

Havlin, J.L., D.E. Kissel, L.D. Maddux, L.M. Claassen, and J.H. Long. 1990. Crop rotation and tillage effects on soil organic carbon and nitrogen. *Soil Science Society of America Journal* 54: 448-452. https://doi.org/10.2136/sssaj1990.03615995005400020026x

Huang, P.M. 2004. Soil mineral – organic matter – microorganism interactions: Fundamentals and impacts. *Advances in Agronomy* 82: 391-472. https://doi.org/10.1016/S0065-2113(03)82006-0

Hubbard, R. K., T.C. Strickland, and S. Phatak. 2013. Effects of cover crop systems on soil physical properties and carbon/nitrogen relationships in the coastal plain of southeastern USA. *Soil and Tillage Research* 126: 276-283. https://doi.org/10.1016/j.still.2012.07.009

Johns, C. 2017. *The role of carbon in promoting healthy soils*. Strategic Analysis Paper. Future Directions International. http://www.futuredirections.org.au/publication/role-carbon-promoting-healthy-soils/

Kahlon, M.S., R. Lal, and M. Ann-Varughese. 2013. Twenty two years of tillage and mulch impact on physical characteristics and carbon sequestration in Central Ohio. *Soil and Tillage Research* 125: 151-158. https://doi.org/10.1016/j.still.2012.08.001

Lado, M., A. Paz, and M. Ben-Hur. 2004. Organic matter and aggregate-size interactions in saturated hydraulic conductivity. *Soil Science Society of America Journal* 68:234-242. https://doi.org/10.2136/sssaj2004.2340

Lal, R. 2016. Soil health and carbon management. *Food and Energy Security* 5(4): 212-222. https://doi.org/10.1002/fes3.96

Murphy, B.W. 2014. *Soil organic matter and soil function - Review of the literature and underlying data*. Department of the Environment, Canberra, Australia. http://www.ecaf.org/downloads/books/17-soil-organic-matter-and-soil-function-review-of-the-literature-and-underlying-data/file

Natural Resources Conservation Service (NRCS). 2018. Soil Health. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/mgnt/?cid=stelprdb1237584 accessed 8/22/2018.

Olson, K., S.A. Ebelhar, and J.M. Lang. 2014. Long-term effects of cover crops on crop yields, soil organic carbon stocks and sequestration. *Journal of Soil Science* 4: 284-292.

Schillinger, W.F., A.C. Kennedy, and D.L. Young. 2007. Eight years of annual no-till cropping in Washington's winter wheat-summer fallow region. *Agriculture Ecosystems & Environment* 120: 345-358. https://doi.org/10.1016/j.agee.2006.10.017

United States Department of Agriculture (USDA). 2014. *Soil quality indicators – Reactive carbon*. USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=stelprdb1237387

———. 2015a. *Soil quality indicators – Chemical indicators and soil functions*. USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=stelprdb1237387

———. 2015b. *Soil health literature summary – Effects of conservation practices on soil properties in areas of cropland*. USDA Natural Resources Conservation Service, National Soil Survey Center. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/mgnt/?cid=stelprdb1257753

———. 2015c. Soil quality indicators – Physical, chemical, and biologic indicators for soil quality assessment and management. USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=stelprdb1237387

———. 2016a. *Soil health literature summaries – Summary of peer-reviewed articles, including citations*. USDA Natural Resources Conservation Service, National Soil Survey Center. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/mgnt/?cid=stelprdb1257753

———. 2016b. *Soil health literature summary – Effects of implementation of soil health management practices on infiltration, saturated hydraulic conductivity (K_{sat}), and runoff*. USDA Natural Resources Conservation Service, National Soil Survey Center. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/mgnt/?cid=stelprdb1257753

———. 2018. *Effects on soil water holding capacity and soil water retention resulting from soil health management practices*. USDA Natural Resources Conservation Service, National Soil Survey Center. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/mgnt/?cid=stelprdb1257753

Wang, T., W.R. Teague, S.C. Park, and S. Bevers. 2015. GHG mitigation potential of different grazing strategies in the United States Southern Great Plains. *Sustainability* 7: 13500-13521. https://doi.org/10.3390/su71013500

Section B. Assessment of Existing Water Quality Protocols

1) Summary of the Relationship Between Water Quality, Soil Health, and Ecosystem Service Markets

A number of water quality benefits are attributed to improved soil health, primarily due to reduced losses of sediment and nutrients to surface waters. These benefits are attributed to greater storage and more efficient cycling of carbon and nutrients in soil organic matter, increased water-holding capacity, and reduced surface runoff and erosion (USDA 2018; Derner et al. 2016; Manale et al. 2018).

In general, water quality impacts associated with nutrient losses occur as the increased availability of nutrients in rivers, streams, and lakes contribute to excess growth of aquatic plants and microorganisms. This growth can, in turn, negatively impact dissolved oxygen concentrations and increase algal toxin concentrations, leading to adverse impacts on macroinvertebrates, fish, and local communities. Increased algae growth and sediment erosion can increase organic loading and alter aquatic habitats and food webs.

Relationships between agricultural land use practices and these water quality characteristics have been studied for decades. For example, increased tillage and use of pesticides and fertilizers are known to increase the potential for degradation of surface and groundwater quality (Unger et al. 1998; Reicosky 2015). Studies on the use of cover crops have shown reductions in nutrient and sediment losses from fields due to the presence of protective cover, absorption of raindrop energy, and increasing soil surface roughness (Blanco-Canqui et al. 2015).

A significant challenge to describing the relationship between soil health and water quality is that agricultural land use/water quality relationships have generally been evaluated in terms of the effects of implementing certain farming/ranching and soil conservation practices to improve water quality rather than in terms of changes in soil health attributes. Of the hundreds of conservation practices determined to have associated water quality benefits, only a few are being promoted for soil health (see for example, Table C-1). Still, a large body of research has yielded several computational tools that support water quality markets linking conservation practices to water quality improvements. Importantly, current water quality markets are underpinned by science that links conservation practices to water quality benefits. The metric used in water quality trading programs (i.e., the unit of trade) for nutrients and sediments is the reduction in "load" expressed as mass per time. Output from computational models expresses water quality benefits in terms of load reductions.

The computational tools relating changes in nutrient and sediment loads to soil health, per se, do not yet exist as do the tools for relating conservation practices and water quality benefits. One example is the NTT/APEX computer simulation model. This tool synthesizes much of the current scientific understanding of relationships between conservation practices and water quality and has been shown to provide useful predictions to help guide farm-/field-scale decisions (Gassman et al. 2010). As characterized by Saleh et al. (2015), NTT/APEX is a "method of evaluating the impacts of proposed and existing conservation practices (CPs) on water quality and quantity." As such, it directly simulates nutrient and sediment loss reductions for a number of conservation practices including use of cover crops, contouring, no tillage, nutrient application management, and others identified in Table C-1 (Saleh et al. 2015).

In addition to incorporating conservation practices and market-relevant nutrient and sediment losses, the NTT/APEX modeling tool can yield predictions of attributes that are important to assessments of soil health, such as soil organic carbon, soil texture, soil water, and others. Therefore, it can be used to help generate the information needed to explicitly relate soil health with water quality characteristics. New applications of this existing modeling tool can help advance the state of the science relating soil health and water quality and support the NRI ESM Program.

Notably, conservation practice research and models also help define unexpected water quality outcomes attributable to common practices that are generally considered to enhance soil health. This is an important consideration for computational approaches to assess water quality outcomes associated with soil health by production region and farming practices. One such area of active research is focused on understanding the role of soil macropores and freeze-thaw conditions on the loss of dissolved phosphorus from fields undergoing reduced tillage or planted in cover crops, especially where tile drains are present (Goehring et al. 2001; Williams et al. 2016; Riddle and Bergstrőm 2013).

Tools that compute water quality benefits as load reductions in regulated markets may not be necessary for supply chain or corporate sustainability investments where social context, as compared to compliance markets, is a more prominent interest tied to water quality benefits. In these instances, more qualitative tools such as indices may be used. Such could be useful for tiered crediting approaches. For example, the Water Quality Index (WQI) combines multiple water quality factors into a single dimensionless number by normalizing their values to subjective rating curves (Miller et al. 1986). It is a simple, convenient way to express risk to water quality in easy-to-understand terms. Traditionally, it has been used for evaluating the quality of water for waterbodies such as rivers, streams, and lakes. Factors included in a WQI vary depending upon the designated water uses of the waterbody and local preferences. Some of these factors include dissolved oxygen (DO), pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total coliform bacteria, temperature, and nutrients (nitrogen and phosphorus). These parameters are measured in different ranges and expressed in different units. The WQI takes the complex scientific information of these variables and synthesizes them into a single number. A similar approach could potentially be correlated to a yet-to-be devised Soil Health credit.

Applications of the WQI are in play where compliance trading for nutrients and sediments is not the focus, but rather the focus is improved water quality outcomes associated with producers implementing conservation practices. A WQI derivative tool for agriculture (WQIag) is being applied in the Minnesota Agricultural Water Quality Certification Program as a certification program of voluntary efforts by farmers to protect water quality (Minnesota Department of Agriculture 2018).

In a quasi-compliance setting in southern California's San Jacinto River watershed, another variation of the WQIag tool focuses on edge-of-field nutrient loss concerns associated with a Conditional Waiver of Waste Discharge Requirements for Agricultural Discharges (CWAD) and a pending Total Maximum Daily Load (TMDL). The tool is instrumental for the Western Riverside County Agriculture Coalition (WRCAC) to help producers flexibly operate within regulatory constraints absent strict adherence to a specified load reduction.[1] Adjustments to

[1] This material is based upon work supported by the Natural Resource Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-259. Any opinions, findings, conclusions, or recommendations expressed in

inputs within the index tool, as well as the values associated with them, were based on hydrodynamic model simulations of region-specific soils and rainfall events, as well as best professional judgement and scientific literature.

This WQIag tool can be used by WRCAC member producers to determine their relative water quality impact of their fields or farms. By using the WQIag to calculate the single index value for a field, then averaging all the field values for the farm, the producer can obtain an overall picture of the contributions of the farm to water quality conditions. Over time, the producer can track progress in reducing runoff or sediment losses in an adaptive management process. Scoring with the index tool may eventually determine required farmer payments towards TMDL implementation goals.

Social implications of this approach are substantial as farmers can band together to, in some ways, trade superior field performance within a group of farmers in a subwatershed to meet collective water quality goals set at a relative index value. The index provides relative scores such that the public focus is on good performance rather than pollutant loading. Again, this potentially suggests outcome-based performance somewhere between the traditional water quality trading compliance markets and voluntary water quality improvement efforts and/or supply chain incentive programs.

Missing in the voluntary or semi-quantitative applications of relative water quality indices is the direct linkage to soil health management systems, much like the missing direct linkages cited for the compliance settings. The more direct linkage to water quality benefits again is tied to conservation practice implementation. Linkages to soil health management systems that may encompass conservation practices associated with soil health attributes may also require these indices to focus on relevant practices. Bridging soil health and water quality outcomes via a Water Quality Index is likely achievable with a focus on conservation practices. Relative outcomes in these regards could potentially represent an intermediate tier of credits for a select group of buyers interested in water quality outcomes.

2) Summary of Findings for Protocol Components

i. Findings for Data Collection & Management

Within the water quality protocols assessed in this technical brief, the data collection requirements are dictated by information needs for: 1) establishing eligibility; 2) identifying baseline attainment; 3) credit quantification model inputs, and; 4) ongoing verification of conservation or BMP maintenance or effectiveness. Each of these considerations is discussed as follows.

Data Collection Needs for Establishing Eligibility

Compliance with Water Quality Standards and Regulations: All protocols evaluated had a minimum baseline requirement for agricultural producers to be in compliance with all relevant water quality standards and regulations at the local, state, and federal level. For most protocols, this includes a requirement to in some manner, comply with relevant TMDLs and state nutrient reduction strategies and/or a demonstration of attainment with any associated load allocations (further discussed in *Data Collection Needs for Credit Quantification Model Inputs)*.

---

this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.

Historically, rigid baseline requirements associated with TMDL load allocations have limited producer participation in WQT programs. These programs are recognizing this as a barrier to participation and providing various forms of baseline flexibility. Data required to demonstrate compliance with relevant water quality standards and regulations can be minimal, requiring only basic information on farm history and operation.

Cost-share Restrictions: Many, but not all, protocols have restrictions on the use of cost-share dollars to implement practices to meet baseline required practices. For protocols that restrict the use of BMPs funded by cost-share for meeting baseline requirements, applicants must provide documentation that cost-share funded BMPs were not used to meet baseline requirements. To demonstrate that a practice is providing additional environmental benefit that would not have otherwise occurred, most protocols generally do not allow practices funded by Clean Water Act cost-share dollars (e.g., Section 319 funding) to be eligible for crediting.

NRCS cost-share funding restrictions generally do not apply to the farmer match. This restriction should be considered for the ESMC protocol to comport with other state or watershed-based trading programs. Flexibility should, however, be a priority.

Data Collection Needs for Identifying Baseline Attainment

Baseline Load: For almost all protocols examined in this assessment, credit generators are required to identify an initial water quality pollutant load prior to entry in the program. The majority of protocols defined the baseline water quality pollutant load for an agricultural producer as the current load prior to the implementation of credit generating/pollutant reduction generating BMP(s). Other protocols, such as the Ohio River Basin Trading Pilot and the Iowa Nutrient Reduction Exchange (tentative baseline policy), defined the baseline load as the agricultural producer's load at the fixed initiation date of the program.

