Final Deliverable

Technical Memorandum

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Subject: Leveraging Agricultural Conservation Planning Framework (ACPF) Toolset Data – Ingestion into the Prioritize, Target, and Measure Application (PTMApp)

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Project[1]: Middle Cedar Conservation Collaboration Grant
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EXECUTIVE SUMMARY

The Iowa Agriculture Water Alliance (IAWA) received a Conservation Collaboration Grant (CCG) from the Natural Resources Conservation Service (NRCS) to evaluate methods, processes, and tools to speed the development of watershed plans and expedite the delivery of conservation practices. Considerable investment has been made in Iowa by using the Agricultural Conservation Planning Framework (ACPF) to develop conservation practice placement data. These data are used during watershed planning to identify locations where conservation practices may be placed. This project is focused on evaluating and demonstrating the technical feasibility of bringing the ACPF practice placement data into the Prioritize, Target, and Measure Application Desktop (PTMApp – Desktop) application to attribute the practice locations with estimates of the loads delivered, practice benefits, and practice cost. One of the key considerations in attributing the practice placement data is how load reduction removal equations within PTMApp – Desktop are applied to the ACPF data. Additional technical considerations include methods used to estimate peak discharges, runoff volumes, and assign costs to the practice placement data. This Technical Memorandum[2] (TM) shows that bringing the ACPF data into PTMApp – Desktop is technically feasible. The estimated load reductions and benefits of the practices are consistent with literature values at the practice. Some adjustment to parameters within PTMApp – Desktop will be necessary before it's used in Iowa. These adjustments include the estimated practice removal efficiencies and estimated annual life cycle costs.

[1] Some financial assistance also provided by the Minnesota Board of Soil and Water Resources under SWIFT contract no. 121193.
[2] A special thank you to Dr. Mark Tomer and Dr. David James for their many conservations and guidance.

This TM is organized into the following sections:

INTRODUCTION

The information about the placement of conservation practices within a watershed, developed by using the ACPF, is a valuable resource for completing watershed plans not only within Iowa but elsewhere in the upper Midwest. The ACPF toolsets developed by the United States Department of Agriculture (USDA) – Agricultural Research Service (see https://data.nal.usda.gov/dataset/agricultural-conservation-planning-framework-acpf-toolbox) uses a series of algorithms within a geographic information system (GIS) environment along with high resolution topographic data (usually collected using Light Detection and Ranging [LIDAR]) to identify conservation practice placement opportunities in a watershed. By using ACPF toolsets one can determine the tendency of agricultural fields to deliver water directly to a stream and the characterization of vegetation types adjacent to a stream (i.e., riparian zones) as well as complete an assessment of potential tile drainage areas. Identifying potential locations for placing conservation practices on the landscape can be created and shown visually through map products generated by the ACPF toolset. Conservation practice placement opportunities mapped by the ACPF toolset include 13 different practices, including controlled drainage, grassed waterways, water and sediment control basins, and nutrient removal wetlands. The ACPF products are intended to be used during the watershed planning process to inform decision-making, rather than for use in making specific implementation recommendations (Porter, et. al., 2017) Once conservation practice locations are identified, the water quality benefits of the practices can then be evaluated using other tools or by applying literature values.

The ACPF toolsets are a well accepted method for identifying conservation practice placement opportunities and will continue to be used into the foreseeable future for watershed planning. Although the ACPF toolsets identify conservation practice placement opportunities on the landscape, watershed plans are becoming more technically sophisticated and the need for assurance that water quality goals can be achieved is increasing. This project is focused on whether conservation practice placement locations can be attributed with additional water quality planning data using PTMApp – Desktop, thereby adding value (HEI, 2016). This work is being completed under a NRCS CCG to the IAWA.

PROJECT PURPOSE

The Iowa Nutrient Reduction Strategy (NRS) is a science- and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico (see http://www.nutrientstrategy.iastate.edu/). Although the NRS places focus on reducing the hypoxia within the Gulf of Mexico, Iowa water quality needs to be improved as well. The Iowa Department of Natural Resources (IDNR) maintains and periodically updates a list showing waters failing to achieve water quality standards and considered "impaired." A stream or lake designated as being impaired means the beneficial uses (e.g., for drinking water) of the waterbody fall short of their intended uses.

Improving water quality and increasing flood resiliency ultimately requires something to happen (i.e., a change in the management practices used and/or the construction of structural best management practices [BMPs][3] and conservation practices [CPs]). Implementing management practices and constructing BMPs typically begins with a local staff person from the Soil and Water Conservation District (SWCD) discussing how conservation can be cost-effectively implemented with a grower's operation. Information and data are needed to effectively describe and communicate the opportunity for implementing conservation to the grower. Watershed plans can be a source of this information, be useful for describing watershed-wide conservation opportunities, describe the water quality benefits, and identify the necessary fiscal investment. Watershed plans are typically a prerequisite to access state and federal funding sources (e.g., Section 319 funds from the EPA).

Watershed plans can be a valuable tool for increasing the application of conservation practices. Watershed plans identify the locations of lakes and rivers that may be impaired and need to be restored or protected (i.e., maintained). Plans are typically completed to guide implementation and, within Iowa, are being completed at both the basin (i.e., 8-digit Hydrologic Unit Code - HUC) and subwatershed (i.e., 12-digit HUC) scales. There are 1,715 HUC-12 and 58 HUC-8 subwatersheds partially or wholly located within Iowa. With a typical cost for a subwatershed plan ranging $25,000-$35,000, the fiscal investment in plans alone is substantial, not to mention the challenge of timely completion before implementation.

[3] BMPs are structural practices such as water and sediment control basins and CPs are non-structural or management practices such as tillage and cover crops.

One of the purposes of the IAWA CCG is to develop methods and means to speed watershed planning, explore how to reduce the cost of planning, and expedite the delivery of conservation within the Middle Cedar Watershed (MCW). A template developed within the MCW could be transferable to other Iowa watersheds.

A considerable investment has occurred within Iowa to apply the ACPF, which is an excellent tool for speeding watershed planning and expediting the delivery of conservation. An important product of ACPF is geo-spatial data, which identifies potential conservation practice placement on the landscape. These locations can then be further evaluated using additional considerations, such as social factors to assess practicability and used by field staff to engage growers in a discussion about conservation opportunities. The purpose of this project is to assess the ability to add value to the ACPF products by using the PTMApp framework. This TM is intended to document the proposed methods for ingesting ACPF products into PTMApp to add benefits information to the ACPF products. Adding information to the ACPF products will allow for the identification of the most cost-effective practices, their load reduction benefits, and the development of a benefit-cost analysis (i.e., see **Figure 1**) for assessing whether water quality goals can be achieved through surface load reductions.

METHODOLOGY

BUSINESS NEED

The primary business needs are related to providing improved information about the benefits of conservation practice placement to expedite watershed planning and for the local water quality practitioner to identify the "best" (or most cost-effective) conservation practices. For watershed planning, the business need is to enhance the ACPF practice placement data to include information that facilitates identifying the best practices and includes the ability to assess the feasibility of achieving load reduction goals at multiple locations within a watershed. The business need includes a prioritized list of the BMPs which can be used by the local water quality practitioner to effectively identify specific growers to engage in a conversation about their interest in implementing a conservation practice. The planning need includes an estimate of the cost to achieve load reduction goals.

PRIMARY TECHNICAL CONSIDERATIONS

An overview of the theory and steps for running PTMApp - Desktop is summarized online (https://ptmapp.bwsr.state.mn.us/User/Documentation) and presented graphically in **Figure 2**. The basic concept is to bring the practice placement polygons generated by ACPF into PTMApp and apply the algorithms within PTMApp – Desktop to attribute the polygons. A preliminary analysis of the primary technical considerations for using PTMApp – Desktop to ingest and attribute the ACPF polygons identified the following items that need resolution:

- Estimating annual sediment, total phosphorus, and total nitrogen yields and loads leaving each cell of a raster (which represents the land surface);
- Estimating the annual estimated load delivered to the field edge/waterway;
- Mass routing from the field edge downstream to a conservation practice or specific location;
- Estimating annual runoff volume and event peak discharges;
- Assignment of ACPF practice polygons into PTMApp Treatment Groups;
- Treatment of ACPF riparian boxes within PTMApp;
- Estimated load delivered to a practice;
- Estimated practice removal efficiencies;
- Unit costs used to estimate practice cost and cost effectiveness;
- Describing practice features and characteristics;

Figure 1. Benefit-cost curve example for the Upper Pomme de Terre River 10-digit HUC in central Minnesota for total phosphorus (TP) using structural BMPs. Blue line (edge of field) and orange line (10-digit HUC outlet) are estimated benefit–cost curves for the most cost-effective practices that reduce TP. Green line represents the estimated benefit-cost curve for the most cost-effective practices for reducing sediment at the edge of field and TP at the 10-digit HUC outlet. The load reduction goals are achieved at the intersection of the horizontal lines and benefit-cost curves.

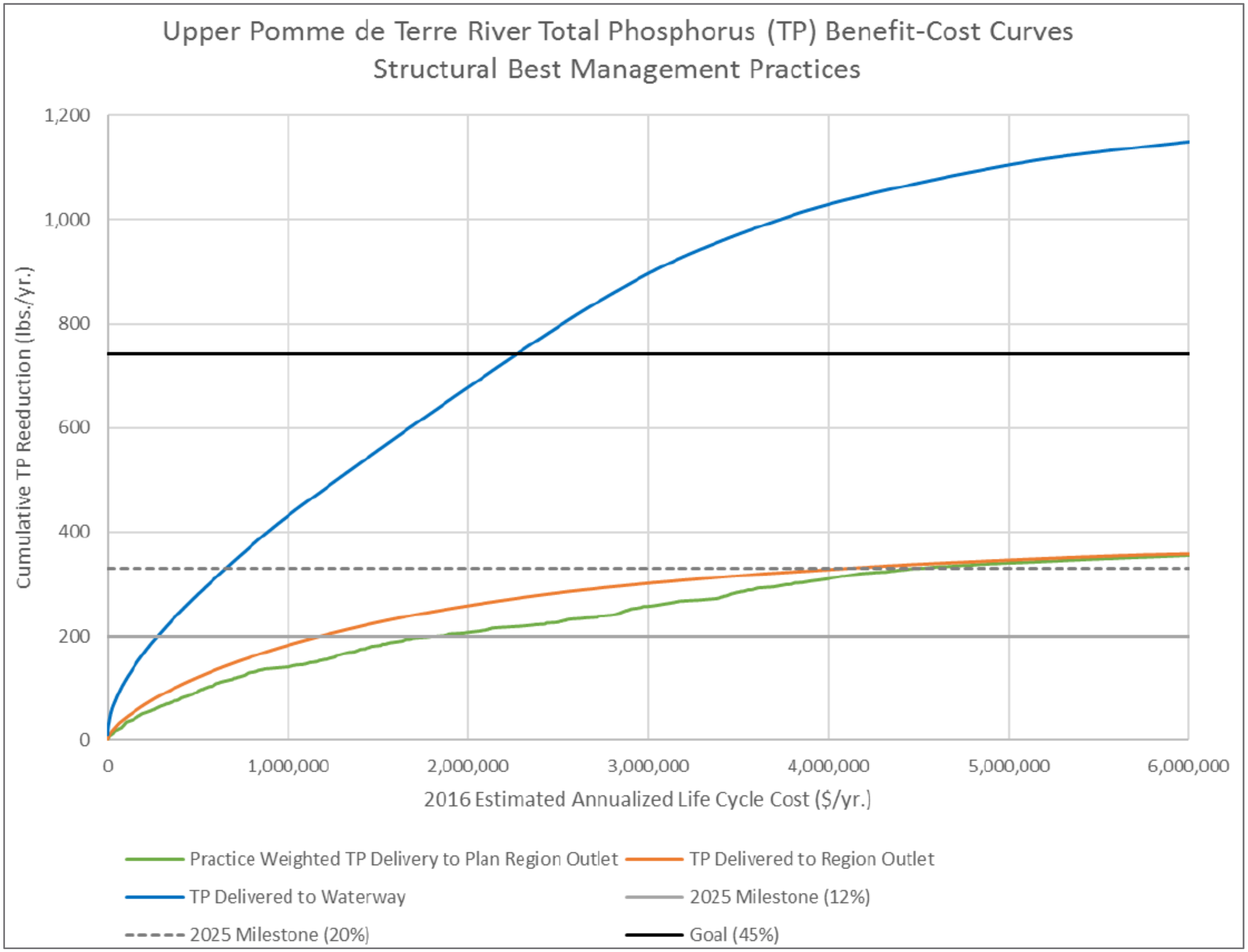
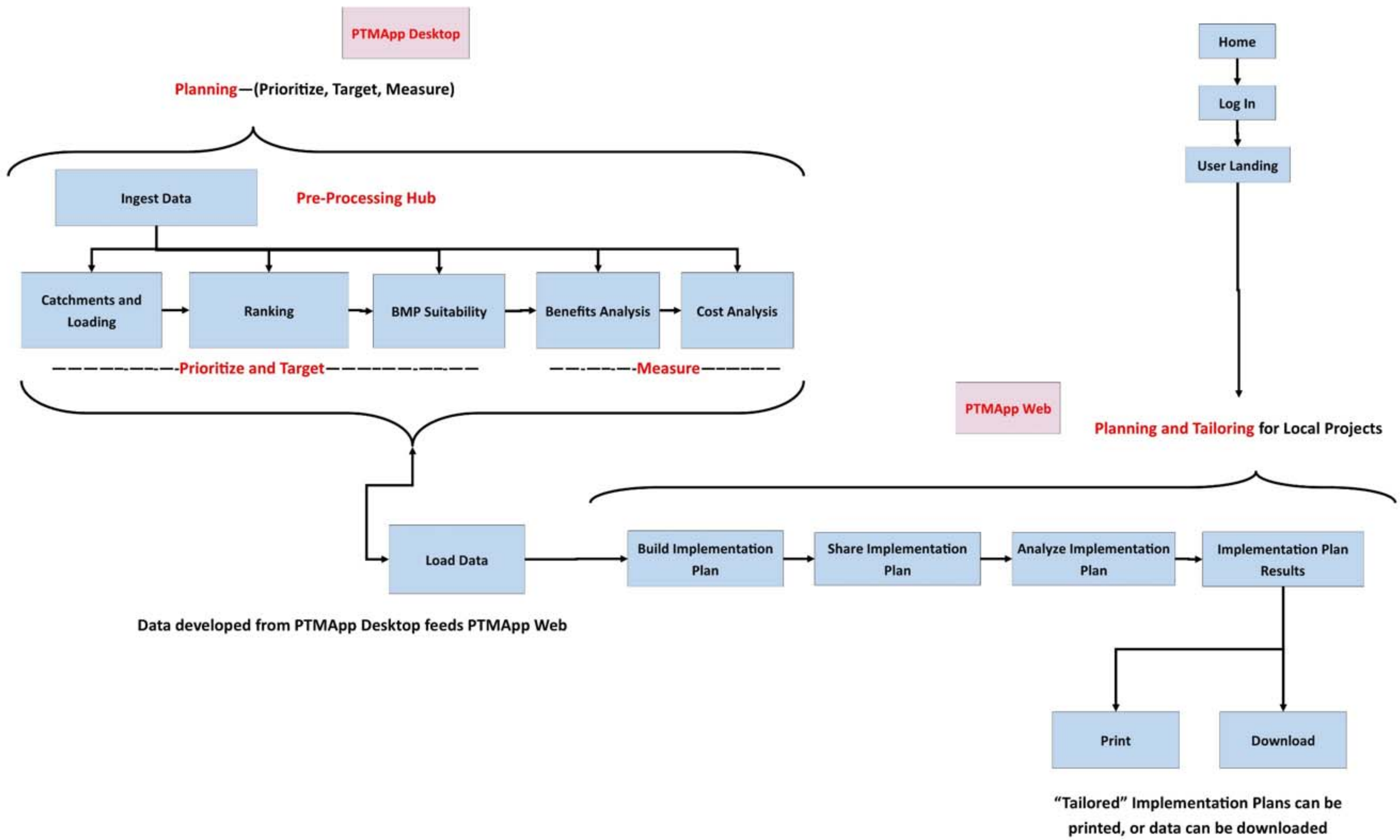


Figure 2. Workflow overview of PTMApp – Desktop and PTMApp – Web. The boxes represent specific steps in either creating the standard PTMApp – Desktop products or using PTMApp – Web. The ACPF practice placement polygons are populated using these data.



- Nomenclature and application structure; and
- Assessing performance.

The remainder of this section addresses each of these items.

Estimating Annual Sediment, Total Phosphorus, and Total Nitrogen Yields and Loads

Sediment Yield

Estimated annual sediment yields are based on the implementation of the Revised Universal Soil Loss Equation (RUSLE). RUSLE is used because of its ease for implementation within an ArcGIS framework and because PTMApp – Desktop is focused on developing implementation strategies for annual load reductions. The RUSLE estimates annual sediment yield as a function of the type of land cover, soil type, topography, and presence or absence of management practices. RUSLE requires several input parameters. The estimated annual sediment yield is calculated as:

$$\text{Estimated Annual Sediment Yield (tons/ac/yr)} = R * K * LS * C * P$$

where R is the Rainfall and Runoff Factor, K is the Soil Erodibility Factor, LS is the Length-Slope Factor, C is the Cover and Management Factor, and P is the Support Practice Factor.

The R-factor accounts for the impact of meteorological characteristics of the watershed on erosion rates. The K-factor accounts for the effects of soil characteristics on erosion rates, whose soil erodibility values are used in PTMApp are taken directly from the NRCS's SSURGO Database. The LS-factor accounts for physical characteristics of the landscape on erosion rates. The USDA's Predicting Soil Erosion by Water: A Guide to Conservation Planning with RUSLE, Agricultural Handbook No. 703 summarizes the methodology used to derive the LS-factors within PTMApp (USDA, 1997). Length data are derived from the hydro-conditioned digital elevation model (DEM) and slope data were derived from the raw "bare earth" DEM.

The C-factor accounts for land cover effects on erosion rates. The most recent National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL) is the recommended land use/land cover data source. PTMApp currently uses generalized C-factors as data on future crop rotations. Values for C-factors were adjusted based on percent residue and type of rotation using information from the Iowa State University, Daily Erosion Project.

The P-factor accounts for the impact of support practices on erosion rates, including contour farming, cross-slope farming, and buffer strips. For the purposes of PTMApp and due to insufficient information, variations in P-factors across a study are typically not accounted for in sediment yield and load calculations.

Total Nitrogen (TN) and Total Phosphorus (TP) Yield

Yields for TP and TN follow an empirical approach using land use export coefficients from literature values. Because of the complexity of bio-geochemical pathways, no effort is made to speciate nitrogen or phosphorus. The yield coefficient is applied to each cell with the raster of a watershed (generally at less than a 10-m scale). TP and TN annual yields are estimated by applying the values in **Table 1** and **Table 2** to land use classes in the 2011 National Land Cover Dataset (NLCD), respectively. These can and should be adjusted by the user based on actual monitoring data, if available.

Table 1. Total Phosphorus Yield for NLCD 2011 Land Use Classifications.

NLCD Classification	Description	TP Loading [kg/ha/yr]	Source
11	Open Water	0	MPCA 2004
21	Developed, Open Space	1	Lin 2004
22	Developed, Low Intensity	0.91	LimnoTech 2007
23	Developed, Medium Intensity	1.15	LimnoTech 2007
24	Developed, High Intensity	1.5	LimnoTech 2007
31	Barren Land	1	MPCA 2004
41	Deciduous Forest	0.075	LimnoTech 2007
42	Evergreen Forest	0.075	LimnoTech 2007
43	Mixed Forest	0.075	LimnoTech 2007
52	Shrub/Scrub	0.075	LimnoTech 2007
71	Grassland/Herbaceous	0.17	LimnoTech 2007
81	Pasture/Hay	0.17	LimnoTech 2007
82	Cultivated Crops	0.38	LimnoTech 2007
90	Woody Wetlands	0	LimnoTech 2007
95	Emergent Herbaceous Wetlands	0	LimnoTech 2007

Table 2. Total Nitrogen Yield for NLCD 2011 Land Use Classifications.

NLCD Classification	Description	TN Loading [kg/ha/yr]	Source
11	Open Water	3.5	MPCA 2013
21	Developed, Open Space	3.5	MPCA 2013
22	Developed, Low Intensity	5.4	US EPA 1983
23	Developed, Medium Intensity	9.6	US EPA 1983
24	Developed, High Intensity	18.0	US EPA 1983
31	Barren Land	3.5	MPCA 2013
41	Deciduous Forest	2	Smullen et al. 1999
42	Evergreen Forest	2	Smullen et al. 1999
43	Mixed Forest	2	Smullen et al. 1999
52	Shrub/Scrub	2	Smullen et al. 1999
71	Grassland/Herbaceous	1.3	USDA MANAGE[1] database
81	Pasture/Hay	2.4	USDA MANAGE[1] database
82*	Cultivated Crops	7.8	USDA MANAGE[1] database
90	Woody Wetlands	3.5	MPCA 2013
95	Emergent Herbaceous Wetlands	3.5	MPCA 2013

*Adjusted to a value to 20.65 for corn/bean rotation and high probability of tiled condition using ACPF data. Value of 20.65 derived from Minnesota Discovery Farms edge of field monitoring data (https://discoveryfarmsmn.org/) for western corn belt plains ecoregion.

[1]https://swat.tamu.edu/publications/manage-database/

The development of yield values requires the prudent and careful collection of water quality samples and discharge measurements at several spatial scales (i.e., edge of field, small watershed, and large watershed). Most monitoring data are collected at the large watershed scale and therefore integrate the influence of additional biogeochemical process after leaving the edge of field. The data used are the best available based on the current state of monitoring, however they could be improved through diligent edge of field monitoring.