Setting the baseline load to a specific time allows credible practices that have been implemented since that time to be recognized. Protocols that have set the baseline load as the initiation date of the program require credit generators to provide data relating to the farm's current load as well as data leading up to the initiation date. For all other protocols, the data required will be related to the "current load" at the time of entry into the program. The data requirements for the baseline load are typically part of the credit quantification model inputs (further discussed in *Data Collection Needs and Methods for Credit Quantification Model Inputs).*

Baseline Required Practices: Some protocols require credit generators to have practices in place (e.g., minimum vegetated buffer width of 35 feet for Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program) before participating in credit generation (Virginia Department of Environmental Quality 2008). Data to verify that required practices are in place include photographs of BMP implementation and BMP information such as location, type, and acres or linear feet implemented.

Baseline Water Quality Index Score: The water quality protocol that does not use a baseline water quality pollutant load in this assessment is the Field Stewards Program (Field Stewards 2018). The Field Stewards Program is unique in this assessment as it offers a certification for achieving and maintaining a score on the Minnesota Water Quality Index for Agriculture (WQIag). The Minnesota Water Quality Index for Agriculture is an assessment tool that scores a farm operator's water quality impact on a scale from 1 to 10. The current baseline WQIag Index score required to participate in the Field Stewards Program is set at 8.5.

Data Collection Needs and Methods for Credit Quantification Model Inputs

The type and sophistication of data required to run a credit quantification model for both the baseline pollutant load and the post-BMP implementation load depends on both the water quality pollutant evaluated and to a lesser degree, whether the quantification model is empirical or mechanistic. As most of the water quality protocols focus on crediting nitrogen, phosphorus, and/or sediment, it is standard to require data on nutrient management, including application rates, timing, and location by field for both baseline load and post-BMP implementation load. Most of these data can be obtained from existing nutrient management plans and operator records.

It is important to note that many protocols that credit phosphorus require some form of soil test sampling (Mehlich-3 P, Bray, or Olson). Additionally, it is often standard to require data on soil type, which can typically be obtained from the NRCS soil web survey for empirical models.

Protocols that require the use of a mechanistic model such as APEX may require more complex input data such as field elevations and other types of geospatial data. Although this would typically increase the need for technical assistance, it is possible to automate data collection from online databases such as those available from the United States Geological Survey (USGS) and NRCS. Note that NRCS's NTT model already automates some of this data collection for users.

Data Collection Needs and Methods for Ongoing Monitoring

Data collection needs for ongoing monitoring (typically, by the project developer) and verification (typically, by the program administrator) requirements in these protocols are based on BMP maintenance and are relatively basic. These typically involve simple geo-referenced and time-stamped photographs of BMP implementation, documentation of maintenance, and/or records of nutrient management or operation management. Required data collection methods for ongoing monitoring can be as simple as a verification phone call (Field Stewards Program), self-inspection and reporting (Iowa Nutrient Reduction Exchange), or a site-inspection by a third-party verifier or program administrator (Ohio River Basin Trading Pilot). Given the relative simplicity and ubiquity of data collection requirements for ongoing monitoring in existing protocols, the data and methods summarized above can be easily adapted for the ESMC protocol.

Data Collection and Management Responsibility

Data collection and management is generally the responsibility of the project developer. However, data collection requirements such as soil test sampling or obtaining geospatial data may not be accomplished solely by the agricultural producer and often require technical assistance. Some protocols have found ways to leverage the existing technical expertise and relationships of Soil and Water Conservation Districts (Ohio River Basin Trading Pilot, Great Miami River Watershed Credit Trading Program) or NRCS staff (Field Stewards) to assist agricultural producers with collecting and managing data and submitting applications.

ii. Findings for Quantification Methods

The level of complexity used to quantify baseline and improvement scenarios varies in terms of modeling approach and data requirements. Water quality models can be broken down into two general categories: empirical models and mechanistic models.

Empirical models commonly rely on a mathematical or statistical function, supported by scientific research, that describes the desired output based on a number of inputs. Such functions can often be simple regression equations describing relationships found in observed data.

Mechanistic models, on the other hand, attempt to predict outcomes based on an understanding of various physical, chemical, and biological processes. Mechanistic models may contain empirical sub-models within them. While mechanistic models can provide superior output accuracy over empirical models, they often require calibration by region or site. The Master Protocol Assessment Crosscut Table summarizes many of the water quality models currently available. The list below summarizes some existing trading protocols and which category of model they utilize.

- Protocols using empirical models:
    - Iowa Nutrient Reduction Exchange [Spreadsheet Tool for Estimating Pollutant Load (STEPL)]
    - Ohio River Basin Trading Pilot (Region V Calculator)
    - Pennsylvania (Pennsylvania Department of Environmental Protection Nitrogen and Phosphorus Calculation Spreadsheets)
    - South Nation River Watershed (Various equations from literature, depending on practice)
    - Western Lake Erie Basin Water Quality Trading [EPA Region V Calculator and Western Lake Erie Basin Dissolved Reactive Phosphorus (WLEB-DRP) Calculator]
- Protocols using mechanistic models
    - Vermont Phosphorus Protocol [Agricultural Policy Environmental eXtender (APEX)]
    - Virginia Chesapeake Bay Watershed Nutrient Credit Exchange Program [Chesapeake Bay Model; Hydrological Simulation Program - Fortran (HSPF)-based]
    - Wisconsin [Soil Nutrient Application Planner (SNAP-PLUS); Revised Universal Soil Loss Equation (RUSLE2)-based]

Water quality model input needs vary depending on the complexity of the model. Simpler models such as Region V or Spreadsheet Tool for Estimating Pollutant Load (STEPL) use the Universal Soil Loss Equation (USLE) as their core in which site topography, soil, precipitation, and crop cover are represented by coefficients. The USLE uses these coefficients to compute a soil loss value which may be used in additional equations dependent on the model to predict nutrient losses. More complex models such as APEX or SWAT (Soil Water Assessment Tool) rely on the same categories of information that go into the USLE. However, rather than single coefficients, these inputs include spatial and temporal variation. Topography and soil type are represented by elevation and soil maps to model variation throughout the field of interest. Precipitation variation is incorporated in model runs using monthly or daily values, including individual storm events. Crop cover varies over time as crops grow from seed and are then harvested.

While model data needs may be substantial, modeling software may include methods for automatically extracting detailed inputs from state or national soil, topography, and weather databases. Other model inputs must be entered separately, including field-specific data such as soil test phosphorus and soil organic matter, and operation details (fertilizer application types, rates, and times, tillage types and times, and planting/harvest types and times).

Water quality model outputs generally include nutrient or pollutant loads (such as phosphorus or coliforms) as well as their carriers (sediment loss and runoff volume). Simpler models may be able to provide only these as final values, while more complex models may be able to provide time series output with nutrient/pollutant concentrations and runoff flow rates.

iii. Findings for Aggregation Methods

A few protocols do utilize or allow for the use of traditional aggregators to compile multiple producers for credit generation. These include the Pennsylvania Nonpoint Source (NPS) Nutrient Trading Program, Laguna de Santa Rosa Watershed Water Quality Trading Program, and Maryland's Nutrient Trading Program. However, it is more common for the protocols assessed to assign and utilize project developers to fulfill important functions on behalf of the producers, including soil and water conservation districts, trained NRCS staff, credit exchanges, and credit brokers. Table B-1 summarizes the types of aggregators or project developers that facilitate aggregation-like functions in water quality protocols.

Table B-1. Aggregators or Project Developers Assigned by the Program Administrator to Facilitate Aggregation Functions

Protocol	Aggregator/Project Developers that Facilitate Aggregation
Ohio River Basin Trading Pilot	State Water and Soil Conservation Districts
Pennsylvania NPS Nutrient Credit Trading Program	Aggregators, Credit Brokers
Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program	Offset Broker
Wisconsin Water Quality Trading Program	Credit Brokers/Exchange
West Virginia Nutrient Credit Trading Program	None
Great Miami River Watershed Water Quality Credit Trading Program	Soil Water Conservation Districts
South Nation River Watershed Water Quality Trading Program	Farmer Program Representatives
Lake Simcoe Phosphorus Offset Program	Trade Administration (Potential Clearinghouse)
Oregon Water Quality Trading Program	None
Maryland Nutrient Trading Program	Aggregators, Credit Brokers
Iowa Nutrient Reduction Exchange	None
Field Stewards Program	Conservation Marketplace Midwest (Acting Aggregator)
Laguna de Santa Rosa Watershed Water Quality Trading Program	Aggregators
Western Lake Erie Basin Water Quality Trading Program	Aggregators, Credit Brokers

iii. Findings for Monitoring, Reporting, Verification

Monitoring

Ongoing Monitoring Requirements: In the context of water quality, monitoring requirements in protocols are typically based on verifying the maintenance of a credit generating activity/BMP as opposed to sampling for pollutant reductions. Depending on the type of BMP, these monitoring requirements usually take the form of photographs and reporting of nutrient management or other operational records. These can be achieved either in a site inspection or through self-reporting by the farm operator, project developer, third-party verifier assigned by the project developer or program administrator, or program administrator staff.

It is important to note that water quality sampling is not a monitoring requirement in any of the assessed water quality protocols. Historically, some trading programs have integrated monitoring options that could reduce discounting factors and/or establish more specific trade ratios. Monitoring for ESMC protocols will more specifically focus on soil nutrient testing and not water quality monitoring prerequisites. Identifying instream water quality benefits is an expensive and long-term proposition to detect improvements associated with mass load reductions from water quality trades. Thus, compliance trades typically focus on trading unit of mass/time versus instream benefits. On-site soil testing and other site-specific field data for improving model estimates of loading are therefore the more typical monitoring target in these programs.

Monitoring Frequency Requirements: Almost all protocols that were assessed required a minimum of annual soil monitoring. The exceptions to this include Maryland's Nutrient Trading Program (biannual monitoring) and Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange (no monitoring required from project developer or agricultural producer).

Approaches of Monitoring BMP Maintenance: Different approaches towards monitoring BMP maintenance were observed in the water quality protocols. These methods are categorized below.

- Minimal required monitoring from project developer: These protocols require minimal or no monitoring from project developers. However, these protocols still require an initial verification inspection before the sale of a credit. These utilize randomized, ongoing, on-site verification inspections from the program administrator. Programs that utilize this method include Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program and the Field Stewards Program.

- Self-monitoring and reporting: These protocols require self-monitoring in the form of annual reporting with documentation and geo-referenced and time-stamped photographs of BMP maintenance. This approach is being utilized by the Iowa Nutrient Reduction Exchange for its formally tracked pollutant reductions. The Iowa Nutrient Reduction Exchange's monitoring requirements for water quality trading credits require self-monitoring to be paired with a mandatory initial verification inspection and selective ongoing verification inspections from the program administrator (Iowa Department of Natural Resources, IDNR).

- Monitoring approach approved by program administrator: These protocols allow the project developers to submit their own approaches for approval for monitoring BMP maintenance in either a Verification Plan, Water Quality Trading Plan, or Water Quality Trading Contract. This approach represents the majority of protocols, including Pennsylvania NPS Nutrient Trading Program (verification plan), Wisconsin Water Quality Trading Program (water quality trading plan), West Virginia (verification plan), Oregon's Water Quality Trading Program (verification plan), and Maryland's Nutrient Trading Program (contract).

- Program administrator monitoring/third-party verification: These protocols utilize a traditional approach of using program administrator staff or a program administrator-approved third-party verifier to conduct all ongoing verification inspections. The only protocols utilizing this approach are the Western Lake Erie Basin Water Quality Trading Program, which utilizes third-party verifiers to conduct annual reports, and the Ohio River Basin Trading Pilot, which has tasked the Soil and Water Conservation Districts with conducting annual on-site inspections.

All these approaches provide different benefits and disadvantages. Protocols with varying monitoring requirements under a tiered crediting system that utilize the "No required monitoring from project developer" may eliminate monitoring costs for project developers but also decrease accountability due to a lack of required inspection. The "Self-monitoring and reporting" approach significantly reduces costs for project developers and program administrators but also decreases accountability. Protocols utilizing a "Monitoring approach approved by program administrator" provide flexibility in monitoring methods for project developers but shift the monitoring costs to project developers and create an administrative burden of reviewing case-by-case monitoring approaches. The "Program administrator monitoring/third-party verification" approach significantly reduces costs for project developers and provides greater accountability by shifting all costs to the program administrator.

In light of Noble's efforts to create a tiered approach to the protocol, a particularly relevant innovation with the Iowa Nutrient Reduction Exchange's use of "Self-monitoring and reporting" is its integration into Iowa's tiered approach towards formally tracked pollutant reductions and water quality trading credits. Although the use of "Self-monitoring and reporting" may have lower accountability than an approach that requires an on-site inspection, the approach is still appropriate for monitoring formally tracked pollutant reductions. For project developers seeking to generate water quality trading credits to meet compliance, the "Self-monitoring and reporting" approach is stacked with mandatory verification requirements (of both monitoring annual reports and on-site verification inspections) from the program administrator (IDNR) to increase accountability.

Reporting

With the exception of the Iowa Nutrient Reduction Exchange, reporting requirements for most of the protocols were specifically designated to non-agricultural producer project developers such as third-party verifiers or permittees (credit purchasers). The Iowa Nutrient Reduction Exchange, as described in the section *Approaches of Monitoring BMP Maintenance,* does require self-reporting on an annual basis from a project developer (although this does not have to necessarily be conducted by the agricultural producer).

Verification

Verification Process: The overall verification process for all the protocols assessed had some commonalities that were effective and can be easily incorporated into an ESMC protocol, especially the use of a project screening/certification process and the nearly ubiquitous requirement for an onsite inspection. This is further described below and illustrated in Table B-2.

1) *Project Screening/Certification*: The verification process begins with the screening and approval of projects before implementation by the program administrator or approved third-party verifier. A number of protocols refer to this process of project review and approval before the verification inspection as the "certification process" (i.e., Pennsylvania NPS Nutrient Credit Trading Program, Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program, West Virginia Nutrient Credit Trading Program, Western Lake Erie Basin Water Quality Trading Program). This process usually

involves reviewing applicant documentation and verifying the project developer's eligibility to generate credits and review and approval of the credit quantification methodology. This review is largely the responsibility of the program administrator but can be delegated to a program administrator-approved third-party verifier in some cases (Field Stewards Program).

An interesting tiered approach to the Project Screening/Certification step of verification can be observed in the Iowa Nutrient Reduction Exchange. Project screening (referred to as the "Administrative Completeness Review") is required only for projects seeking to generate water quality trading credits. Projects seeking to formally track pollutant reductions will be selectively reviewed on a periodic basis by the program administrator (IDNR). This is similar to the protocol's approach of stacking monitoring requirements for formally tracked pollutant load reductions and water quality trading credits.

The majority of protocols utilize a preapproved quantification method, with some allowing case-by-case review of other quantification approaches (Iowa Nutrient Reduction Exchange).

Note that in the case of Oregon's Water Quality Trading Program, there are suggested quantification methodologies, but no preapproved methods. An approach like Oregon's Water Quality Trading Program may provide too little guidance for project developers and increase the administrative review burden of this step.

2) *Verification Inspection*: Once the documentation has been approved or certified, all assessed protocols (with the exception of the South Nation River Watershed Water Quality Credit Trading Program) require an onsite verification inspection of BMP implementation by the program administrator or approved third-party verifier. Although a number of protocols do not specify the timing of this verification inspection, the Pennsylvania Nutrient Credit Trading Exchange, Vermont Phosphorus Protocol, and Field Stewards Program require the project developer to request a verification inspection only prior to the sale of a credit.

3) *Ongoing Verification for BMP Maintenance*: In lieu of requiring program administrator staff/third-party verifiers to perform annual verification inspections or the use of other ongoing monitoring approaches discussed in the section *Approaches of Monitoring BMP Maintenance,* some water quality protocols have opted to use either a randomized or selective approach to provide ongoing verification of BMP maintenance for a percentage of approved projects. After the initial verification inspection to confirm BMP implementation, three of the protocols require randomized audits of a minimum percentage of approved projects (Field Stewards 10% and South Nation Watershed Water Quality Trading Program 10%). Any project that is randomly selected for a verification audit and passes in the Field Stewards Program will not be eligible for a random audit for another five years. Two other protocols (Maryland's Nutrient Trading Program and the Iowa Nutrient Reduction Exchange) will selectively conduct ongoing verification inspections on 10% of all approved projects. The use of randomized or selective protocols is also summarized in Table B-3.

Table B-2. Water Quality Protocols Utilizing a Project Screening/Certification Process and Requiring an Onsite Verification Inspection

Protocol	Utilization of Project Screening/Certification Process	Required Onsite Verification Inspection
Ohio River Basin Trading Pilot	Project Screening	Yes
Pennsylvania NPS Nutrient Credit Trading Program	Certification Process	Yes
Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program	Certification Process	Yes
Wisconsin Water Quality Trading Program	No	Yes
West Virginia Nutrient Credit Trading Program	Certification Process	Yes
Great Miami River Watershed Water Quality Credit Trading Program	Project Screening	Yes
South Nation River Watershed Water Quality Trading Program	No	No
Lake Simcoe Phosphorus Offset Program	Project Screening	Yes
Oregon Water Quality Trading Program	No	Yes
Maryland Nutrient Trading Program	Not Specified	Yes
Iowa Nutrient Reduction Exchange	Certification Process	Yes
Field Stewards Program	Certification Process	Yes
Laguna de Santa Rosa Watershed Water Quality Trading Program	Not Specified	Yes
Western Lake Erie Basin Water Quality Trading	Certification Process	Yes

Table B-3. Water Quality Protocols Utilizing a Stratified/randomized Verification Approach for Verifying Project Implementation

Protocol	Stratified/Randomized Verification	Percentage of Projects Verified Annually
Ohio River Basin Trading Pilot	No	--
Pennsylvania NPS Nutrient Credit Trading Program	Not Specified	--
Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program	Not Specified	--
Wisconsin Water Quality Trading Program	Not Specified	--
West Virginia Nutrient Credit Trading Program	Not Specified	--
Great Miami River Watershed Water Quality Credit Trading Program	Not Specified	--
South Nation River Watershed Water Quality Trading Program	Yes, Program Representatives randomly inspect 10% of projects	10%
Lake Simcoe Phosphorus Offset Program	Not Specified	--
Oregon Water Quality Trading Program	Not Specified	--

Maryland Nutrient Trading Program	Yes, Randomized audits	10%
Iowa Nutrient Reduction Exchange	Yes, a percentage of projects will be verified. Protocol specifies this to be done selectively.	Unspecified
Field Stewards Program	Yes, Randomized audits	10%
Laguna de Santa Rosa Watershed Water Quality Trading Program	Based on credit life	--
Western Lake Erie Basin Water Quality Trading	Not Specified	--

iv. Findings for Registration for Sale

In the water quality trading context, credits are typically transacted through market structures such as clearinghouses, exchanges, or individual transactions (bilateral trades). Market structures can be combined, and all three market structures may work with registries for tracking credits. However, protocols that only utilize individual transactions/bilateral trades typically may have a registry for credit sale or purchase. The majority of protocols that included a credit registry were used to facilitate and track individual transactions/bilateral trades. Only Pennsylvania's PennVest registry and the Great Miami River Watershed Water Quality Trading Program's registry were used to facilitate auctions and reverse auctions (respectively).

Registering Credits: Those responsible for registering a credit once it has been processed through the appropriate verification process are generally project developers such as aggregators and credit brokers, or the program administrators. Several approaches to registration of a credit for sale were observed in this assessment:

- *Registration as part of Verification Process*: In the Iowa Nutrient Reduction Exchange, projects seeking to generate water quality trading credits are submitted on the registry itself where the project awaits a project completeness review by Iowa DNR and routine onsite verification inspection by the developer before it can be sold. Note that this is possible in this instance because the program administrator has full access to the registry.

- *Registration as a Separate Process from Verification*: Several existing protocols utilize a registry for selling registered credits after the verification process (and sometimes also after a certification process) is completed. This can be handled in different ways, including registering credits directly to the registry by the program administrator (Ohio River Basin Trading Pilot), registering credits by the program administrator after a request from the project developer (Pennsylvania NPS Nutrient Credit Trading Program), or registration directly by the project developer without the program administrator (Oregon Water Quality Trading Program) where there has been third party verification.

3) Summary of Findings for Priority Elements

i. Scalability

Every water quality protocol assessed can quantify a suite of agricultural practices. It is standard for these protocols to place a strong emphasis on field nutrient management, but most are able to quantify water quality credits from grazing and ranching practices, manure management, and livestock exclusions. As most of the protocols generate water quality trading credits, they tend to be developed to address water quality issues regulated at the watershed to state level. Although this means that most protocols are intrastate in scope, the Western Lake Erie Basin Water Quality Trading Program and Ohio River Basin Trading Pilot represent an interstate level. To date, none of the water quality trading protocols assessed cover use in Oklahoma or Texas.

ii. Scientifically Rigorous

The levels of scientific rigor demonstrated in the assessed protocols varied by the type of fungible water quality assets being produced (i.e., formally tracked pollutant reductions, certified credits for corporate sustainability, water quality trading credits). In cases where varying levels of scientific rigor were deliberately structured in a protocol to generate different water quality assets, protocols were more likely to make changes in the monitoring, reporting, and verification (MRV) processes than the selection of quantification method and data needs for the quantification method.

This is most clearly depicted in a protocol like the Iowa Nutrient Reduction Exchange where two different environmental assets are being produced within the same protocol. Within Iowa's Nutrient Reduction Exchange, formally tracked pollutant reductions and other ecosystem services can be generated without attaining the stricter local, state, and federal water quality standards and regulations for nutrient compliance credits generated and utilized to achieve compliance with a National Pollutant Discharge Elimination System (NPDES) might otherwise require. This has led to the beneficial outcome of a process of generating several assets that are subject to the same monitoring, reporting, and verification requirements (including mandatory verification of documentation and onsite inspections) using the same quantification tool (STEPL) and tool data requirements.

A protocol with stratified tiers of scientific rigor could be advantageous in significantly reducing costs and increasing participation in generating different environmental assets. This review of existing protocols suggests that there may be limited advantages to establishing tiers based on different levels of complexity in quantification methods. This may be due to the fact that the cost savings associated with meeting data collection requirements for model inputs and the level of technical assistance required typically vary little from model to model. For example, data collection requires little to no sampling and agricultural producers will require technical assistance in most protocols. All the while, outputs are of sufficient scientific rigor in most water quality trading programs. However, using varying MRV processes to create stratified degrees of validation associated with the use of acceptable quantification methods could be more advantageous. In short, trade-offs in MRV processes may produce much larger benefits (cost-effectiveness, required level of technical assistance) than the apparent minimal variation in benefit associated with using different models. This finding may be helpful as ESMC considers how to develop different tiers of protocols with different degrees of scientific rigor.

iii. Transparency

Transparency with multiple stakeholders and the public is important in providing public accountability and creating trust in the outcomes of a protocol. Different forms of transparency and accountability are observed across water quality protocols. Although there are no discernable trends in forms of transparency utilized by water quality protocols, some common themes and best practices for providing transparency are detailed as follows.

Transparency during Protocol Development

Providing transparency during the development of the protocol should lead to a greater understanding of the protocol by multiple stakeholders and can allow for stakeholder concerns to be addressed early. Protocols like the Ohio River Basin Trading Pilot and the Lake Simcoe Phosphorus Offset Program used a participatory approach during protocol development. This involved including stakeholders such as NPDES permittees, environmental groups, planners and policy makers, and members of the community in the design and delivery of the protocol. Note that this process may generate stakeholder support but will likely equate to a lengthier protocol development process.

Transparency of Protocol Process

All the protocols provided the public with a clear definition of the protocol process and components. This form of transparency is important as it provides project developers and members of the public an understanding of how they can participate in the protocol and eventually the process (where desired or appropriate). Many, including the Ohio River Basin, Lake Simcoe Phosphorus Offset Program, and Great Miami River Watershed Water Quality Credit Trading Program provided literature about their processes that were tailored for the general public.

Additionally, protocols can provide public accountability during protocol components such as the verification process. The South Nation River Watershed Water Quality Trading Program uses a Clean Water Committee consisting of technical stakeholders (academics, regulators, environmental groups) to review applications for credit quantification.

Transparency of Data

Some protocols provide public access to information such as credit trading and project reports. Although many protocols use a registry to internally track credits, the Pennsylvania NPS Nutrient Credit Trading Program's PennVest Registry provides information to the public on credit auctions and some project reports (Pennsylvania Department of Environmental Protection 2018). Any information related to agricultural producers that could be made publicly available should be treated as sensitive information by the program administrators. Information that is publicly available, such as project reports, should redact sensitive information such as names and locations. Guidelines should be in place to ensure agricultural producers that their data will be confidential and to make explicit which information will be made available to the public.

iv. Standards-Based (Regulatory and CSR) & Commensurability with Financial Returns

Most of the protocols examined herein were developed to generate water quality trading credits to meet local, state, and federal water quality standards and regulations. Although water quality trading credits generated in these programs could be sold to meet Corporate Social Responsibility (CSR) standards, the higher additional cost to ensure scientific integrity for water quality trading per credit could present a potentially serious barrier to corporate demand. Currently, none of the assessed protocols use American National Standards Institute (ANSI) or International Organization for Standardization (ISO) verified bodies, including the Field Stewards Program which is the only protocol assessed that produces CSR credits.

v. Farmer-Facing

The level of technical assistance required for the protocols was generally similar as the data collection requirements were focused on farm operation data, nutrient management by field, and BMP information. Protocols that required a soil phosphorus test, including the Pennsylvania NPS Nutrient Credit Trading Program, Wisconsin Water Quality Trading Program, and Lake Simcoe Phosphorus Offset Program, were considered more technical. The protocol considered to require the most technical assistance was the Wisconsin Water Quality Trading Program. The

Wisconsin program was considered high due to the level of technical expertise required to operate the Wisconsin-specific SNAP-PLUS model. Table B-4 below illustrates the levels of technical assistance required for the water quality protocols' data collection and quantification, monitoring, and reporting requirements and the overall technical assistance.