Mass Delivery to the Field Edge

Sediment Delivery

Once the sediment yield is estimated within PTMApp for each cell in the raster within a watershed, the sediment reaching the watershed outlet (i.e., flowline) is estimated using a sediment delivery ratio (SDR). The estimated SDR for the watershed is a function of area (Maidment, 1993).

$$Overland\ SDR = 0.41 * catchment\ drainage\ area\ (sq.km)^{-0.3}$$

The SDR for each cell within an overland watershed is estimated as a function of the watershed SDR adjusted by the distance from a cell to the nearest line generated from the flow accumulation raster representing channelized flow.

$$Overland\ SDR\ Adjustment\ Factor = 1 - \frac{\frac{Flow\ Length}{Maximum\ Flow\ Length\ in\ Catchment}}{0.75 + \frac{Flow\ Length}{Maximum\ Flow\ Length\ in\ Catchment}}$$

The SDR for each cell is computed as Overland SDR (for the watershed) multiplied by Overland SDR Adjustment Factor (for the cell).

TN and TP)Delivery

The mass leaving each cell comprising the raster is “routed” downstream to the overland watershed outlet using a first order decay equation computed as a function of overland and in-channel flow and travel times. The decay or “loss” of mass after leaving the landscape is used to represent the reduction in mass from physical, chemical, and biological processes as water moves downstream. A travel time raster for the watershed (in hours) is developed and applied to a first order loss coefficient (% / day). The first order loss occurs across the distance from the watershed pour point to the flowline as a function of travel time:

W = exp(-kT)

where W is the mass leaving landscape, k is the decay rate (% / day) and T is travel time from the cell in the raster within a watershed to the flowline. The default value used for k is 10% per day for TP and TN.

Mass Routing from the Field Edge Downstream to a Conservation Practice or Specific Location

Sediment Routing

The sediment transported downstream to a priority resource is further reduced using a first-order transport loss equation. In-channel downstream transport and loss follows an exponential decay function using travel time and median diameter of sediment:

$$SY = Ye^{-\beta T\sqrt{d_{50}}}$$

Where SY is the sediment mass downstream, Y is sediment mass at the upstream location, β is transport coefficient, T is travel time, and d_{50} is mean sediment diameter. Values of 0.2 and 0.1 are used as defaults for β and the d_{50}, respectively. These values can be adjusted based on local knowledge.

TN and TP Delivery

The nutrient mass loss, as it is transported downstream once it reaches a flowline, is represented using a first order loss equation as a function of travel time:

$$W = \exp(-kT)$$

where W is mass delivered to the flowline, k is the decay rate (% / day), and T is travel time from the flowline to a specific location downstream. The default values used for k is 0.1 for TP and TN. These values can be adjusted to “calibrate” to monitoring data.

Estimating Annual Runoff Volume and Event Peak Discharges

Estimates of the annual runoff volume and peak discharges (event magnitude can be specified; duration is 24-hour) are used within PTMApp-Desktop to develop a continuous function for estimating practice removal percentage, bounded by literature values. The runoff volume (i.e., excess depth multiplied by watershed area) is calculated in PTMApp-Desktop using the NRCS runoff curve number (CN) method. The CN value is computed for the drainage area that contributes to a specific cell in the raster and the annual runoff volume for the area upstream assigned to the cell. Peak discharge is then calculated based on methods describe in NRCS TR-55 (NRCS, 1986) for each cell in the raster.

Assignment of ACPF Practice Polygons into PTMApp Treatment Groups

A treatment group within PTMApp - Desktop is essentially a “group” of NRCS conservation practices (i.e., Practice Codes) sharing similar biological, chemical or physical process causing the removal or reduction in mass sediment, TN, and TP, as water moves through a practice. NRCS practice codes have been mapped to each PTMApp treatment group and to each ACPF practice.[4] Each ACPF practice polygon must be mapped into a Treatment Group for the purposes of applying the mathematical equations for estimating the load reduction benefits. Within PTMApp-Desktop, conservation practices are grouped into one of six treatment groups. The treatment groups are storage, filtration, bio-filtration, infiltration, protection, and source reduction. Practices within the ACPF output geodatabase were assigned to one of these treatment groups (**Table 3** and **Figure 3)**.

Once assigned to a treatment group, the ACPF shapefiles containing feasible practice locations were structured with the appropriate architecture and naming conventions and “run through” the benefit analysis portion of PTMApp - Desktop. Output from this benefit analysis can be used in the development of a targeted conservation implementation plan, based on nutrient reduction goals outlined in the Iowa NRS (IDALS, 2017).

One of the most challenging parts of assessing water quality improvements is estimating the reduction in TN, TP, and sediment resulting from implementing agricultural BMPs and CPs on the landscape. Some of the reasons that estimating the pollutant reduction benefits of agricultural BMPs and CPs is challenging include:

- The dependence on specific design factors related to the BMP or CP;
- Effectiveness is a function of the location of the BMP or CP on the landscape, relative to the particular waterbody it is intended to protect or restore;
- Highly variable removal efficiencies, caused in part because of the changing environmental conditions (e.g., amount of runoff); and
- Challenges associated with the ability to extrapolate monitoring data from one setting to another.

Because of these challenges, the mass reduction benefits of agricultural nonpoint source BMPs and CPs are often assumed as fixed percentages of the loads received and estimated at the BMP or CP locations. These methods are inadequate for measuring progress toward achieving water quality goals at the actual waterbody where a protection or restoration strategy is being developed. PTMApp utilizes treatment groups (see **Table 4**) to estimate load reductions at the BMP and at the downstream resource. A specific mass removal equation is applied to each treatment group. The load reduction benefits of each BMP location within a treatment group is adjusted based on the ability to treat the runoff received (see **Table 5**). The load reduction benefits also vary

[4] https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849

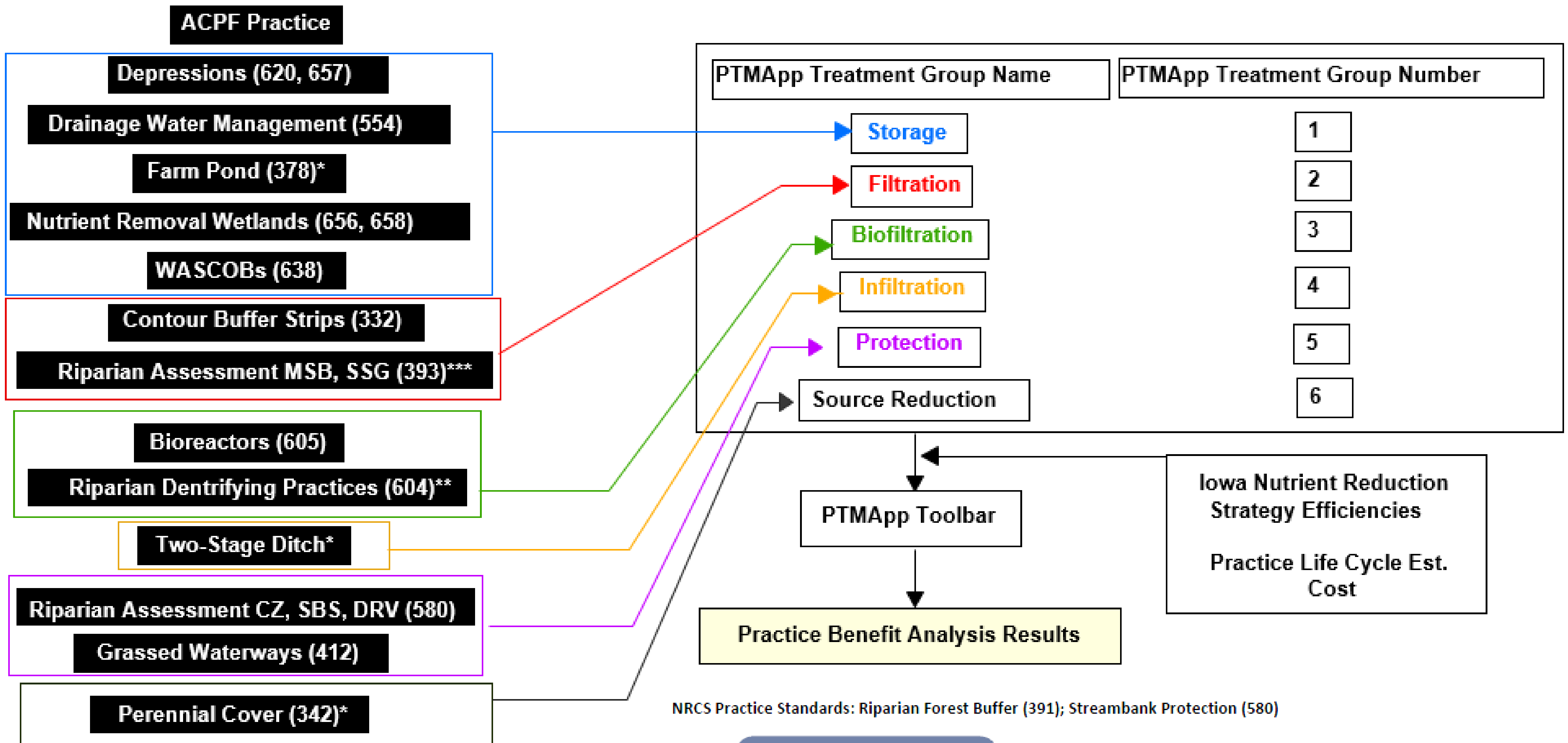
Table 3. ACPF Practice Shapefile and Practice Type Relative to NRCS Practice Code and the PTMApp Treatment Group Assigned.

Layer Name	Practice Type	NRCS Practice Code	Treatment Group
Bioreactor071000060202	Denitrifying Bioreactor	605	Biofiltration
CBS071000060202	Contour Buffer Strips	332	Filtration
Depressions071000060202	Underground Outlet, Wetland Restoration	620, 657	Storage
DrainageMgmt071000060202	Drainage Water Management	554	Storage
GrassWaterways071000060202	Grassed Waterways	412	Protection
NRW071000060202	Constructed Wetland, Wetland Creation	656, 658	Storage
RiparianFunctionDRV071000060202	Deep Rooted Vegetation	393	Protection
RiparianFunctionMBS071000060202	Multi Species Buffer	393	Filtration
RiparianFunctionSBS071000060202	Stream Bank Stabilization	393	Protection
RiparianFunctionSSG071000060202	Stiff Stemmed Grasses	393	Filtration
SaturatedBuffer071000060202	Saturated Buffer	604	Biofiltration
WASCOBBasin071000060202	Water and Sediment Control Basin	638	Storage

Table 4. BMP and CP Treatment Groups and Primary Process for the Reduction of Loads.