Table B-4. Technical Assistance Required for Agricultural Producer across Water Quality Protocols

Protocol	Technical Assistance Required			
	Data Collection & Quantification	Monitoring	Reporting	Overall for Farmer
Ohio River Basin Trading Pilot	Low - Moderate	Moderate - High	None	Low - High
Pennsylvania NPS Nutrient Credit Trading Program	Moderate	Low	None- Moderate (depending on use of aggregator)	Low - Moderate
Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program	Low	Moderate - High	Low	Low - High
Wisconsin Water Quality Trading Program	High	Moderate	None for farm operator	Moderate - High
West Virginia Nutrient Credit Trading Program	TBD	TBD	None for farm operator	TBD
Great Miami River Watershed Water Quality Credit Trading Program	Low	Low	None for farm operator	Low
South Nation River Watershed Water Quality Trading Program	Low	Low	None for farm operator	Low
Lake Simcoe Phosphorus Offset Program	Moderate	Low - High	None for farm operator	Low – High
Oregon Water Quality Trading Program	TBD	Low	None for farm operator	Dependent on Quantification Method Selected
Maryland Nutrient Trading Program	TBD	Low - Moderate	None for farm operator	TBD
Iowa Nutrient Reduction Exchange	Low	Moderate	Low	Low - Moderate
Field Stewards Program	Moderate	Moderate	Low	Low - Moderate
Laguna de Santa Rosa Watershed Water Quality Trading Program	Dependent on Quantification Method	Moderate - High	Low	Dependent on Quantification Method Selected
Western Lake Erie Basin Water Quality Trading	Moderate	Moderate	None for farm operator	Moderate

vi. Legal Considerations

Water quality trading programs that focus on compliance use a variety of mechanisms to ensure trades meet program standards for landowner performance and credit delivery. As permitted compliance buyers cannot be absolved of their permit liability under the Clean Water Act, water quality trading programs incorporate provisions for certification, verification, and tracking of farmer-related voluntary actions undertaken to generate compliance grade credits. These responsibilities may fall to the buyer when trades are conducted within permits versus by promulgated rules (where permits simply reference these rules that will otherwise specify who is responsible for these). Only civil contract obligations are typically placed on the seller of credits. Other trading programs have typically evolved to use third parties and/or regulatory agencies to ensure land-based practices are being implemented as contracted with the landowner. Thus, farmer liability in these cases is most often simply performance-based as specified in bilateral contracts.

Early compliance trading programs included penalties on farmers to discourage non-performance or gaming the market. Most programs now manage this buyer liability for non-performance by sellers with credit purchases in an expanded portfolio as a means of self-insurance for credit shortfalls. Farmers are often more willing to contract for performance or outcome-based projects with simplified contracts. Where such contracts originate with aggregators or other third parties, there is less reluctance compared to contracts directly with buyers. In a growing number of settings, use of a credit clearinghouse is being contemplated as a means of assigning credit liability (verification, certification, accounting) to one entity. Sales and purchase contracts are administered by the clearinghouse minimizing transaction steps and associated costs.

Contractually, acts of God and related project failures are typically covered by programmatic features that allow for a true-up period. This period provides the opportunity for the credit seller to correct such failures without penalties. Distributed contractual payments for credits are also used to minimize performance shortcomings, whereas an upfront, one-time payment for a multiple year practice might otherwise encourage a credit generator to end a practice early if there were limited returns on investment through yield or production increases (e.g., buffer strips).

In general, trading programs have developed sufficient rigor to address most legal requirements and risks associated with compliance trades. Such program elements are now also typically being incorporated in voluntary payment programs to landowners to better ensure investor returns. Contracts with landowners in these cases do not vary substantially from performance contracts under compliance trading.

4) Research Needs and Data Gaps Relevant for Protocol Development

The following research needs and data gaps have been identified for protocol development.

- **Applying Computational Tools Used to Relate Conservation Practices and Water Quality Benefits to Soil Health/Water Quality Markets**: Although specific tools for soil health and water quality do not yet exist, they do exist for computing water quality benefits from conservation practices in water quality trading markets. The more sophisticated tools such as NTT/APEX (recommended for use in the ESMC program) can be used to model the water quality benefits of both conservation practices and practices that improve soil health. Knowledge gaps regarding the latter exist but should be reduced as more case examples are generated.
- **Addressing Weaknesses in the Science Relating Conservation Practices for Soil Health and Water Quality**: A current research need that is applicable to both includes quantifying how water quality benefits vary geographically with soil health practice

implementation in different agricultural production regions. A specific example involves developing a better understanding of the role of macropores in reduced tillage fields with tile drains in the increased loss of dissolved reactive phosphorus in the Midwest. Additionally, Sharpley (2015) notes that a traditional view of the benefits of conservation practices to water quality through erosional loss of phosphorus needs to be revisited. This is due to research showing unintended consequences of conservation practices in which particulate phosphorus loss may be reduced but dissolved phosphorus losses increase. Accurately estimating the relative impact of these processes on phosphorus losses to surface waters is likely to be important to properly characterizing the relationship between soil health and water quality. This capability will be important in future research since the link between soil health and water quality is likely to be complex and influenced by many factors (Smith 2015).

- **Cost of Meeting Water Quality CSR Standards**: It is important to note that the majority of protocols reviewed were developed to meet compliance with local, state, and federal water standards and regulations. The Field Stewards protocol focused on options for meeting CSR standards. More clearly understanding CSR details and expectations around water quality will help translation of compliance credit expectations and costs with CSR alignment. Comparing this kind of information with the cost of a water quality trading credit would help inform the conversation around how to structure a tiered protocol approach.
- **Buyer Interest in Water Quality CSR Credit**: Only one of the reviewed protocols generated a certified credit for a corporate social responsibility purchaser (Field Stewards Program). However, even this program is new, and no results can be currently referenced. It may be the case that the corporate purchasers are not interested in purchasing offsets and instead are interested in using the protocol to help reduce the impacts of their own supply chains. These are important questions and conversations for the ESMC.

References for Assessment of Existing Water Quality Protocols

Blanco-Canqui, H., T.M. Shaver, J.L. Lindquist, C.A. Shapiro, R.W. Elmore, C.A. Francis, and G.W. Hergert. 2015. Cover crops and ecosystem services: Insights from studies in temperate soils. *Agronomy Journal* 107(6), 2449-2474.

Derner, J.D., C. Stanley, and C. Ellis. 2016. Usable science: Soil health. *Rangelands* 38(2): 64-67. https://doi.org/10.1016/j.rala.2015.10.010

Field Stewards. 2018. Field Stewards: An Environmental Initiative Program. Available online at: http://www.fieldstewards.org/.

Gassman, P.W., J.R. Williams, X. Wang, A. Saleh, E. Osei, L.M. Hauck, R.C. Izaurralde, et al. 2010. The Agricultural Policy/Environmental Extender (APEX) model: an emerging tool for landscape and watershed environmental analysis. *Transactions of the American Society of Agricultural and Biological Engineers* 53(3): 711-740. https://doi.org/10.13031/2013.30078

Goehring, L.D., O.V. McHugh, M.T. Walter, T.S. Steenhuis, M.S. Akhtar, and M.F. Walter 2001. Phosphorus transport into subsurface drains by macropores after manure applications: Implications for Best Manure Management Practices. *Soil Science* 166(12): 896-909. https://doi.org/10.1097/00010694-200112000-00004

Manale, A., A. Sharpley, C. DeLong, D. Speidel, C. Gantzer, J. Peterson, R. Martin, C. Lindahl, and N. Adusumilli. 2018. Principles and policies for soil and water conservation. *Journal of Soil and Water Conservation* 73(4): 96A-99A. https://doi.org/10.2489/jswc.73.4.96A

Miller W.W., H.M. Joung, C.N. Mahannah, and J.R. Garrett. 1986. Identification of water quality differences in Nevada through index application. *Journal of Environmental Quality* 15:265-272. https://doi.org/10.2134/jeq1986.00472425001500030012x

Minnesota Department of Agriculture. 2018. Minnesota Agricultural Water Quality Certification Program. Available online at: https://www.mda.state.mn.us/environment-sustainability/minnesota-agricultural-water-quality-certification-program.

Pennsylvania Department of Environmental Protection. 2018. Trading Resources – Other Resources. Available online at: https://www.dep.pa.gov/Business/Water/CleanWater/NutrientTrading/Pages/TradingResources.aspx#Resources.

Reicosky, D.C. 2015. Conservation tillage is not conservation agriculture. *Journal of Soil and Water Conservation* 70(5): 103A-108A. https://doi.org/10.2489/jswc.70.5.103A

Riddle, M.U., and L. Bergstrőm. 2013. Phosphorus leaching from two soils with catch crops exposed to freeze–thaw cycles. *Agronomy Journal* 105: 803–811. https://doi.org/10.2134/agronj2012.0052

Saleh, A., O. Gallego, and E Osei. 2015. Evaluating Nutrient Tracking Tool and simulated conservation practices. *Journal of Soil and Water Conservation* 70(5): 115A-120A. https://doi.org/10.2489/jswc.70.5.115A

Sharpley, A.N. 2015. The Phosphorus paradox: Productive agricultural and water quality. *Journal of Environmental Indicators* 9:3-4.

Smith, K.R. 2015. Assessing the relationship between soil health and water quality in the St. Joseph River Watershed. Master's thesis. Purdue University.

Unger, P.W., A.N. Sharpley, J.L. Steiner, R.I. Papendick, and W.M. Edwards. 1998. Soil management research for water conservation and quality. In *Advances in Soil and Water Conservation*, ed. F.J. Pierce and W.W. Frye. Chelsea, MI: Ann Arbor Press.

United States Department of Agriculture. 2018. *Fact sheet: Unlock the secrets in the soil - Principles of high functioning soils*. February. USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=stelprdb1049236

Virginia Department of Environmental Quality. 2008. *Trading nutrient reductions from nonpoint source best management practices in the Chesapeake Bay Watershed: Guidance for agricultural landowners and your potential trading partners*. Available online at: https://www.deq.virginia.gov/Portals/0/DEQ/Water/PollutionDischargeElimination/VANPSTradingManual_2-5-08.pdf.

Williams, M.R., K.W. King, W. Ford, A.R. Buda, and C.D. Kennedy 2016. Effect of tillage on macropore flow and phosphorus transport to tile drains. *Water Resources Research* 52(4): 2868–2882. https://doi.org/10.1002/2015WR017650

Section C. Assessment of Existing Water Quantity Protocols

1) Summary of the Relationship Between Water Quantity, Soil Health, and Ecosystem Service Markets

Understanding the effects of soil health improvements on water quantity starts with understanding a simple water balance of the soil profile. Figure C-1 illustrates this water balance for rainfall and irrigation conditions. The pore space in the soil profile represents temporary water storage, often thought of as a sponge. Water held in the soil profile is taken up by the roots of crops and native vegetation, or it drains to groundwater and nearby surface water channels.

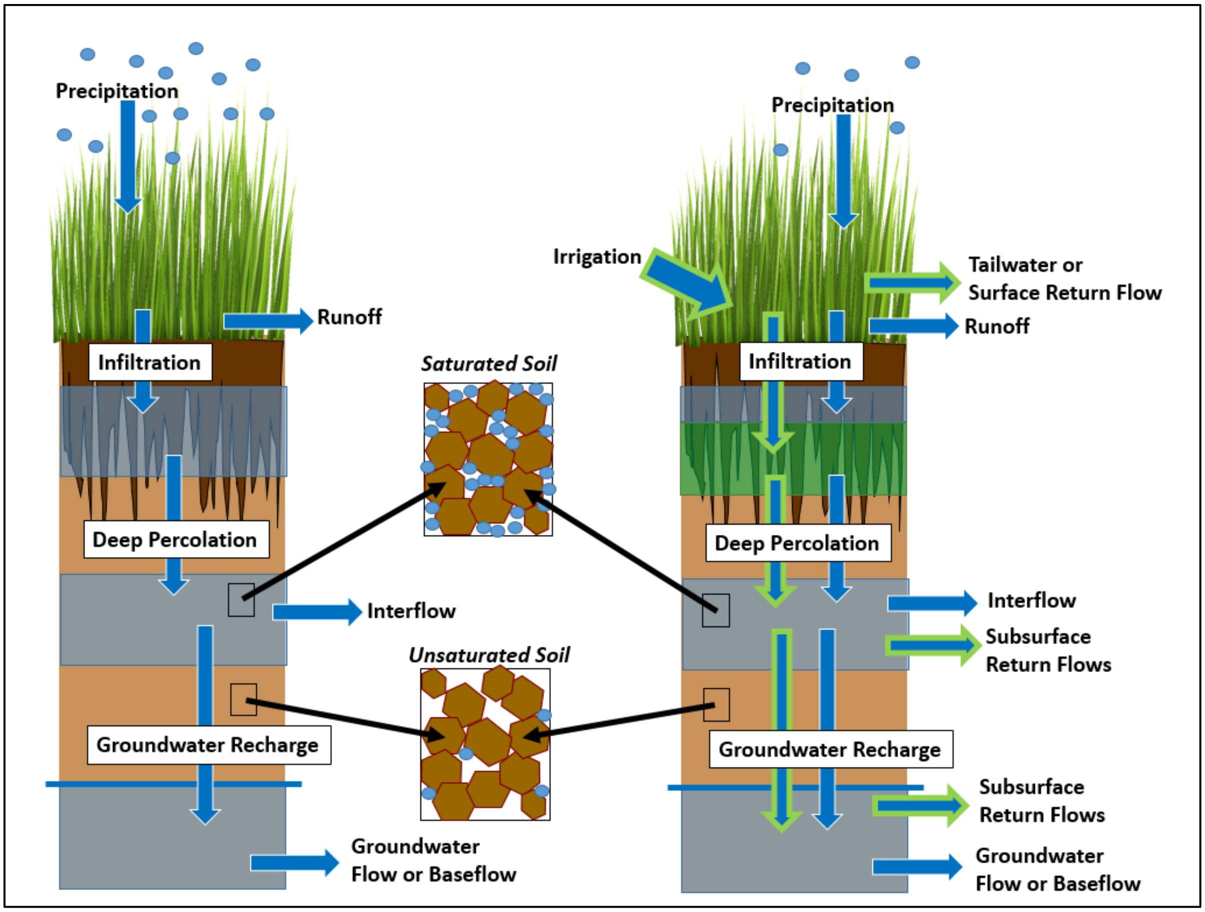

Figure C-1. Illustration of the Water Balance for a Soil Profile

Notes:

(1) Runoff is generated by infiltration excess if the precipitation rate is greater than the infiltration rate of the soil and/or by saturation excess if the soil pore space is completely saturated with continued precipitation.

(2) Infiltration rates are determined primarily by soil properties and land use/land cover conditions. Clay soils have a smaller pore size and cannot convey water as quickly as sandy soils. Bare soils typically have lower infiltration rates compared with vegetated soils, and tilled soils have a lower infiltration rate compared with no till conditions.

(3) Available water holding capacity of the soil represents the pore space between soil particles available for holding water, defined between a relatively dry (unsaturated) soil condition and a wet (saturated) condition

(4) Interflow represents subsurface water flows that contribute to channel flow in a time lagged fashion compared with surface runoff. Groundwater flow provides baseflows in river channels outside of storm events.

(5) Irrigation water applications mimic natural rainfall processes and supplement the water available to the crop root zone. The flow paths resulting from irrigation have slightly different terminology.

Changes in soil health result in changes to the water receiving and retention properties of the soil (NRCS 2016, 2018). In other words, changes in soil health change the character of the sponge. In healthy soils, the soil profile is relatively water absorbent, having a higher infiltration rate and higher porosity and available water holding capacity. A degraded soil has the opposite properties, with reduced infiltration capacity and water holding capacity. Table C-1 presents a summary of research studies supporting these concepts.

Table C-1: Literature Review of Improved Water Properties based on Soil Health Practices

Soil Practice	Water Benefit	Reference/Report Title
Cover crop or other soil cover	Increased infiltration	Maidment. 1993. *Handbook of Hydrology*
		UCS. 2017. *Turning Soils into Sponges*.
		White, NWF. 2015. *Can Soil Save Us?*
	Increased water holding capacity	UCS. 2017. *Turning Soils into Sponges*.
		Stewart and Peterson. 2015. *Managing Green Water in Dryland Agriculture*
		NRCS. Soil Quality Indicators.
		NRCS. 2018. *Effects on Soil Water Holding Capacity and Soil Water Retention Resulting from Soil Health Management Practices*
		White, NWF. 2015. *Can Soil Save Us?*
	Reduced runoff	Schwab et al. 1993. *Soil and Water Conservation Engineering*
		O'Connell et al. 2007. *Is there a link between agricultural land-use management and flooding?*
No tillage	Increased infiltration	UCS. 2017. *Turning Soils into Sponges*.
		Fischer, NRCS. *Water Movement on the Landscape*.
	Increased water holding capacity	UCS. 2017. *Turning Soils into Sponges*.
		NRCS. Soil Quality Indicators
		NRCS. 2018. *Effects on Soil Water Holding Capacity and Soil Water Retention Resulting from Soil Health Management Practices*
Increase organic matter	Increased infiltration	Maidment. 1993. *Handbook of Hydrology*
		Fischer, NRCS. *Water Movement on the Landscape*.
	Increased water holding capacity	NRCS. Soil Quality Indicators
		NRCS. 2018. *Effects on Soil Water Holding Capacity and Soil Water Retention Resulting from Soil Health Management Practices*
Rotational or managed grazing	Increased infiltration	Maidment. 1993. *Handbook of Hydrology*
		UCS. 2017. *Turning Soils into Sponges*.
		NRCS. Soil Quality Indicators
Contouring/ Terracing	Reduced runoff	Schwab et al. 1993. *Soil and Water Conservation Engineering*
Vegetation buffers	Reduced runoff	O'Connell et al. 2007. *Is there a link between agricultural land-use management and flooding?*
Diversify crop rotation	Increased water retention	UCS. 2017. *Rotating Crops, Turning Profits*
		NRCS. Soil Quality Indicators
		NRCS. 2018. *Effects on Soil Water Holding Capacity and Soil Water Retention Resulting from Soil Health Management Practices*

The ability of a healthy soil to receive and hold water can have varied benefits and beneficiaries. In the agricultural sector, crop and forage production is dependent upon water available in the root zone. Crop yield is a function of crop evapotranspiration (ET), which in turn is a function of available water supply if climate conditions are held constant (FAO 2012). Therefore, increased water retention in the soil can increase yields on cropland and rangeland. This benefit is particularly pronounced during drought periods and months with limited water supply to the root zone (FAO 2003).

For rainfed agriculture, soil health provides better retention of available rainfall in the root zone. For irrigated agriculture, soil health can decrease the need for supplemental irrigation water applications and/or increase the efficiency of irrigation applications, which reduces irrigation costs and/or increases yields (CAWSI undated). These agricultural (on-farm) benefits of soil health can also translate to downstream/regional benefits. In the case of rainfed cropland and rangeland, improved soil health can result in greater rainfall retention during storm events, resulting in a reduction in downstream flooding (UCS 2017b). For irrigated agriculture, the potential for soil health improvements to reduce irrigation diversions can benefit natural water sources by increasing streamflow and/or groundwater aquifer levels.

The distinction between on-farm and off-farm beneficiaries is important to consider as the ESMC protocol is being developed. Soil health has significant water quantity benefits on the farm and for the agricultural producer. These on-farm benefits are not considered transferrable to an outside party, in the form of a credit, and are not considered to be a part of the ESMC protocol. The off-farm benefits of soil health are the focus of the ESMC protocol for water quantity and are considered to produce marketable credits under the ESMC program. The off-farm benefits and associated credits are organized as follows:

- **Flood Reduction Credit**: Soil health practices can increase stormwater retention in the soil profile, with the soil acting as a flood retention reservoir. Downstream entities impacted by flooding can benefit from this increased retention. A Flood Reduction Credit would be generated by quantifying the benefits in the form of reduced flood peaks and elevations and would be marketed to downstream beneficiaries.
- **Water Conservation Credit**: Soil health practices can include reduced irrigation deliveries, rotational cover cropping, and other practices which reduce the crop consumptive use relative to a historical baseline. A reduction in consumptive use associated with an irrigation water right forms the basis for a Water Conservation Credit and can increase water supplies available instream or to a downstream beneficiary. In order to realize these benefits, the reduced consumptive use is protected through a formal water right transfer process under state laws and policies, and therefore a Water Conservation Credit is considered to operate in a transfer market.
- **Water Efficiency Credit**: Soil health practices can include various practices which improve irrigation efficiency and reduce irrigation diversions. A Water Efficiency Credit is simply quantified as a reduction in withdrawals from a water source relative to a historical baseline condition. This type of credit would operate in an offset market and be marketed to entities looking to offset their water diversions and use for public relations reasons but outside any regulatory requirement.

For water quantity, it is proposed that the ESM protocol be divided into these three categories, as each category has a distinct beneficiary, regulatory requirement, marketing potential, and precedent. The following sections expand upon each category in more detail.

2) Summary of Findings for Protocol Components

This section summarizes the general findings from existing water quantity protocols and expands upon ideas for establishing the ESM protocol. The three water quantity categories have varying degrees of precedence and existing protocol, summarized as follows:

- **Flood Reduction Credit**: There is no known precedent or existing protocol for quantifying a flood reduction benefit from improved farmland and rangeland practices. The concept has been the subject of research, but a protocol would need to be developed from scratch for the ESMC program.
- **Water Conservation Credit**: There is substantial precedence and formal (legal) protocols for quantifying and protecting conserved water through a water transfer process. The protocol must follow laws and policies which are unique to each state but have common themes.
- **Water Efficiency Credit**: There is one known existing protocol for quantifying water quantity benefits of improved irrigation efficiency. It is likely that an ESMC protocol for this category would adopt many of the same concepts but may be tailored to meet different objectives and market participants.

The following sub-sections expand upon this summary for each of the three categories.

Flood Reduction Credit

iii. Findings for Data Collection & Management

Based on available research, a protocol for quantifying flood reduction benefits starts with estimating the effect of conservation practices on the soil-water properties and the water balance of the soil profile (COE 2013). These effects can be measured using on-site tests or estimated based on available soils data and existing research on conservation practices. The two data collection options are described below:

- **Site Data Collection**: There are two important soil properties to measure at the project or practice site: 1) infiltration rate and 2) available water holding capacity. These two properties correspond to the two types of rainfall-runoff processes (infiltration excess and saturation excess, respectively). Ideally, these tests would be performed before the practice to establish a baseline and after a practice to understand the degree of change. Infiltration rate is typically measured using a double-ring infiltrometer under American Society for Testing and Materials (ASTM) standards. Available water holding capacity is typically measured in a laboratory setting using a soil sample taken in the field and applying NRCS standard soil survey methods. For both soil properties, it is important to perform the sampling/tests at various locations across the farm field or rangeland, with an emphasis on capturing multiple tests for each mapped soil type (from NRCS soil survey data).

- **Desktop Analysis**: A less accurate method of data collection is to utilize existing information and research on conservation practices to estimate the before and after effects on infiltration rate and available water holding capacity. This method would first collect NRCS soil survey data to delineate the soil types and properties on the project or practice site. The NRCS soil survey data would form the baseline condition. Effects of any conservation practice on the soil properties would be estimated from available research findings. A literature review to help guide such estimates is provided in Table C-1 and in the references.

iv. *Findings for Quantification Methods*

A range of quantification methods are possible, but all have uncertainty. Extensive modeling could be completed to attempt to reduce the level of uncertainty, but the costs would likely be prohibitively expensive (FEMA 2017). Simple analytical estimates could be made based on the data collection described above but these would carry significant uncertainty and may not be well-received by ESMC partners. Table C-2 presents some model options for quantification methods for a flood reduction credit. The objective of these model methods is a quantification estimate of the reduction in peak flood streamflow. Various alternative approaches could be considered as less sophisticated desktop analyses based on engineering judgment or simple soil water balances. In addition to the listed hydrology models or desktop analyses, a quantification of the reduction in peak flood stage (height) would require a hydraulic model such as HEC-RAS (Hydrologic Engineering Center's River Analysis System) or some other means of estimating the relationship between streamflow and river stage. Due to the infrequent and complex nature of flood events, the flood reduction benefits of soil health practices cannot be measured very accurately, and therefore any credit quantification will need to be based on estimates. Also, the best quantification method may depend upon the scale of implementation within a watershed. For example, a basin-wide hydrologic model may represent too much effort if a single set of farms (representing a small portion of the watershed) are ESMC participants.

Table C-2: Model Options for Quantifying Flood Reduction Benefits

Model	Developer	Example Uses	Notes
Basin Characterization Model (BCM)	USGS	UCS. 2017. *Turning Soils into Sponges*	Monthly time-step not suitable for flood modeling
Gridded Surface Subsurface Hydrologic Analysis (GSSHA)	COE	COE. 2015. *CRP Flood Damage Reduction Benefits to Downstream Urban Areas*	Effective at modeling flood runoff. Must be paired with HEC-RAS to model flood elevations
Soil Water Assessment Tool (SWAT)	USDA, Texas A&M	COE. 2015. *CRP Flood Damage Reduction Benefits to Downstream Urban Areas*	Poor results for modeling daily extreme flow events
Hydrologic Simulation Program - Fortran (HSPF)	EPA	Borah and Bera. 2004. *Watershed-Scale Hydrologic and Nonpoint Source Pollution Models: Review of Applications*	
Precipitation Runoff Modeling System (PRMS)	USGS	USGS. 2016. *PRMS for Kings River Basin, CA with application for flood forecasting*	Not widely used for flood hydrology but well suited for changing land/soil conditions
Variable Infiltration Capacity (VIC)	Univ. of Washington	Park. 2014. *Analysis of a changing hydrologic flood regime using the Variable Infiltration Capacity model*	
HEC-HMS	COE	Several international studies	Simple modeling of soil water balance

v. *Findings for Aggregation Methods*

The basic premise of a flood reduction credit is that soil health practices increase the retention capacity of the soil, such that the soil acts as a spatially distributed flood retention reservoir. Based on this premise, it is important to aggregate soil health practices on a significant portion of the watershed in order to have any significant impact on downstream flooding. In addition, not all acres in a watershed are equal in terms of their contributions to streamflow and flooding (COE 2015). Conservation practices targeted on wetlands and buffer strips along drainage channels and riparian areas have a higher degree of influence. Existing brokers and facilitators of conservation practices include NRCS extension agents, but flood reduction benefits have not historically been the focus of their efforts. A new aggregation process will likely need to be developed for the ESMC protocol, likely in collaboration with county and/or federal extension agents.

vi. Findings for Monitoring, Reporting, Verification

One of the most difficult aspects of a Flood Reduction Credit is that it is nearly impossible to monitor, report, and verify the actual flood reduction benefits from soil health practices. As stated above, the infrequent, spatially distributed, and hydrologically complex nature of floods makes it difficult to quantify the flood reduction benefits beyond modeling and analytical estimates. It is possible to estimate the additional flood impact after a storm event, if soil health practices were not in place, but such methods would parallel those of estimating the benefits and be based more on model estimates than verifiable measurements on flood reduction.

vii. Findings for Registration for Sale

There is no existing platform for registering or certifying a Flood Reduction Credit. The concept of flood reduction from upstream soil management practices is in a state of research and not organized implementation. The current regulatory landscape for flood damage and flood insurance is managed by the Federal Emergency Management Agency (FEMA) through the National Flood Insurance Program (NFIP). The NFIP produces a Flood Insurance Rate Map (FIRM) which delineates the extent of the 100-year floodplain based on modeling. Any structures and property located within the floodplain on the FIRMs are required to carry flood insurance, for communities enrolled in the NFIP and for any federal loan.