	Storage	Filtration	Bio-Filtration	Infiltration	Protection	Source Reduction
Primary Treatment Process	Sedimentation	Sedimentation	Sedimentation & Biological	Volume abstraction	Physical protection of the landscape	Reduction of Mass Potential
Primary Form of Treatment	Particulate	Particulate	Particulate	Dissolved	Total (Dissolved & Particulate)	Total (Dissolved & Particulate)

Figure 3. ACPF BMPs and PTMApp Treatment Groups Definition and Benefits Analysis Flowchart.



NRCS Practice Standards: Riparian Forest Buffer (391); Streambank Protection (580)

Riparian Assessment: Identify riparian function by stream reach

Shallow water table width (columns); Runoff Delivery (rows)

	H	M	L
H	CZ	MSB	SSG
M	MSB	MSB	SSG
L	DRV	DRV	SBS

Design types for Riparian Buffers:

- CZ Critical zone/sensitive sites
- MSB Multi-species buffer for water uptake, nutrient & sediment trapping
- SSG Trap runoff & sediment with stiff-stemmed grasses
- DRV Use deep rooted vegetation tolerant of saturated soils
- SBS Emphasize stream bank stability

*This is a proposed BMP not currently created as an output in ACPF.
**ACPF uses the terms Riparian Denitrifying Practices and Saturated Buffers interchangeably.
***See table to the right from ACPF Manual regarding Riparian Assessment design types.

between treatment groups. The variation between treatment groups is derived from the scientific literature using available performance data.

Table 5. Methods for Estimating the Reduction Ratio for BMP and CP Treatment Groups.

	Storage	Filtration	Bio-Filtration	Infiltration	Protection	Source Reduction
Reduction Ratio (*r*)	Treatment Volume / Runoff Volume Delivered	Velocity Design Standard / Velocity During Peak Discharge	Treatment Volume / Runoff Volume Delivered Treatment	BMP Abstraction Volume / Volume Delivered	Modified RUSLE Parameters	Actual reduction in mass

A key step in assessing the impacts of BMPs within PTMApp is estimating the volume of runoff that can be treated by a BMP (treatment potential) resulting from different precipitation events (delivery potential). By default, 2-year, 24-hour and 10-year, 24-hour precipitation events are used as the standard precipitation events using NOAA Atlas 14 data for the Midwest Region, as most BMPs are designed for treatment within this range. The assumption is that the mass reductions estimated using the 2-year, 24-hour precipitation event will approximate annual average values (since it is a 50% chance precipitation event). Users can adjust the precipitation depths. However, the precipitation event duration is fixed at 24 hours.

The most common method used to estimate BMP and CP effectiveness is to assign an assumed percentage reduction value typically based on a literature review. This approach fails to acknowledge that the effectiveness of BMPs and CPs in reducing load is typically based on either the volume of water treated (e.g., storage) or how rapidly water moves across the surface (e.g., filter strips). Conceptually, the approach used within PTMApp-Desktop uses a continuous mathematical function between lower and upper percent reduction values (obtained from the literature) to estimate the in-load reduction received by the BMP, based on either the volume of water that can be treated (surrogate for hydraulic residence time) or the rate by which water moves through the BMP (surrogate for overflow rate).

Within PTMApp, the percent reduction of a water quality constituent is based on a reduction ratio and the empirical statistical distribution of BMP effectiveness within the treatment category (**Table 5**). For instance, the reduction ratio for storage BMPs (e.g., wetlands, sediment control basins) is calculated as the ratio of the volume of water delivered (delivery potential) to the BMP under 2-year, 24-hour and 10- year, 24-hour precipitation events to the volume of water held by the storage BMP (treatment potential). The method used to estimate the reduction ratios for each treatment group are shown in **Table 5**. BMPs and CPs are placed in treatment groups based on the process by which water is treated (see **Table 3**). This is necessary due to the large number of equations that would need to be developed for each type of BMP and CP if they were not placed into treatment groups as well as the general lack of data relative to effectiveness.

Storage

Storage BMPs generally provide treatment through sedimentation processes. The effectiveness of sedimentation is therefore related to the volume of dead storage (i.e., water stored within a permanent pool) and the volume of water delivered to the BMP. The storage reduction ratio is calculated based on the treatment volume of the practice (treatment potential) derived from topographical data and the total volume of water delivered to the practice (delivery potential) under 2-year, 24-hour and 10- year, 24-hour precipitation events. The volume of water delivered to a storage BMP is calculated using the CN method.

Filtration

Filtration practices generally provide treatment by slowing the velocity of water to allow for sedimentation processes to occur. The effectiveness of filtration BMPs are therefore a function of the velocity design standard and the velocity of runoff delivered across the surface of the BMP. Filtration practices are typically designed to treat a maximum velocity of 0.06 ft. sec^{-1}. PTMApp – Desktop uses 0.05 ft sec^{-1} as the treatment potential of filtration BMPs and CPs. This treatment potential velocity was calculated using Stoke's Law, assuming a 50-foot-wide filtration practice that results in the silt and sand fractions of sediment being retained within the BMP. The velocity resulting from the peak rate of runoff (delivery potential) is then calculated using the CN method and unit hydrograph theory to determine peak discharge for the 2-year, 24-hour and 10-year, 24-hour precipitation events. The reduction ratio is reduced if the velocity exceeds 0.05 feet sec-1.

Bio-Filtration

Bio-filtration practices generally provide treatment through sedimentation and biological processes, depending on whether the practice is located on the ground surface or subsurface. The effectiveness is related to the water residence time and therefore the volume of dead storage (i.e., water stored within a permanent pool) and the volume of water delivered to the BMP. The storage reduction ratio is calculated based on the treatment volume of the practice (treatment potential) derived SSURGO soils available water holding capacity data and the total volume of water delivered to the practice (delivery potential) under 2-year, 24-hour and 10- year, 24-hour precipitation events.

Bioreactors and saturated buffers are two of the more common BMPs being implemented through the Iowa Nutrient Reduction Strategy. The practices treat subsurface water movement. For the purposes of this work, these practices were assumed to be represented by this treatment group. The mass and volume of water delivered to the treatment group was modified by the proportion of the rainfall depth infiltrated.

Infiltration

Infiltration practices generally provide treatment by allowing water to infiltrate through the soil or other media. PTMApp calculates the reduction ratio for infiltration BMPs based on the volume abstracted (i.e., infiltrated) from runoff (treatment potential) and the volume of water delivered (delivery potential) to the BMP under 2-year, 24-hour and 10-year, 24-hour precipitation events. Both the abstraction volume and volume delivered to the BMP are calculated using the CN method.

Protection

Protection practices generally provide treatment by physically armoring the landscape in areas with high potential for erosion. This could include natural materials (e.g. tree, shrub, grass plantings) and/or manmade materials (e.g. rock filled gabion baskets). PTMApp estimates the reduction potential of protection BMPs and CPs based on the amount of water quality constituents (TP, TN, Sediment) no longer eroding from areas where protection BMPs can be placed on the landscape. The percent reduction in water quality constituents is based on the empirical statistical distribution of protection BMPs. For protection practices, reduction ratios will be set to 1 and their effectiveness will vary based on empirical data

Source Reduction

Source reduction practices generally provide treatment by reducing the amount of water quality constituents (typically TP and TN) applied to the landscape. For example, nutrient management plans may reduce the amount of fertilizer applied to agricultural areas or suggest changes in the form or timing of application. PTMApp measures the reduction potential of source reduction CPs based on their empirical statistical distribution for reducing TP and TN. This empirical distribution is a function of published effectiveness values (e.g. Agricultural BMP database, National BMP database) for the BMPs that are categorized into the source reduction treatment group.

Treatment of ACPF Riparian Boxes Within PTMApp

Riparian functions assigned to each ACPF riparian assessment box were matched to PTMApp treatment groups as outlined in **Table 6**. Feasible filtration and protection practice location polygons, identified within PTMApp-Desktop as present within Multi Species Buffer, Still Stemmed Grasses and Critical Zone, Deep Rooted Vegetation and Stream Bank Stabilization riparian boxes respectively, were pulled to run through the PTMApp benefits analysis. Once benefits were generated for the appropriate filtration and protection polygons, they were attached back to the original related ACPF Riparian Box (**Table 6)**.

Table 6. Classification of Riparian Box Designation to PTMApp Treatment Group.

Riparian Function	PTMApp Treatment Group
Multi Species Buffer	Filtration
Still Stemmed Grasses	Filtration
Critical Zone	Protection
Deep Rooted Vegetation	Protection
Stream Bank Stabilization	Protection

Estimated Load Delivered to a Practice

The estimated annual TP, TN, and sediment load delivered to a practice is represented as the maximum load from a specific cell within the delivered to the flowline raster for the localized drainage area of the practice. The estimated loads are likely therefore “high.”

Estimated Practice Removal Efficiencies

An empirical treatment function is used to transform the reduction ratio (r) into a percent reduction within a BMP. The percent reduction (R) is estimated as:

$$R = ar^k$$

where ɑ is a percent reduction in a water quality constituent taken from the empirical statistical distribution of the BMP treatment group (derived from literature; see **Table 7**), r is the reduction ratio (see **Table 5**), and k is a coefficient based on the interquartile range of the empirical statistical distribution of the BMP treatment group. To account for variation in removal efficiency, the ɑ term is estimated as the median (Q2), upper (Q3), and lower limit (Q1) of the inter quartile range of the empirical statistical distribution of the BMP treatment group. The values of Q1, Q2, and Q3 are based on literature monitoring values for BMP effectiveness. The coefficient, k, is calculated as:

$$k = \frac{Q3 - Q2}{Q2 - Q1}$$

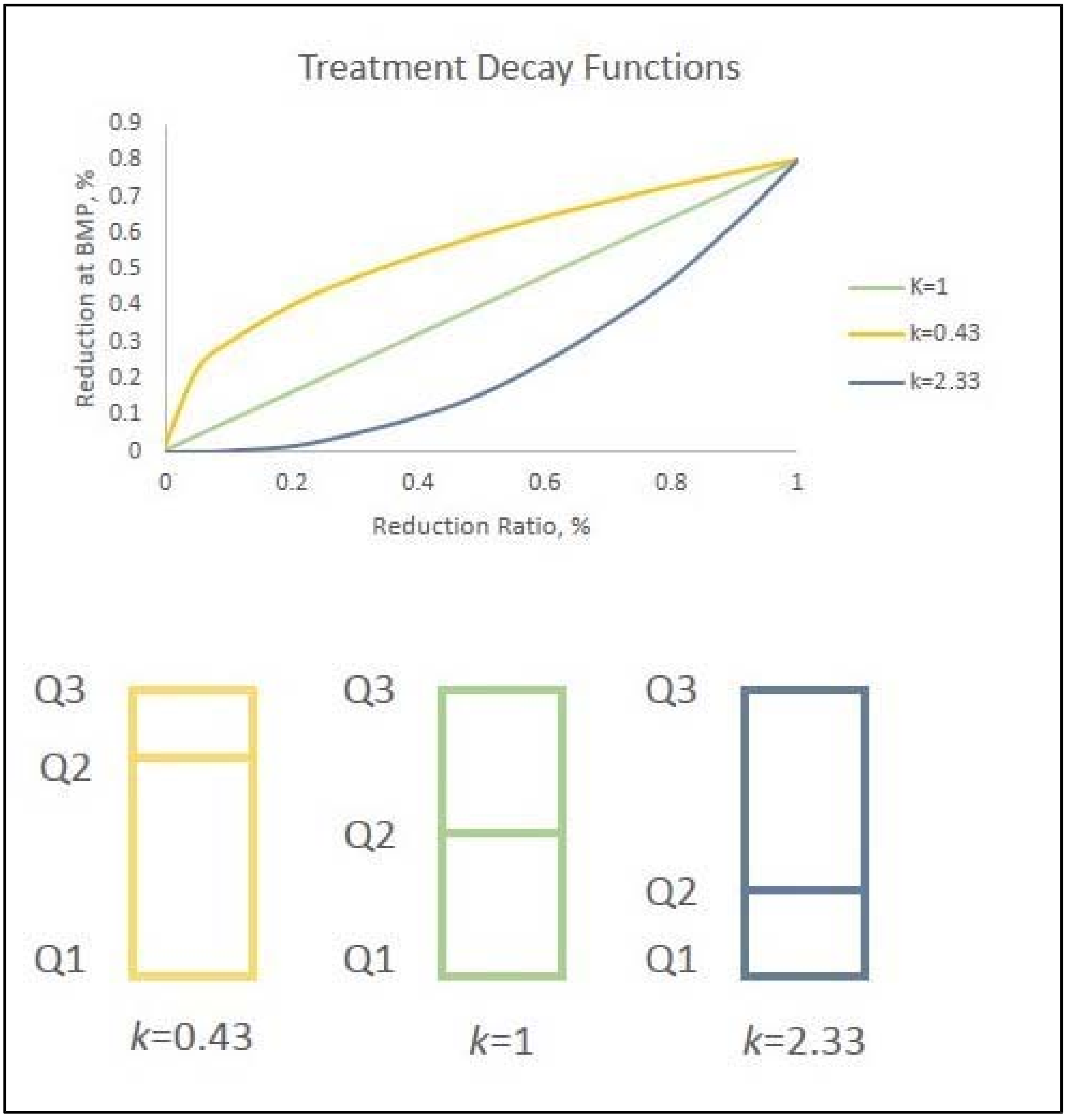
where Q3 is third quartile (i.e. upper limit) of the empirical statistical distribution of the BMP and CP treatment group, Q2 is the second quartile (i.e. median) of the empirical statistical distribution of the BMP treatment group, and Q1 is the first quartile (i.e. lower limit) of the empirical statistical distribution of the BMP treatment group. The empirical statistical distribution was based on the availability of research on a particular treatment group with priority going to studies conducted in Minnesota, then the Upper Midwest, and then the United States. **Figure 4** illustrates treatment function ranges assuming different values of k. The values (k) for each treatment group based are based on best available data. The reduction ratio varies for each practice (**Table 4**) depending on the practice's ability to "treat" the amount of water received based either on annual runoff volume or peak discharge. **Table 7** provides a summary of the reduction ratios used for PTMApp analysis within each treatment group for all sediment, total nitrogen (TN) and total phosphorus (TP) removal quartiles.

Table 7. Reduction ratios used for PTMApp Analysis by Treatment Group. These values are derived from statistical analysis of BMP monitoring data. These can be modified to reflect anticipated design performance. Q1=25th percentile, Q2=median, Q3=75th percentile removal, k=first order decay rate. Value for protection set to 1. Data are from Clary et al. 2016. Values are consistent with those used in the NRS.

			Sediment *			
Treatment Group	**Q1**	**Q2**	**Q3**	**Minimum**	**Maximum**	**k**
Storage	0.24	0.69	0.87	-86.00	1.00	0.41
Filtration	0.00	0.50	0.72	-67.00	1.00	0.45
Biofiltration	0.65	0.84	0.93	-47.00	1.00	0.50
Infiltration	0.58	0.90	0.94	0.17	0.98	0.12
Protection	No data	No data	No data	No data	No data	1.00
Source Reduction	0.13	0.52	0.70	-3.84	0.90	0.46
			Total Phosphorus*			
Treatment Group	**Q1**	**Q2**	**Q3**	**Minimum**	**Maximum**	**k**
Storage	0.01	0.39	0.69	-207.00	0.99	0.77
Filtration	0.00	0.00	0.21	-254.00	0.99	1.00
Biofiltration	0.17	0.50	0.66	-6.21	0.99	0.50
Infiltration	0.00	0.24	0.63	-0.08	0.76	1.69
Protection	No data	No data	No data	No data	No data	1.00
Source Reduction	0.01	0.41	0.49	-2.07	0.87	0.21
			Total Nitrogen			
Treatment Group	**Q1**	**Q2**	**Q3**	**Minimum**	**Maximum**	**k**
Storage	0.06	0.57	0.88	-69.67	1.00	0.60
Filtration	0.00	0.00	0.31	-35.16	0.97	1.00
Biofiltration	0.80	0.84	0.90	0.75	0.93	1.50
Infiltration	0.16	0.58	0.86	0.10	0.87	0.65
Protection	No data	No data	No data	No data	No data	1.00
Source Reduction	0.00	0.16	0.33	-1.10	0.95	1.01

* Biofiltration treatment group assumed to represent wood chip bioreactor. Therefore, data were post processed to achieve zero reduction for TP and sediment.

Figure 4. Illustration of Different Treatment Decay Functions Based on Different Decay Coefficients (k).



Describing Practice Features and Characteristics

Each practice is attributed with a variety of features, including the estimated physical characteristics (e.g., surface area, mass reduction), watershed characteristics (e.g., drainage area, runoff volume received) and estimate cost. These attributes are stored within a variety of tables with the PTMApp – Desktop processing data geodatabase for retrieval and use by the user.

Unit Costs Used to Estimate Practice Cost and Cost Effectiveness

Unit costs applied to practice type features (typically size or volume) are specified by the user and can represent first cost (i.e., design and capital), EQIP cost, grant eligible cost, or annual life cycle cost. Use of annual life cycle cost is recommended and, specifically for Iowa, we recommend using 2016 annual life cycle estimated costs developed by Iowa State University (https://www.nrem.iastate.edu/bmpcosttools/download).

Performance Assessment

A standard protocol has been developed for the purpose of assessing the reasonableness of the estimated annual loads and practice effectiveness. The protocol consists of completing a statistical analysis of the PTMApp yield data and comparing these to the range of literature values (https://ptmapp.bwsr.state.mn.us/files/QAQC-Desktop-Outputs.pdf). Provided sufficient long-term load monitoring data are available, the analysis can be completed in the future.

CONCEPT DEVELOPMENT AND PRELIMINARY RESULTS

ArcGIS Model Builder was used to build a working prototype of the application. **Figure 5** shows the concept for ingesting ACPF data developed within Model Builder. A dataset from the Headwaters Cedar Creek HUC-12 Watershed (071000060204) was used to complete testing, primarily because the data were readily available. Eight priority resource points were identified within the 34,932-acre watershed located within Clay, Palo Alto, Buena Vista, and Pocahontas counties. A priority resource point is a location where information is needed from PTMApp – Desktop. Priority resource points are often the most downstream location in a 12-digit HUC or the location of an impaired stream reach or lake where information about loads and practice effectiveness is desired. Priority resource points are the locations at which TN, TP, sediment source loads, and practice cost-effectiveness can be estimated. They are also the locations where source load reductions can be summarized for potential BMPs and CPs (**Figure 6**). The test dataset included outputs processing results from PTMApp-Desktop including base, processing, and planning geodatabases. The content of these databases has been provided within **Appendix A**. The test dataset also includes a Processing_ACPF geodatabase, whose contents are described in the following section.

Several of the more common products from PTMApp – Desktop specific to the primary technical considerations (described previously) are summarized in a series of tables (Tables 8–Table 12), and all ACPF practice locations within the study area are represented in **Figure 7**. Additional summary statistics, specific to individual ACPF layers, have been provided in Appendix B. These data are preliminary and are being reviewed first to ensure proper function of the ArcGIS Model Builder and second to begin assessing the reasonableness for Iowa. These results assume no conservation practices are currently placed on the landscape.

DISCUSSION OF PRELIMINARY RESULTS

The preliminary results can be used to assess the reasonableness of the estimated yields (**Table 8**), hydrology (**Table 9**), and downstream delivery of mass (**Tables 10** and **11**). The estimated sediment, TN, and TP yields leaving the land assume no practices are in place and fall within a reasonable range. Provided monitoring data are available for the Middle Cedar Watershed, the yield values can be adjusted to match estimated annual yields within PTMApp or to adjust the export coefficients for the various land uses (for TN and TP only).

Table 8. Yields leaving the land and delivered to the flowline of a subwatershed. Values are the descriptive statistics for all subwatersheds within the test area (Headwaters Cedar Creek – see **Figure 6**).

Sediment Yield Leaving the Land (tons/acre/year)					Sediment Yield Delivered to Flowline* (tons/acre/year)				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile	25th Percentile	Median	Mean	Standard Deviation	75th Percentile
2.32	2.59	2.54	0.84	2.85	1.44	1.61	1.60	0.55	1.86
Total Nitrogen Yield Leaving the Land (lbs/acre/year)					**Total Nitrogen Yield Delivered to Flowline* (lbs/acre/year)**				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile	25th Percentile	Median	Mean	Standard Deviation	75th Percentile
6.45	6.78	6.54	0.70	6.95	6.38	6.70	6.47	0.70	6.88
Total Phosphorus Yield Leaving the Land (lbs/acre/year)					**Total Phosphorus Yield Delivered to Flowline* (lbs/acre/year)**				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile	25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.34	0.34	0.37	0.08	0.38	0.33	0.34	0.36	0.07	0.38

**Values are affected by the travel time to the nearest flowline and first order decay coefficient. The travel time is normally small, so results are similar to leaving the land. Can be adjusted to edge of field monitoring data*

Table 9. Two and ten-year estimated runoff depths, volumes, and peak discharge. Values are the descriptive statistics for all subwatersheds within the test area (Headwaters Cedar Creek – see **Figure 6**).

2 Year Run-Off Depth (Inches)					10 Year Run-off Depth (Inches)				
25th Percentile	Median	Mean	Standard Deviation	75 Percentile	25th Percentile	Median	Mean	Standard Deviation	75th Percentile
1.11	1.12	1.12	0.09	1.13	2.27	2.28	2.28	0.14	2.30
2 Year Run-Off Volume (acre-feet)					**10 Year Run-Off Volume (acre-feet)**				
25th Percentile	Median	Mean	Standard Deviation	75 Percentile	25th Percentile	Median	Mean	Standard Deviation	75th Percentile
1.58	2.71	4.05	3.23	5.55	3.20	5.48	8.22	6.54	11.30
2 Year Peak Flow (cubic feet/sec)					**10 Year Peak Flow (cubic feet/sec)**				
25th Percentile	Median	Mean	Standard Deviation	75 Percentile	25th Percentile	Median	Mean	Standard Deviation	75th Percentile
10.08	14.95	19.28	27.87	20.39	21.05	30.53	40.19	60.80	42.13

Table 10. Yields and mass delivered to the most downstream priority resource point (i.e., watershed outlet). Values are the descriptive statistics for all subwatersheds within Headwaters Cedar Creek (see **Figure 6**).