The 100-year floodplain can be modified through an approved Letter of Map Revision (LOMR) based on new modeling of changes in watershed hydrology and/or channel hydraulics. Through this regulatory process, it is conceptually possible to implement soil health practices sufficient enough to change the model inputs such that a LOMR would decrease downstream flooding and the lateral extent of the 100-year floodplain on the FIRM, resulting in decreased need for federal flood insurance for some structures and a monetary benefit to the downstream community.

In practice, this series of actions would be challenging and costly to undertake, and there is uncertainty that soil health practices would have any significant effect on 100-year flood condition. Our literature review indicates that soil health practices have been found to have a greater effect (benefit) on more frequent/less severe flood events with a return interval of about 25 years and may have minimal effect on an infrequent/severe flood event (COE 2015). For the flood reduction benefits likely to be realized from soil health practices, a new registration process will need to be established.

Water Conservation Credit

i. Findings for Data Collection & Management

The required data for generating a Water Conservation Credit are dependent upon state laws, regulations, and practices for formal water transfers. Typically, in most states, the critical data element is historic consumptive use of the crop or forage under irrigation. More broadly, most transfer applications require the construction of a farm-level irrigation water budget for the historical period. The protocol for a Water Conservation Credit will have a similar need. A basic water balance for irrigated agriculture is shown in Figure C-2. Not all of the water flows need to be individually tracked and accounted for, but most water right transfers focus on the following elements:

- **Canal Diversions or Groundwater Withdrawals (Pumping)**: These are usually measured on a continuous basis with a datalogger. Most state water agencies require some form of measurement device on all structures diverting from natural water sources. Therefore, it is likely that measurement capabilities are already in place. For surface water diversions, flow measurements are typically made by a depth sensor tied to a weir or flume in the canal. For groundwater diversions, a flow meter is usually installed at the well pump-head. In some cases, a Power Conversion Coefficient (PCC) can be used along with electricity records for the pump.
- **Conveyance Losses**: In most cases, conveyance losses in a canal system are estimated based on historical measurements, canal bed material, and length of canal. In some cases, flow monitoring is done to measure conveyance losses in relatively long or highly porous sections of canal. If farm headgate deliveries are measured, it is less important to accurately estimate conveyance losses in the canal system.
- **Farm Headgate Deliveries**: In many older irrigation ditch systems, records are not kept on when certain water users were provided deliveries from the canal. In more modern systems, the farm deliveries are tracked on a daily or continuous basis. Depending on the hydraulic setup of the farm delivery, a measurement device can be installed to monitor farm deliveries. For groundwater wells located on the farm field, the farm delivery is equal to the well pumping.
- **Irrigation Practices**: Typical irrigation practices include wild flooding, border flooding, furrow, hand-line sprinklers, wheel-line sprinklers, center pivot sprinklers, and drip (among others). Each practice has a typical efficiency associated with it, with efficiency representing how much of the water delivered at the farm headgate actually makes it to the crop root zone and contributes to crop ET. Reference standards are often applied to estimate on-farm irrigation efficiency depending on the type of practice. Site-specific conditions (soil type, climate, timing of irrigation) can significantly affect the efficiency of irrigation practices, and judgment or a desktop analysis is usually required to factor in such conditions.
- **Crop ET**: The most important and scrutinized water balance element is usually the crop ET, which is a function of climate conditions, crop type, and available water supply to the root zone. Various methods exist for estimating crop ET from climate station data. These methods are defined in ASCE Manual No. 70 (2016) and have a long track record of use in the industry and to support water transfers. For the most part, these methods based on climate station data are still used because historical crop ET data (50+ years of record) are the relevant data for a water transfer, not crop ET in any one recent growing season. New technologies (e.g., remote sensing and drones) being developed to measure crop ET at the field scale will likely make climate-based ET estimates more accurate.
- **Natural (Effective) Precipitation**: Irrigation water requirements are the difference between crop ET and natural precipitation, and most legal frameworks do not allow crop ET from precipitation to be included in the transferrable quantity of a water right. Standard formulas exist for estimating the portion of total precipitation which is available in the crop root zone and available to meet crop ET, also known as the effective precipitation. The only data

requirements are relatively local precipitation data from climate stations and limited soils information, typically obtained from soil surveys.

- **Groundwater Elevations**: Subsurface irrigation can occur when the groundwater table rises up into the root zone of the crop. Similar to natural precipitation, subsurface irrigation from a high groundwater table does not count towards the transferrable quantity of a water right. Therefore, local data on groundwater elevations is needed to factor in or factor out subsurface irrigation. In cases of a fluctuating groundwater table, a daily or monthly soil water balance is often applied to quantify the extent of subsurface irrigation over the growing season.
- **Return Flows**: Water diverted into canals and applied to fields which is not consumed is understood to enter into natural hydrologic pathways and return to natural surface and groundwater sources. Various pathways exist for these return flows, as shown in Figure C-2. Accurately measuring and tracking return flows can represent a burdensome cost, and in many states, it is not required. For surface return flows, such as the tail-end flow out of a canal or ditch, standard flume and weir measurement devices can be installed and monitored. For groundwater (subsurface) return flows, engineering estimates are often made to approximate the timing and volume of return flows on a monthly basis.

For the ESMC protocol, it is recommended that the items listed above be considered for data collection or estimation. State policies and practices will dictate the level of rigor needed to complete a water right transfer to support a Water Conservation Credit, but the items listed above are generally needed. In past practice, a farm water balance can be constructed with minimal data collection at the farm or field level. A site visit is usually required to better understand the farm condition and layout, and canal diversion or pumping records are required to track the irrigation water available to the crop. Beyond these two data inputs, desktop analyses can be applied to estimate the remainder of the water balance.

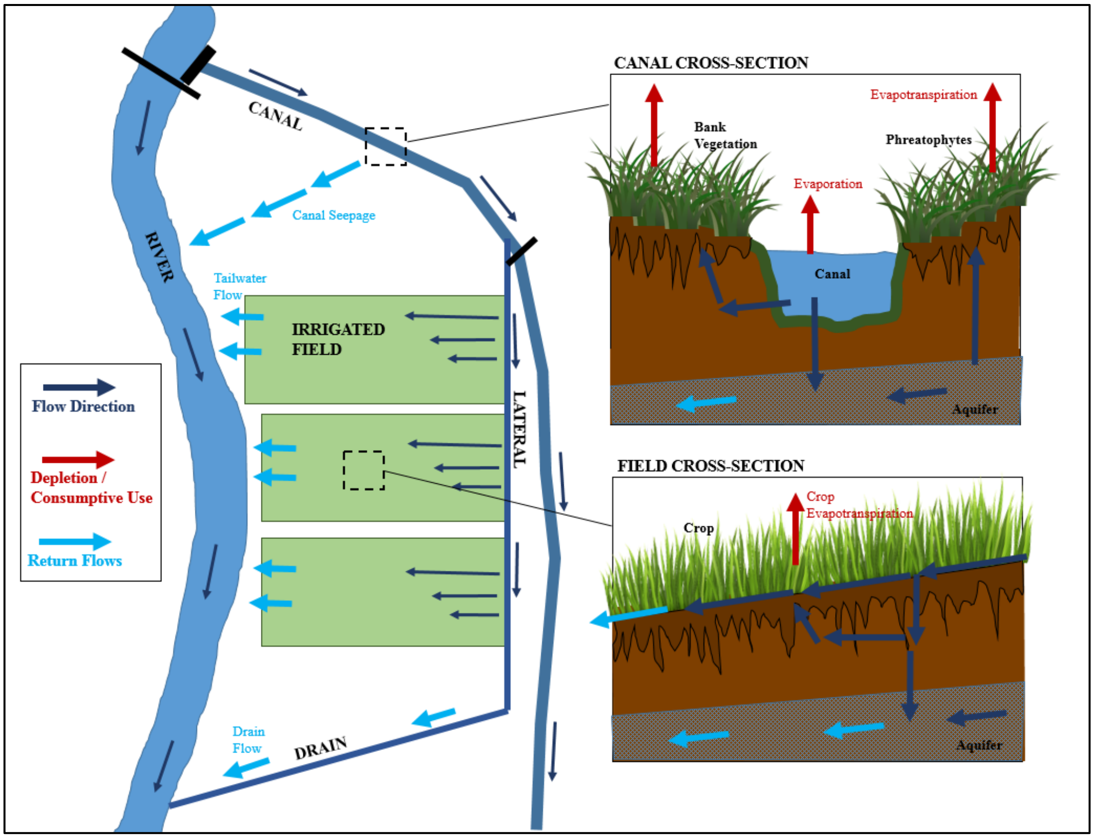

Figure C-2. Example Water Balance for Irrigated Agriculture

ii. Findings for Quantification Methods

A Water Conservation Credit will be quantified based on the volume of water protected under a formal transfer proceeding, following state policies. A simple irrigation water balance (see Figure C-2) is usually constructed using a desktop analysis to support a water transfer application. In some states, tools have been developed to make the water balance analysis easier. Table C-3 provides an inventory of such tools. These tools are developed specific to each state, with certain data pre-loaded for only that state.

In addition, for many states, the state NRCS office has developed a software or spreadsheet tool to estimate irrigation water requirements, generally using less rigorous methods. CROPWAT is a modeling tool developed by FAO for creating an irrigation water balance. All data time-series (see above list) need to be input by the user, but the tool provides efficiency in applying standard estimation methods. CROPWAT could be a good tool, but it does not provide universal functionality and will not be applicable in all states for water transfer purposes.

Table C-3: Irrigation Water Balance Tools by State

State	Model Name	Link
Arizona	LCRAS	https://www.usbr.gov/lc/region/g4000/wtraccttypes.html
California	CUP+	http://wdl.water.ca.gov/landwateruse/models.cfm
	SIMETAW	

Colorado	StateCU	https://www.colorado.gov/pacific/cdss/consumptive-use-statecu
	Lease Fallow Tool	https://www.colorado.gov/pacific/cdss/lease-fallow-tool
Idaho	ET-Idaho	https://idwr.idaho.gov/water-rights/transfers/resources.html
Kansas	KanSched	http://www.bae.ksu.edu/mobileirrigationlab/kansched2
Montana	Water Use Standards	http://www.mtrules.org/gateway/ruleno.asp?RN=36.12.115
	IWR	https://www.nrcs.usda.gov/wps/portal/nrcs/mt/technical/engineering/nrcs144p2_056931/
Nebraska	CROPSIM	-
New Mexico	ET Toolbox	https://www.usbr.gov/uc/albuq/water/ETtoolbox/riogrande.html
	Water Use by Categories	http://www.ose.state.nm.us/Pub/pub_waterUseData.php
Texas	Bulletin 6019	http://www.twdb.texas.gov/publications/reports/bulletins/doc/Bull.htm/B6019.asp
Utah	Report 145	https://www.waterrights.utah.gov/wrinfo/policy/wateruse.asp
Washington	WAIG	https://www.nrcs.usda.gov/wps/portal/nrcs/detail/wa/technical/engineering/?cid=nrcs144p2_036314

iii. Findings for Aggregation Methods

A defining characteristic of a Water Conservation Credit is that the conserved water will be protected instream or in support of another off-farm use. This protection is achieved by undergoing a formal water transfer under state laws and policies. Water transfers are usually considered on an individual basis, unless multiple farms on the same ditch system are involved in the transfer application. Therefore, aggregation across multiple farms and fields on different ditch systems and water sources is probably not applicable for a Water Conservation Credit.

In addition, detailed and site-specific analyses are usually required to identify irrigated farms that could satisfy a specific benefit, and not all irrigated farms in a watershed are likely to be candidates for achieving a specific end use or benefit to a Water Conservation Credit buyer. Therefore, aggregation methods will likely be tailored to a particular location and credit transaction.

iv. Findings for Monitoring, Reporting, Verification

A significant data collection and analytical effort is usually required on the front end to support a water transfer application and therefore to support a Water Conservation Credit. This effort is focused on constructing a historical irrigation water balance, as described above. Following an approved transfer, the ongoing monitoring, reporting, and verification requirements are defined by the state court or regulatory agency but are usually modest by comparison. Typical monitoring and reporting requirements include diversion or pumping records.