Sediment Yield Delivered from Catchment Outlet to Priority Resource Catchment Outlet (tons/acre/year)				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.17	0.31	0.41	0.34	0.55
Total Nitrogen Yield Delivered from Catchment Outlet to Priority Resource Catchment Outlet (lbs./acre/year)				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.24	0.45	0.93	1.10	1.25
Total Phosphorus Yield Delivered from Catchment Outlet to Priority Resource Catchment Outlet (lbs./acre/year)				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.01	0.03	0.05	0.06	0.07
Sediment Mass Delivered from Catchment Outlet to Priority Resource Catchment Outlet (tons/year)				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
4.36	10.08	18.36	28.61	22.69
Total Nitrogen Mass Delivered from Catchment Outlet to Priority Resource Catchment Outlet (lbs/year)				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.24	0.45	0.93	1.10	1.25
Total Phosphorus Mass Delivered from Catchment Outlet to Priority Resource Catchment Outlet (lbs/year)				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.32	0.90	2.32	4.47	2.52

Table 11. Ratio of sediment delivered from the catchment outlet to the priority resource point. Values are the descriptive statistics for all subwatersheds within the test area (Headwaters Cedar Creek – see **Figure 6**).

Sediment				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.21	0.37	0.42	0.24	0.59
Total Nitrogen				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.08	0.21	0.29	0.25	0.44
Total Phosphorus				
25th Percentile	Median	Mean	Standard Deviation	75th Percentile
0.08	0.21	0.29	0.25	0.44

Table 12. Constituent delivery at ACPF practice locations and reductions to the subwatershed outlet. Values are the descriptive statistics for all subwatersheds within the test area (Headwaters Cedar Creek – see Figure 6). Estimated percent reductions are based on the 2-year, 24-hour runoff event. (Note: a value of 100% assumes the BMP effectively prevents sediment loss).

		Hydrology & Drainage Area			Sediment			Total Nitrogen			Total Phosphorus		
ACPF Feature	PTMApp Treatment Group	Average Volume of Water Delivered for a 2-year, 24-hour Precipitation Event (acre/feet)	Average Volume of Water Delivered for a 10-year, 24-hour Precipitation Event (acre/feet)	Average Drainage Area (acres)	Average at BMP Delivered to Catchment Outlet (tons/year)	Average Reduction at Catchment Outlet (tons/year)	Percent Reduction	Average at BMP Delivered to Catchment Outlet (lbs./year)	Average Reduction at Catchment Outlet (Practice Group lbs./year)	Average Percent Reduction	Average BMP Delivered to Catchment Outlet (lbs./year)	Average Reduction at Catchment Outlet (lbs./year)	Average Percent Reduction
Bioreactor071000060202	Biofiltration	0.03	0.07	50.76	71.91	0	0.00%	308.71	259.32	84.00%	16.86	0	0.00%
SaturatedBuffer071000060202	Biofiltration	0.01	0.02	77.23	106.28	0	0.00%	462.81	388.76	84.00%	25.11	0	0.00%
CBS071000060202	Filtration	0	0	34.1	0.99	0.49	49.49%	3.23	1	30.96%	0.18	0.04	22.22%
RiparianFunctionMSB071000060202	Filtration	0	0	789.11	1,219.36	341.81	27.97%	4,888.61	494.19	10.11%	262.08	17.97	6.86%
RiparianFunctionSSG071000060202	Filtration	0	0	429.9	1,332.59	331.65	24.89%	5,244.14	448.32	8.55%	291.75	16.78	5.75%
GrassWaterways071000060202	Protection	0	0	302.6	925.48	925.48	100.00%	3683.44	3683.44	100.00%	205.83	205.83	100.00%
RiparianFunctionDRV071000060202	Protection	0	0	6.24	19.41	19.41	100.00%	82.94	82.94	100.00%	4.22	4.22	100.00%
RiparianFunctionSBS071000060202	Protection	0	0	8.9	24.77	24.77	100.00%	110.65	110.65	100.00%	6.19	6.19	100.00%
Depressions071000060202	Storage	7.8	15.8	82.59	120.09	66.37	55.27%	488.58	186.25	38.12%	27.37	10.1	36.90%
DrainageMgmt071000060202	Storage	13.49	26.45	258.24	386.55	173.35	44.85%	1,568.85	483.77	30.84%	87.09	16.55	19.00%
NRW071000060202	Storage	35.37	72.37	386.61	640.98	179.81	28.06%	2,298.20	467.09	20.32%	125.73	16.37	13.02%
WASCOBBasin071000060202	Storage	6.78	14.05	77.26	106.55	17.82	16.72%	409.37	38.94	9.51%	23.16	1.25	5.40%

Figure 5. Flow chart for ingesting ACPF results into PTMApp - Desktop

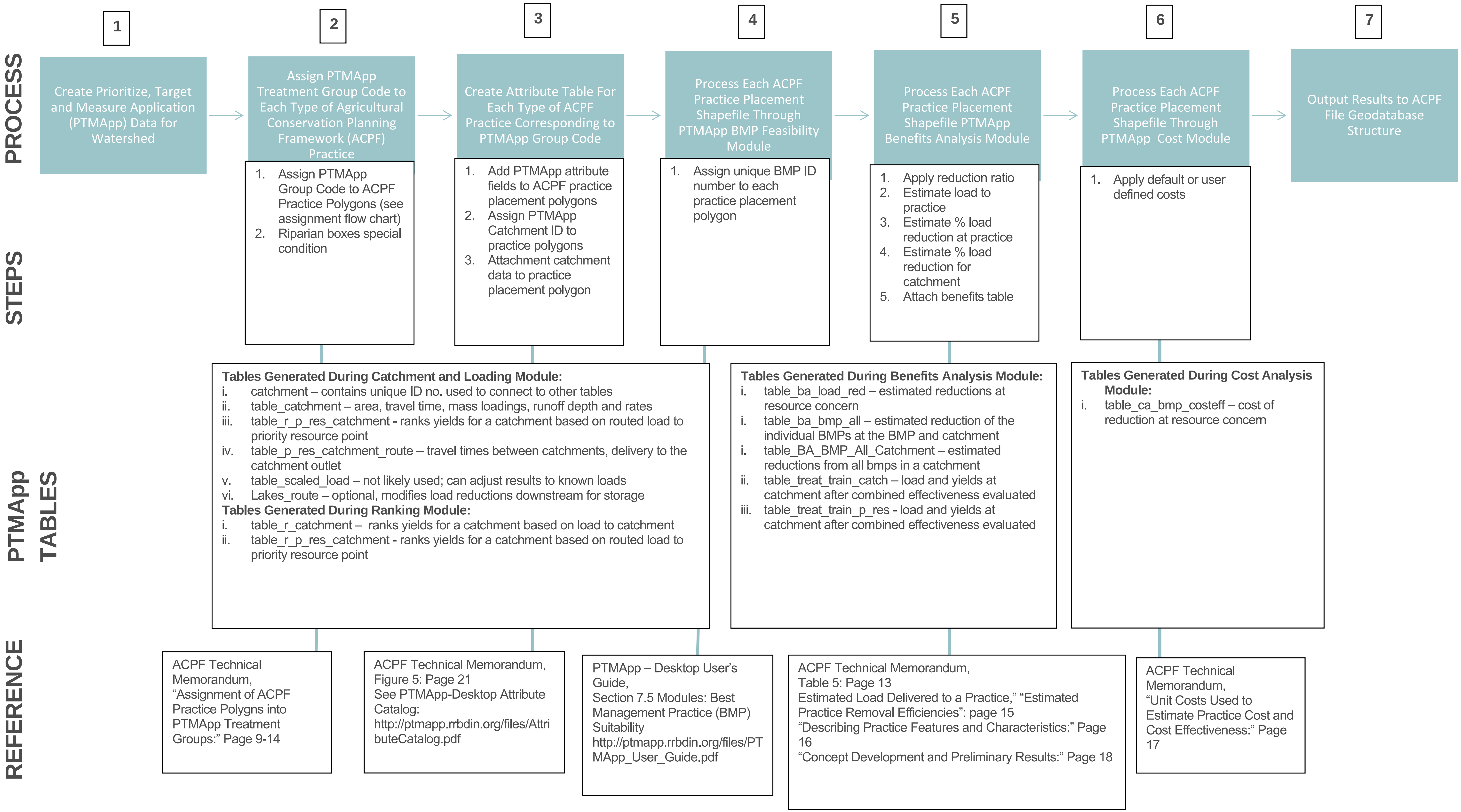


Figure 6. Test Area (Headwaters Cedar Creek) and Locations of Interest (Priority Resource Points – green dots).

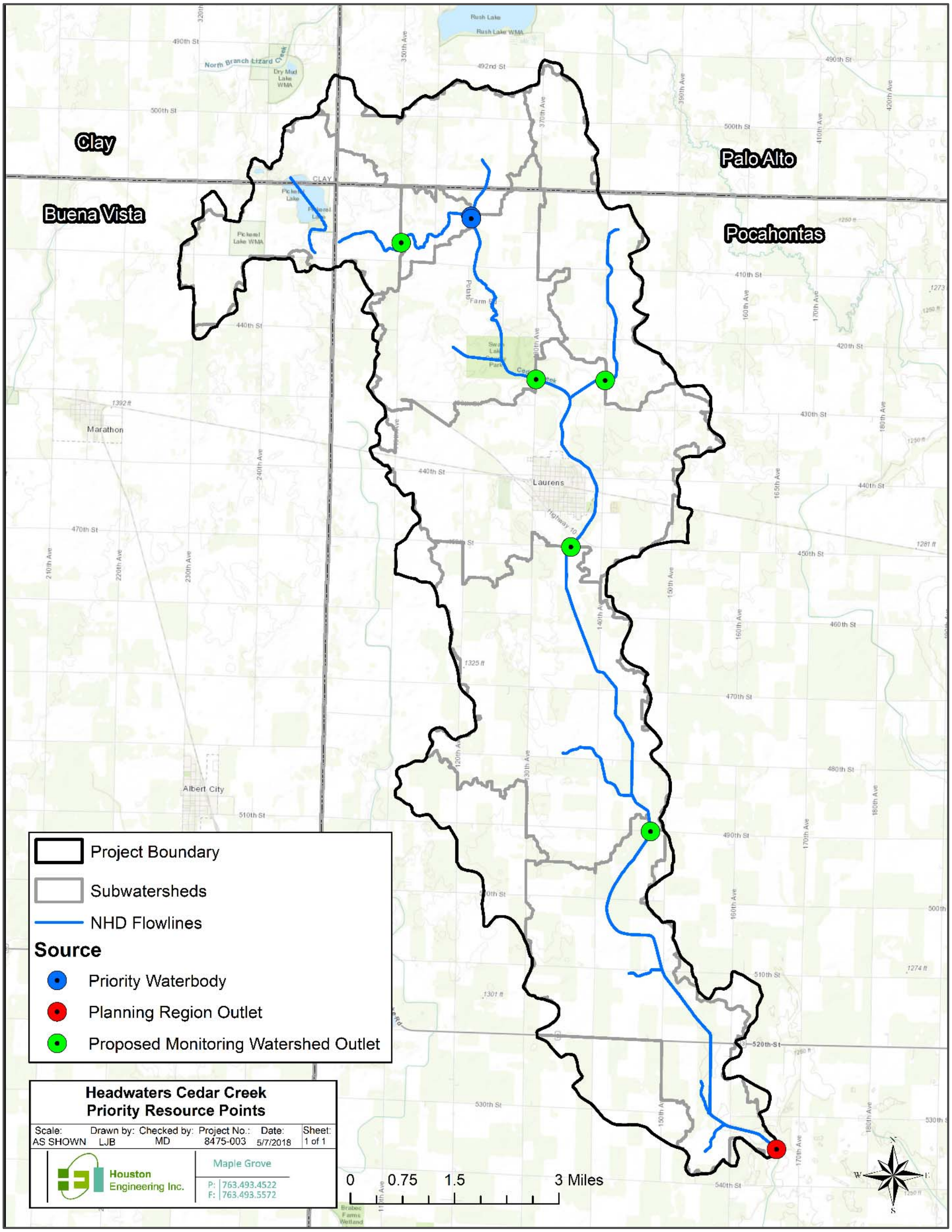
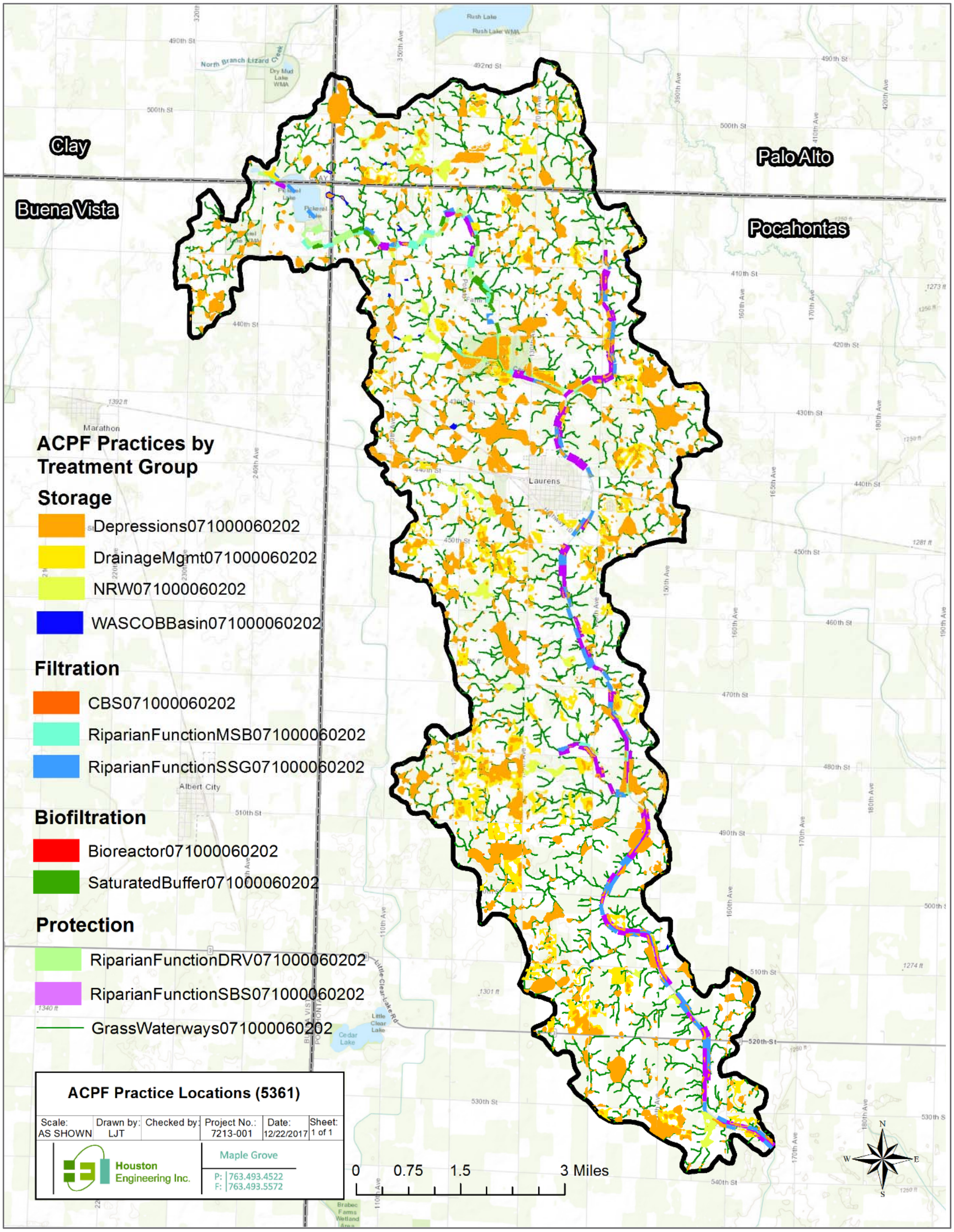


Figure 7. ACPF Practice Locations by Treatment Group.



Depending on the treatment group, the percentage of the mass removed by a practice is either a function of the runoff volume or peak discharge. Both the runoff depth and peak discharges are within the expected range. Curve number hydrology is used within PTMApp to estimate the amount of excess precipitation resulting in runoff. The user can specify two precipitation depths. Normally the precipitation depths for the 2-year, 24-hour and 10-year, 24-hour precipitation events are used. The 2-year, 24-hour event is used to represent average practice performance, while the 10-year, 24-hour event can be used to reflect practice design. Peak discharge is estimated using the NRCS unit hydrograph method. The runoff depths and peak discharges (**Table 9**) fall within a reasonable range.

As sediment is transported downstream, deposition and other losses occur. Nutrients are transformed and reduced through various biogeochemical pathways. The amount of reduction within PTMApp during downstream transport is a function of travel time (i.e., the longer the travel time the larger the reduction). The proportion of the mass delivered downstream is shown in **Table 11**. These results tend to fall within a reasonable range based on literature values.

Table 12 shows data that is helpful in assessing the reasonableness of practice performance. Practice performance is a function of the reduction ratio (**Table 7**) and the ability of the practice to treat runoff based on the amount of water received. The reduction ratios represent practice performance based on monitoring data and can be adjusted to match NRS ranges.

The percent reductions of several practices seem low compared to typical literature values. These low values are a consequence of how ACPF practice placement polygons are related to the flow accumulation raster within the underlying PTMApp data. **Figure 8** shows an ACPF bioreactor polygon relative to the flow accumulation raster. **Figure 9** shows an additional example of a saturated buffer and riparian practice along a waterway. The flow accumulation cell within the largest value within the practice placement polygon is used to estimate the drainage area, load delivered to the practice, runoff volume, and peak flow rates reaching the practice. In some cases, the practice polygon crosses a drainage divide or intersects multiple flow lines. The low estimated removals are typically caused by practice placement polygons intersecting the flow accumulation raster with drainage areas that exceed typical drainage area design criteria. One approach to address the issue is to only retain practices that fall within a predetermined drainage area range (e.g., for bioreactors greater than 5 acres and less than 100 acres).

Some practices, primarily those along a stream channel, cross one or more PTMApp catchment boundaries. The reason is PTMApp catchments (or subwatersheds) are defined at the field scale. These practices could be split to remain wholly in a catchment.

Figure 8. Bioreactor practice polygon (blue square) and flow accumulation raster representing the water flow path (blue lines). Each cell in the flow accumulation raster represents the amount of area upstream of the location. The largest cell value within the practice polygon is used to attribute the practice with the drainage area, amount of water received, and loads delivered to the practice.