In states with administrative record keeping on return flows (such as Colorado), the monitoring requirements become more complicated and costly, and usually involve measurement devices on tail-end canal or drains, and possibly records on the delivery of monthly return flow volumes. For rotational fallowing programs, annual record keeping of farm level land use and water deliveries is critical to support a water transfer. In general, the monitoring, reporting, and verification requirements to support a Water Conservation Credit will depend on the conservation practice and the state regulatory policies and conditions placed on the water transfer.

v. Findings for Registration for Sale

There is no universal registration system for a Water Conservation Credit, but state laws and policies followed through the water transfer process will provide a similar (if not better) level of standardization and validation as a registration system. The attachment, Master Protocol Assessment Crosscut Table, provides an inventory of western state policies regarding conservation practices on irrigated farmlands, focused on maintaining irrigation and crop production with the practice in place. This inventory does not outline state policies and practices involved in a formal water transfer, where irrigation deliveries and farm production are reduced. A complementary inventory on instream flow transfer laws is provided by Stanford Water in the West (2015).

The attachment, Master Protocol Assessment Crosscut Table, provides a discussion of various water quantity credit concepts, including Water Restoration Certificates (WRCs) created by the Bonneville Environmental Foundation. In some instances, a WRC is generated by filing a formal water right transfer application to protect conserved water instream. This is not always the case, and WRC generation looks to maximize instream flow protection of conserved water subject to state laws and available resources. State policies and practices vary, but generally follow prior-appropriation principles of no-injury, beneficial use, and non-speculation. A more detailed investigation of water transfer policies and practices is required for any specific transaction of a Water Conservation Credit, usually requiring legal counsel to be active in the process.

Water Efficiency Credit

i. Findings for Data Collection & Management

The basic data requirement for a Water Efficiency Credit is a measurement of water diversion from a source water supply. Numerous on-farm practices can result in a reduced diversion, but the data needed to support a Water Efficiency Credit are not focused on measurement and management of the practice, but rather the net effect of the practice on water diversions. For surface water sources, with diversions through a canal or ditch, measurements are typically conducted through the use of a water level sensor and downstream water level control structure, such as a weir or flume (USBR 1997). These measurement stations are usually calibrated when installed and periodically checked for accuracy.

For groundwater sources, with diversions through a pumped well, measurements are typically conducted with the use of a flow meter installed on the pipe at the wellhead. These meters require similar calibration and periodic checks. Flow from pumped wells can also be estimated using a Power Conversion Coefficient (PCC) and electrical use records for the pump. A PCC requires a one-time calibration, but then power records are used to estimate water diversions. Diversion data are usually recorded continuously (15-minute intervals) and recorded in an on-site datalogger.

In order to generate a Water Efficiency Credit, it will be important to establish a baseline record of water diversions, with the credit representing the net reduction in diversion from this baseline. Most states require some form of measurement device on diversion structures and wells, particularly for water-stressed regions. If baseline data are not available, it may be challenging to develop a supportable protocol for quantifying a Water Efficiency Credit. Options exist for estimating diversion reductions for some select conservation practices that have an established track record. Some of these will be considered for applications in development of the modular protocol.

ii. Findings for Quantification Methods

One of the marketable benefits of a Water Efficiency Credit is that the quantification methods are simple and the related overhead/transaction costs are relatively small. A Water Efficiency Credit is proposed to be quantified simply as the difference between gross water diversions before and after implementation of a practice. The diversions should be calculated on a daily timescale and summed for each irrigation season. The credit is quantified by the diversion reduction for each season.

iii. Findings for Aggregation Methods

There is potential to aggregate participants to increase the volume benefit of a Water Efficiency Credit transaction. There are no specific methods required to conduct this aggregation. Each participating farm will have a unique credit volume calculated based on the practice and the measured diversions.

iv. Findings for Monitoring, Reporting, Verification

Monitoring, reporting, and verification are tied to accurate measurements of water diversions as compared against an accurate baseline. These measurements are described above. Diversion measurements provide a simple, clear, and accurate means to verify the benefit of a Water Efficiency Credit. The only other aspect of monitoring and verification would involve a periodic site visit to ensure that the participating farm was not diverting water from another source, not captured by the measurements.

v. Findings for Registration for Sale

There is one known program that has similarities to a Water Efficiency Credit. The attachment, Master Protocol Assessment Crosscut Table, describes a Water Restoration Certificate (WRC) generated and funded by the Bonneville Environmental Foundation. A WRC may resemble a Water Conservation Credit in cases where consumptive use is reduced on participating farms and the conserved water is kept instream for environmental benefit, with state administrative protections for the water in some cases. A WRC may resemble a Water Efficiency Credit in cases where water diversions for irrigation are reduced with potential (but unprotected) benefits to the water source.

Certain practices funded under the NRCS Environmental Quality Incentives Program (EQIP) are targeted at improved irrigation efficiency and therefore are similar to practices that would generate Water Efficiency Credits under the ESMC protocol. EQIP does not generate a marketable credit, however. Establishing a registration protocol for a Water Efficiency Credit is considered to be simple compared with other water quantity categories. A significant benefit of a Water Efficiency Credit is that the credit should be marketable at a national scale, since the reduced diversions are not being legally transferred to an alternate use and since a downstream beneficiary is not required. This provides a much broader market for potential partners (buyers).

3) Summary of Findings for Priority Elements

This section summarizes the general findings from research into the desired elements of an ESMC protocol for each category of water quantity credit.

- **Flood Reduction Credit**: The concept of flood reduction is certainly scalable to almost anywhere in the country and must be transparent, but there are significant concerns about the legal implications of such a credit and the costs associated with being scientifically rigorous.

- **Water Conservation Credit**: The scale of water conservation, with protection through a formal water right transfer process, is limited to irrigated farms in the western states. The nature of a water transfer provides a high degree of transparency and scientific rigor, but there are significant legal considerations and limitations on protocol transferability.

- **Water Efficiency Credit**: All of the priority elements can be met by this category of water quantity and this type of credit is considered to be well-suited to the ESMC objectives.

The following sub-sections expand upon this summary for each of the three categories.

Flood Reduction Credit

i. Scalability

A Flood Reduction Credit should be applicable to most parts of the U.S., because flood hazard is ubiquitous. The basic data collection and quantification methods are applicable to any watershed. The following points summarize some ideas on the applicability of a Flood Reduction Credit to various locations and thus scalability.

- **Landownership and Land Use in the Watershed**: In several parts of the western U.S., the upper reaches of the watershed are federally owned and operated. Depending on the specific circumstances, this may present an opportunity or an obstacle to implementing soil health practices. Private landownership, particularly situations where a single owner holds a large fraction of the land within the watershed, can be well-suited to the ESMC protocol. Farmland and rangeland properties in the upper portions of a watershed are best suited to the concept.

- **Downstream Community Benefit**: In order to have a market for a Flood Reduction Credit, there needs to be a downstream beneficiary, which is likely a community or high-value industry prone to regular flooding. Flood reduction benefits are local and cannot be transferred outside of the watershed. The most likely partners (buyers) would be communities that are located downstream of significant farmland and rangeland that also see fairly regular (10 to 20 year) flood damages.

- **Localized Analysis**: Floodplain mapping and flood hydrologic analysis is highly localized, which helps to explain the FEMA regulatory process around flood insurance mapping. One aspect of scalability that should be considered is the lack of transferability of data and information from one location to another. A significant amount of analysis and effort must be applied to any single location and watershed under consideration for a Flood Reduction Credit.

ii. Scientifically Rigorous

It is possible to make a Flood Reduction Credit scientifically rigorous, but the costs of achieving this objective will likely dissuade interest in such a credit, as compared against other alternative methods of achieving flood reduction benefits. A scientifically rigorous Flood Reduction Credit would look a lot like the LOMR process currently in place by FEMA to adjust floodplain elevations for insurance purposes. Reducing the rigor of analysis does not diminish the generally accepted idea that soil health practices can reduce flooding, but less data and information would be available to support the benefits for a particular location. This is one of the most important areas for further research: Would a downstream community be interested in a Flood Reduction Credit based on soil health practices if the level of scientific rigor (modeling) was reduced, and what would the community be willing to pay for such a credit?

iii. Transparency

Transparency is a critical element when dealing with flooding. There are significant liability issues if a downstream community were to buy a Flood Reduction Credit and then be subjected to a storm event that caused significant flood damage. The ESMC protocol needs to be transparent about what benefit is being offered by the Flood Reduction Credit and clear that such benefits are not guaranteed. Transparency regarding the data collection and quantification process is also critically important considering that the flood reduction benefits are difficult (or impossible) to monitor and verify.

iv. Standards-Based (Regulatory and CRS)

There is no existing standard for a flood reduction benefit that could be applied to a Flood Reduction Credit under the ESMC protocol. The floodplain mapping standards operated through FEMA are described above but are not considered readily applicable to the ESMC protocol for reasons outlined above. A detriment of a Flood Reduction Credit is that there is no existing standard to build upon and therefore any certification or standardization will need to be built from scratch. Considering the significance of flood damages and liability issues, this is a point that deserves serious consideration.

v. Farmer-Facing

The data collection efforts and quantification methods for generating a Flood Reduction Credit will involve relatively little interaction with the farm operator or landowner. As described above, there are limited data collection needs at the field scale, and monitoring and verification are not applicable. A Flood Reduction Credit is a positive outcome for the farmer, and lack of interaction for quantification purposes does not mean that the credit is not farmer-friendly.

vi. Legal Considerations

As described in previous elements, there are significant legal considerations to consider when developing a Flood Reduction Credit. The potential for liability, damage claims, and bad publicity are quite significant for this category of water quantity. A flood is a natural disaster, and those affected are often looking for something or somebody to blame; often political leadership in affected communities. The ESMC protocol needs to be cognizant of these possibilities. A Flood Reduction Credit needs to have some legal protections built into it, to protect against damage claims and provide transparency about exactly what the Credit will provide to the buyer. For legal reasons, a Flood Reduction Credit cannot provide a guarantee of flood reduction benefits.

Water Conservation Credit

i. Scalability

A Water Conservation Credit is applicable only within the 17 western states where water rights are administered by state governments. As described above, a Water Conservation Credit is generated by conserving water on farmland and rangeland, using practices that also benefit soil health, and protecting the conserved water from diversion and use by others. This protection is achieved through water rights and would be difficult to achieve outside of strict water rights administration. A Water Conservation Credit is also applicable only to irrigated farmland and rangelands, because irrigation use defines the water right to be transferred.

As described above in the discussion on aggregation, there are competing concepts on the issue of scalability for a Water Conservation Credit. On one hand, scalability is negatively affected by the fact that each credit and transfer process is individualized and not replicable. Each water transfer and credit transaction will likely be an isolated action, with common methods and protocols employed. On the other hand, the engineering and legal costs (transaction costs) of a water transfer are significant enough that it is common practice to attempt to pool several irrigated farmlands (with a common water source) together as part of a transfer application. The transaction costs motivate larger-scale activities.

ii. Scientifically Rigorous

The water transfer process embedded in a Water Conservation Credit will have to be scientifically rigorous in order to comply with state laws and overcome objections. Administrative water transfers are public-facing actions and it is quite common to have other water users object to a water transfer in order to ensure that their water rights are protected. The result is that water transfer applications often get put through some degree of scientific objection and debate, resulting in a high level of scientific support when (if) the application is approved. Following the irrigation water balance framework outlined above, a Water Conservation Credit should be well-supported from a science standpoint.

iii. Transparency

The water transfer process is public-facing and open to public comment, and therefore transparency is inherent in the development of a Water Conservation Credit. This required transparency is often for the benefit of other water right holders and can be a disadvantage to the farmer or landowner. Past irrigation and water use practices are scrutinized when a transfer application is made, and there have been cases where farm entities have been disadvantaged (in terms of exercising their water rights) after opening up their records and information to public and legal scrutiny. Transparency is inherent in the protocol for a Water Conservation Credit, which may not always be a good thing for participants.

iv. Standards-Based (Regulatory and CRS)

As described above, a Water Conservation Credit will follow state laws and policies on water right transfers, which provide standards and approved practices for quantifying and exercising a credit.

v. Farmer-Facing

There are some practices that can achieve both soil health and water conservation outcomes; however, it is important to understand that water conservation requires that farm productivity (yields) will be reduced. Water conservation for purposes of transfer is isolated to the volume of historical consumptive use (crop ET), which is linearly related to yield. As a result, there can be farmer resistance to engaging in water conservation practices unless adequately compensated for the lost productivity plus a premium. A Water Conservation Credit can be financially beneficial to the farm operation, while also providing soil health benefits, but it will likely entail fallowing fields and changing historic practices. Whether or not water conservation activities are friendly to the farm sector usually depends on the farmer’s perspective.

vi. Legal Considerations

There are substantial legal considerations for a Water Conservation Credit, because the generation of a credit basically tracks with established state laws and policies around water transfers. The attachment, Master Protocol Assessment Crosscut Table, provides an inventory of western state policies regarding water conservation projects and the ability to protect the conserved water instream. In addition, the water transfer process involves a transaction of real property (water rights), and there are contractual and legal considerations to consider in such transactions. As a result, all water transfers and related transactions involve experienced legal counsel to manage these legal considerations. A Water Conservation Credit is likely to have similar needs for legal counsel.

Water Efficiency Credit

i. Scalability

A Water Efficiency Credit is limited to irrigated farmlands and irrigated pastures, because the credit is generated by reduced withdrawals from a water source. Irrigation is being adopted more broadly across the U.S., primarily as a supplemental water supply to increase crop quality and yield and to mitigate drought periods in areas that historically had sufficiently reliable rainfall for crop production. Therefore, the potential scale of Water Efficiency Credits is nationwide, with emphasis in the 17 western states where irrigated agriculture is more common. The flexible nature of a Water Efficiency Credit means that there is no firm limit on how many credits could be transacted in a given year or how many participants might get involved.

ii. Scientifically Rigorous

A Water Efficiency Credit has a simple quantification methodology, which is seen as a benefit. The scientific rigor of diversion measurements is high (if properly installed and maintained) and such measurements are considered to provide a supportable and accurate basis for the credit. However, it is important to be clear about what a Water Efficiency Credit is, and what it is not. A Water Efficiency Credit is a reduction in water diversions from a source, but it does not guarantee additional benefits to the source water or increase available water supply at the basin scale.

iii. Transparency

Transparency is relatively easy to achieve with Water Efficiency Credits because of the simplicity of the data collection and quantification methods. The data supporting a credit can be shared, reviewed, and critiqued for accuracy if needed without very much effort. A more difficult aspect of transparency is properly documenting the baseline condition before implementation of a practice. Efforts should be made to be accurate in defining the baseline, but also transparent about unknown aspects of historical water use on participating farms.

iv. Standards-Based (Regulatory and CRS)

There are diversion measurement standards which should be followed to ensure accuracy of the data supporting a credit. For surface water measurements, standards and methods are generally described by the U.S. Bureau of Reclamation (USBR 1997) and the U.S. Geological Survey (USGS undated). For groundwater meters, the specifications developed by the manufacturer or guidelines developed by the USGS should be followed. Beyond diversion measurement, there are no standards considered to be applicable to quantification or transaction of a Water Efficiency Credit.

v. *Farmer-Facing*

The ongoing annual data collection requirements for a Water Efficiency Credit require a good working relationship between the participating farmers and the ESMC. A Water Efficiency Credit can provide financial benefits to a farm operation by reducing costs associated with water diversions while maintaining productivity and crop yields. Some practices may also provide an improvement in crop quality and yield through improved irrigation scheduling and application practices. In general, the practices that will generate a Water Efficiency Credit are considered to be beneficial to farm operations. There may be concerns regarding the maintenance of a water right under conditions of reduced diversions. The attachment, Master Protocol Assessment Crosscut Table*,* provides a summary of western state policies regarding the water right implications of water conservation and efficiency projects. In most states, water rights are protected if the farmer is enrolled in a recognized conservation program.

vi. *Legal Considerations*

The legal considerations associated with a Water Efficiency Credit are considered minimal. A Water Efficiency Credit does not interface with any regulatory requirements, legal transfers, or liability. A Water Efficiency Credit is developed to operate in an informal offset market, and therefore legal issues should be minimal. As described above, there may be farmer concerns about the water right implications of reducing diversions. The attachment, Master Protocol Assessment Crosscut Table*,* provides an inventory of state legal policies for the 17 western states.

4) Research Needs and Data Gaps relevant for Protocol Development

The following research needs and data gaps are identified for protocol development.

Flood Reduction Credit

- **Cost of Credit Generation**: The research identified a range of quantification methods that could be applied, which vary widely in level of effort and cost. Further research should be done to estimate the costs of various quantification methods so that further protocol development can be informed by knowing the costs associated with different levels of rigor. In general, the engineering costs associated with estimating flood reduction benefits are considered substantial enough that it may influence whether a Flood Reduction Credit continues to be considered.
- **Cost of Alternatives**: Parallel to the above need, it is important to get perspective on a downstream community's alternative approaches to obtaining flood reduction benefits. As described above, soil health improvements are essentially acting as a flood retention pond. The cost of an actual flood retention pond providing the same flood reduction benefit is seen as a critical piece of information in developing the protocol.
- **Community (Buyer) Interest**: There is a lack of precedent for downstream entities paying for flood reduction benefits on upstream watershed areas. The concept is currently the subject of research. If possible, the interest in such a credit and the buyer requirements for such a credit should be better understood when creating the protocol. Since there is a lack of standardization and regulatory oversight, the credit will basically be tailored to fit what the buyers are seeking, and we do not currently have clarity on that.

Water Conservation Credit

- **Need for a Protocol**: The research clearly shows that the water transfer process is unique to each state, with common themes but differing practices and requirements. Therefore, the need for a universal protocol for Water Conservation Credits should be considered. It is realistic to think that the potential development of a Water Conservation Credit will be evaluated on a case-by-case basis, rather than by applying a standard protocol.

- **Overlap with Existing Programs**: Efforts to conserve water from the farm sector and transfer the conserved water to a beneficial use (whether instream or otherwise) have been active for decades. Unlike markets for carbon and water quality, the farm sector has been the target of focused water conservation programs for many years. There are active programs run by The Nature Conservancy, National Fish and Wildlife Foundation, Trout Unlimited, Ducks Unlimited, and other environmental organizations which are dedicated to water conservation in the farm sector. Typically, these programs develop out of instream flow needs in specific river systems. Monetary resources available to these programs are targeted at critical rivers and habitat. The ESMC protocol would likely be different in that it would be driven by the desire to implement soil health practices, with water conservation as a potential consideration to improve the marketability of the credit. It is worth considering and gathering more information to understand whether the ESMC protocol would compete with these existing environmental programs or how it might leverage these programs in place of developing a new and different protocol and process.

Water Efficiency Credit

- **Relevant Farm Practices**: The ESMC program is focused on soil health objectives, which can include a wide range of practices. A Water Efficiency Credit requires a farm practice that increases on-farm efficiency and thereby reduces the diversion requirement from a water source while maintaining crop yields. An inventory of practices that hit both targets (soil health and irrigation efficiency) should be compiled to better understand when a Water Efficiency Credit can be applied to a participating farm.

- **Buyer Interest and Cost Perspective**: The Water Efficiency Credit market is basically an offset market, providing positive public relations and marketing material for a company or community. The one known program which has operated in this space, Water Restoration Certificates, has had some notable success but adoption has not been widespread to date. It is important to better understand the market demand for an offset credit, and what potential buyers are willing to pay for such credits. The buyer perspective may be informed (in part) by the cost of implementing water conservation practices to reduce water use instead of purchasing an offset credit.

References for Assessment of Existing Water Quantity Protocols

American Society of Civil Engineers (ASCE). 2016. *Evaporation, evapotranspiration, and irrigation water requirements*. 2nd edition, ed. M.E. Jensen and R.G. Allen. ASCE Manuals and Reports on Engineering Practice No. 70. Reston, VA: American Society of Civil Engineers.

Borah, D.K. and M. Bera. 2004. Watershed-scale hydrologic and nonpoint source pollution models: Review of applications. *Transactions of the American Society of Agricultural Engineers* 47(3): 789-803. https://www.isws.illinois.edu/iswsdocs/journals/BorahTransASAE47-3-789803.pdf

California Ag Water Stewardship Initiative (CAWSI). Undated. Soil Management. http://agwaterstewards.org/practices/soil_management/

Corps of Engineers (COE). 2013. *Conservation reserve program flood damage reduction benefits to downstream urban areas*. Mississippi Valley Division, Rock Island District Pilot Project Report. Submitted to USDA Farm Service Agency Economic and Policy Analysis Staff. https://www.fsa.usda.gov/Internet/FSA_File/fsa_pilot_report_final.pdf

Federal Emergency Management Agency (FEMA). 2017. *Estimating the value of partner contributions to flood mapping projects* (Blue Book). Version 4.1. https://www.fema.gov/media-library/assets/documents/8978

Food and Agriculture Organization (FAO). 2012. United Nations. *Crop yield response to water*. P. Steduto, T.C. Hsiao, E. Fereres and D. Raes. FAO Irrigation and drainage paper 66. Rome, Italy: Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/016/i2800e/i2800e00.htm

———. 2003. *Optimizing soil moisture for plant production*. F. Shaxson and R. Barber. FAO Soils Bulletin 79. Rome, Italy: Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/006/Y4690E/y4690e00.htm

Fischer, S. (undated). Water Movement on the Landscape. PowerPoint presentation. Steve Fischer, NRCS Resource Conservationist.

Maidment, D. 1993. *Handbook of hydrology*. McGraw-Hill, Inc.

Natural Resources Conservation Service (NRCS). 2016. *Effects of implementation of soil health management practices on infiltration, saturated hydraulic conductivity, and runoff*. A review of the literature posted to the NRCS Soil Health Literature Review Library as of January 2015. C.W. Smith. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrceprd1289235&ext=pdf

———. 2018. *Effects on soil water holding capacity and soil water retention resulting from soil health management practices implementation*. A review of the literature posted to the NRCS Soil Health Website as of September 2016. C.W. Smith. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1392812&ext=pdf.

———. (undated). *Soil quality indicators. Available water capacity*. USDA Natural Resources Conservation Service, National Soil Survey Center https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=stelprdb1237387

National Wildlife Federation (NWF). 2015. *Can soil save us? Making the case for cover crops as extreme weather risk management*. P.A. White. https://www.nwf.org/~/media/PDFs/Water/2015/Drought-and-Flood-Report-Final.pdf

O'Connell, E. Ewen, J., O'Donnell, G. and P. Quinn. 2007. Is there a link between agricultural land-use management and flooding? *Hydrology Earth System Sciences* 11:96-107. https://doi.org/10.5194/hess-11-96-2007

Park, D. and M. Markus. 2014. Analysis of a changing hydrologic flood regime using the Variable Infiltration Capacity model. *Journal of Hydrology* 515: 267-280. https://doi.org/10.1016/j.jhydrol.2014.05.004

Schwab, G.O., Fangmeier, D.D., Elliot, W.J. and R.K. Frevert. 1993. *Soil and water conservation engineering*. 4th Edition. John Wiley & Sons, Inc.

Stanford Water in the West. 2015. *Environmental water rights transfers: A Review of state laws*. http://waterinthewest.stanford.edu/resources/publications-directory/environmental-water-rights-transfers-review-state-laws

Stewart, B.A. and G.A. Peterson. 2015. Managing green water in dryland agriculture. Agronomy Journal 107(4): 1544-1553. https://doi.org/10.2134/agronj14.0038

Union of Concerned Scientists (UCS). 2017a. *Rotating crops, turning profits: How diversified farming systems can help farmers while protecting soil and preventing pollution*. Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/food-agriculture/advance-sustainable-agriculture/rotating-crops-turning-profits#.W3cqmMInaUk

———. 2017b. *Turning soils into sponges: How farmers can fight floods and droughts*. Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/food-agriculture/advance-sustainable-agriculture/turning-soils-sponges#.W3ckIMInaUk

United States Bureau of Reclamation (USBR). 1997. *Water measurement manual*. United States Department of the Interior, Bureau of Reclamation. https://www.usbr.gov/tsc/techreferences/mands/wmm/WMM_3rd_2001.pdf

United States Geological Survey (USGS). 2016. *Development of Precipitation-Runoff Modeling System (PRMS) for the Kings River Basin, California, with application for streamflow predictability and flood forecasting*. https://ca.water.usgs.gov/projects/2013-14.html

———. (undated). Water Resources Techniques, Methods, and Modeling. https://water.usgs.gov/techniques.html

List of Acronyms

ACR	American Carbon Registry
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BMP	best management practices
CAR	Climate Action Reserve
CARB	California Air Resources Board
CDM	Clean Development Mechanism [Part of United Nations Framework Convention on Climate Change (UNFCCC)]
CIG	NRCS Conservation Innovation Grant
COD	chemical oxygen demand
COE	Corps of Engineers
CP	crediting period
CSR	Corporate Social Responsibility
CWAD	Conditional Waiver of Waste Discharge Requirements for Agriculture
DNDC	DeNitrification-DeComposition (Model)
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESM	Ecosystem Services Marketplace
ET	Evapotranspiration
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GHG	greenhouse gas
GLLM	Grazing Land and Livestock Management (Methodology)
HEC-RAS	Hydrologic Engineering Center's River Analysis System (Model)
HSPF	Hydrological Simulation Program - FORTRAN
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
K&A	Kieser & Associates, LLC
LOMR	Letter of Map Revision
LSP	Land Stewardship Program of the Noble Research Institute
MRV	Monitoring, Reporting, and Verification (Platform)
NASS	National Agricultural Statistics Service (part of USDA)
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NRI	Noble Research Institute
NRCS	Natural Resources Conservation Service
NTT/APEX	Nutrient Tracking Tool/Agricultural Policy Environmental eXtender
PCC	Power Conversion Coefficient
POC	particulate organic carbon
RUSLE2	Revised Universal Soil Loss Equation
SOC	soil organic carbon

SALM	Sustainable Agricultural Land Management (Verra Method VM0017)
SNAP-PLUS (Model)	Soil Nutrient Application Planner (Model)
SOM	soil organic matter
STEPL	Spreadsheet Tool for Estimating Pollutant Load
TT	Tetra Tech, Inc.
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
VCS	Verified Carbon Standard
VVB	Validation/Verification Body
WQIag	Water Quality Index for Agriculture
WRC	Water Restoration Certificate
WWR	WestWater Research

ECOSYSTEM
SERVICES MARKET
CONSORTIUM