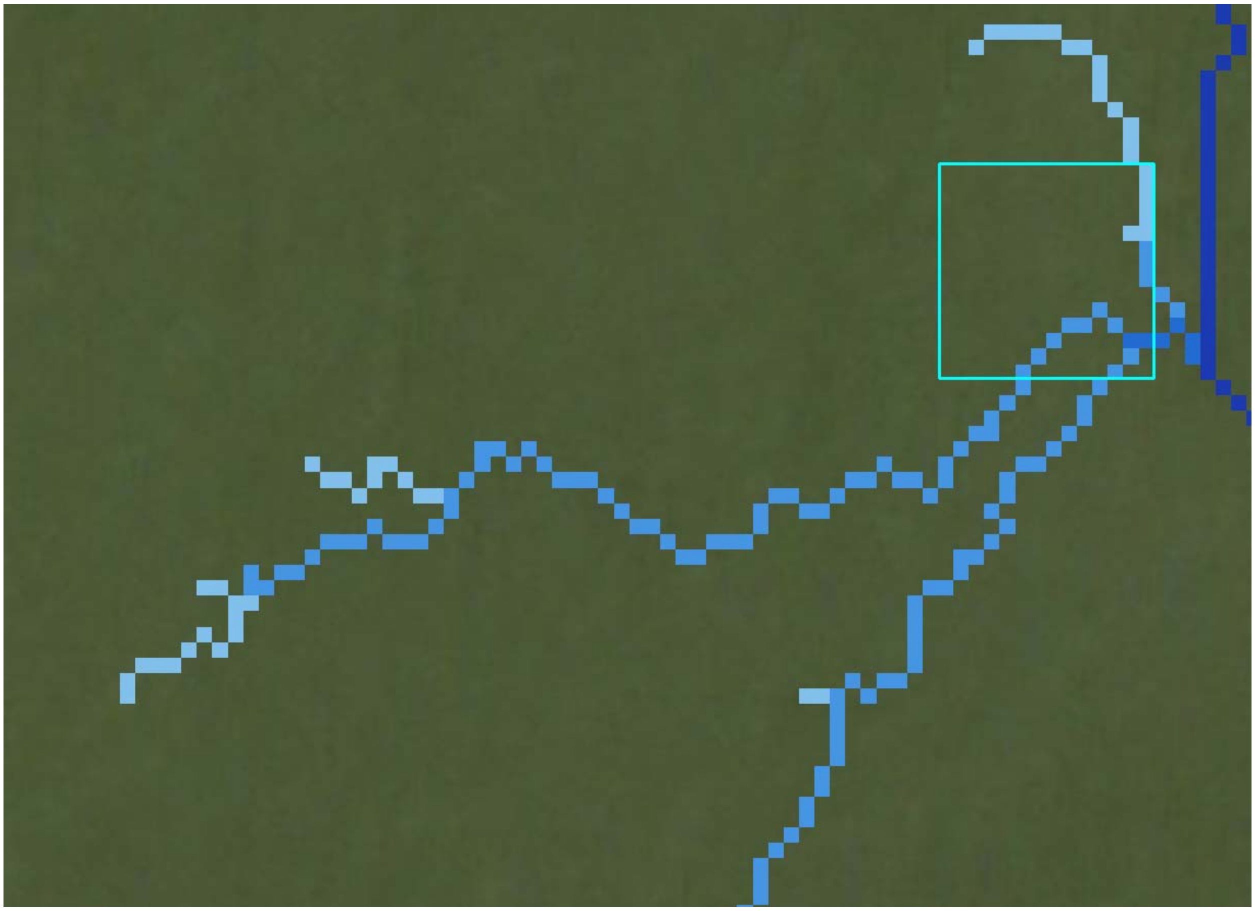
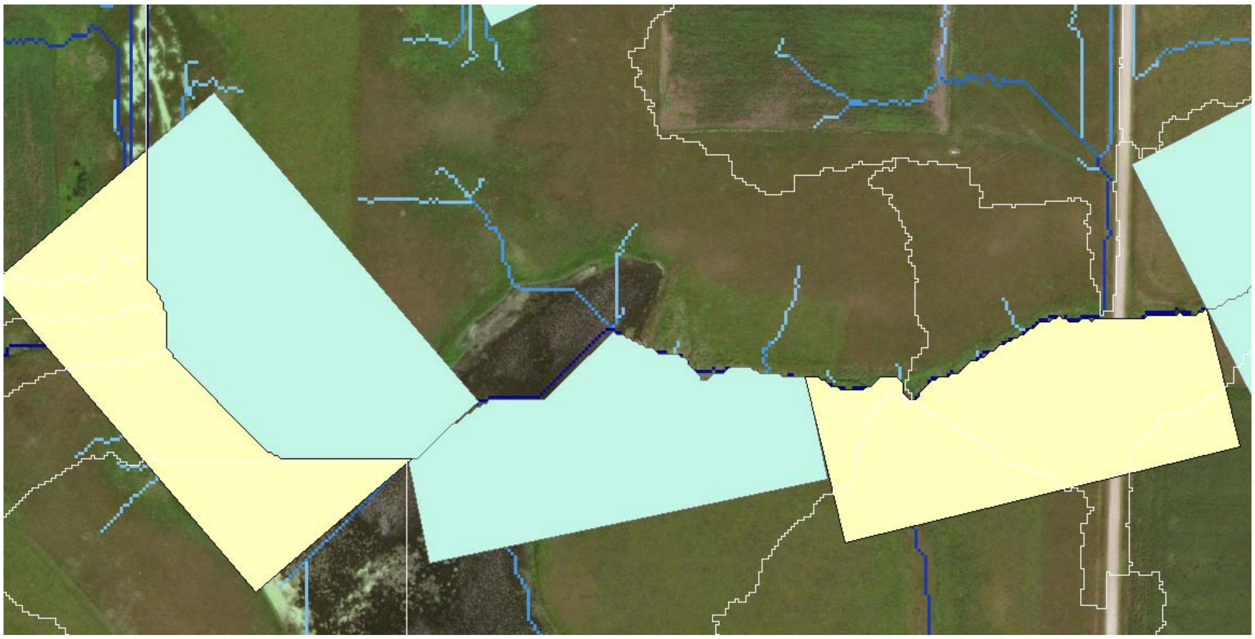


Figure 9. Saturated buffer practice (green polygon) and riparian box locations (yellow polygon) relative to the flow accumulation raster representing the water flow path (blue lines). Each cell in the flow accumulation raster represents the amount of area upstream of the location. The largest cell value within the practice polygon is used to attribute the practice with the drainage area, amount of water received, and loads delivered to the practice.



CONCEPT REVIEW WORKSHOP

Workshops were used to solicit technical input during concept development for attributing ACPF practice polygons using PTMApp. Workshops were completed on January 4, 2018 and March 2, 2018. The initial workshop includes staff from the ARS, the IAWA, and Houston Engineering, Inc (HEI).

Workshop participants concluded that attributing the ACPF practice polygons using PTMApp is technically feasible and identified several issues that are addressed by this project or will be resolved in the future. The primary issue for future resolution is modifying the amount of water and loads delivered to practices that primarily treat subsurface flows. The primary technical issues identified for this project included:

- the need to separate surface and subsurface hydrology and loads delivered to practices for nitrogen (e.g., bioreactors that treat tile runoff);
- how ACPF practice placement feature classes are assigned to PTMApp treatment groups and the equations used to estimate load reductions;
- how the ACPF practice polygons relate to the flow accumulation grid within the ArcGIS environment; and
- the preferred method to assign practice costs.

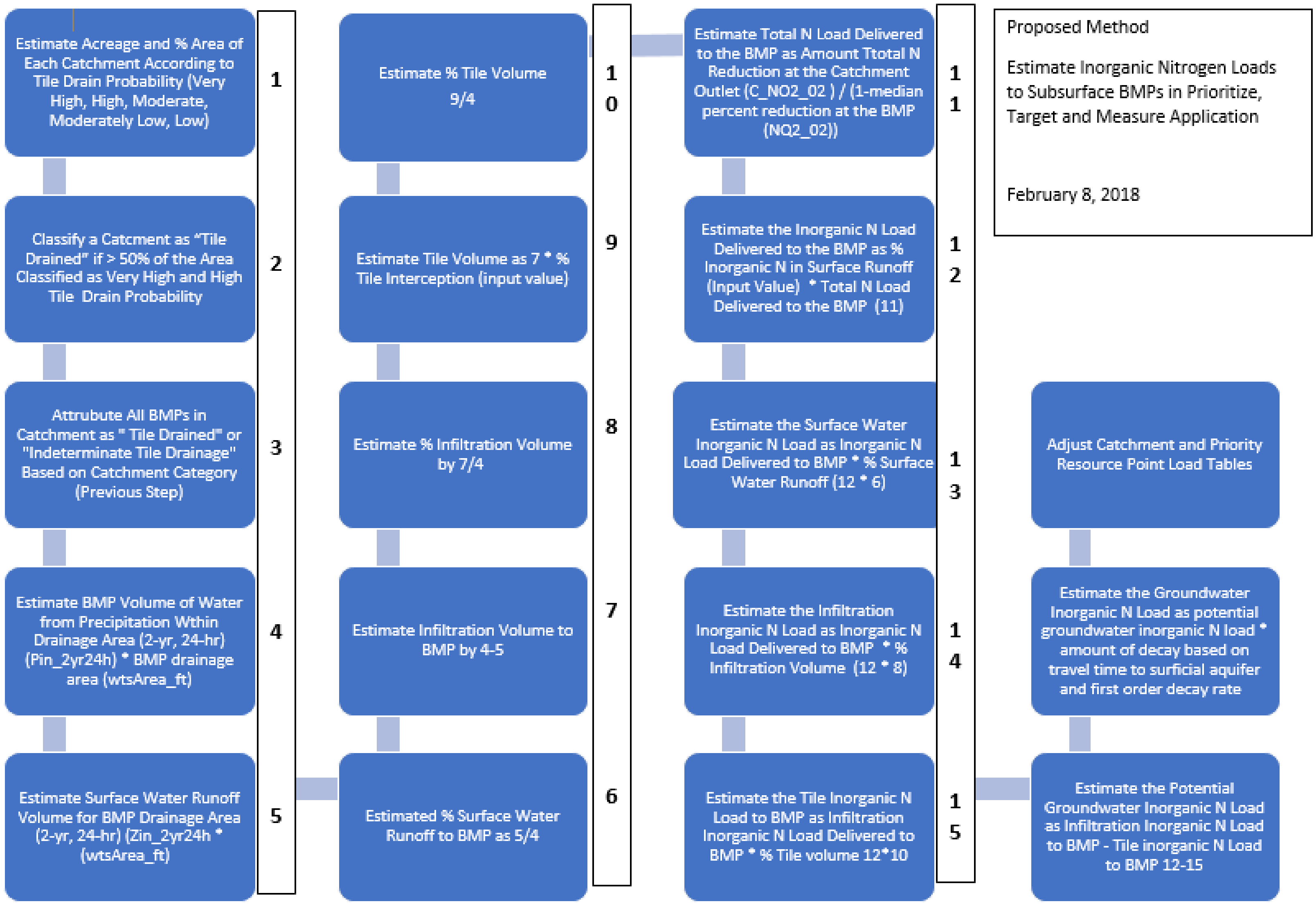
Only surface water hydrology is included within PTMApp, although the infiltration depth is estimated. Two important edge of field practices being used in Iowa to treat water leaving agricultural land are bioreactors and controlled drainage. These practices treat water that moves through the soil horizon and is intercepted by subsurface tile. The amount of water reaching and the loads delivered to these practices using PTMApp are overestimated. The amount of water reaching and the loads delivered to the biofiltration treatment group were adjusted using the process described by **Figure 10** following the development of the standard products (note: **Figure 10** is not reflected in the ACPF ingest code) to reflect subsurface water movement.

PTMApp includes six treatment groups. Each treatment group is intended to represent the physical, chemical, and biological processes that reduce sediment and nutrient mass. Workshop participants noted that some BMPs function by reducing the slope length, specifically contour buffer strips (and in some cases water and sediment control basins). PTMApp lacks a treatment group that reflects a reduction of the slope length. PTMApp constrains the percentage load reduction for each treatment group based on literature value (see **Table 7**) but adjusts the reduction based on the ability of the practice to treat runoff. Sensitivity analysis showed adjusting the LS value within the RUSLE equation results in an estimated sediment removal within the same range for contour buffers as estimated by PTMApp.

Both ACPF and PTMApp generate and use a flow accumulation raster developed from the hydro-conditioned DEM flow direction raster. The ACPF practice placement polygon location is attributed with the amount of water and load delivered using the PTMApp flow accumulation raster. The ACPF and PTMApp flow accumulation rasters generally agree, though there are some small differences. These small differences can be important, especially depending on the relationship between the practice placement polygon from ACPF and the PTMApp flow accumulation raster. ACPF practice placement polygons are sometimes located on a flow accumulation grid value with a drainage area smaller or larger than the practice can effectively be sited. Some practice placement polygons generated by ACPF are identified as being located within a field, rather than a specific physical location.

Based on workshop guidance and to address how the practice placement polygon relates to the flow accumulation raster, ACPF practice placement polygons were attributed using the field boundary feature class within ACPF. The ACPF practice placement polygons sizes or locations were not modified. Rather, the ACPF field boundaries were used to “search” within a field to identify the locations with flow accumulation cell values meeting specific criteria. For example, bioreactors are intended to be placed on tile lines with a drainage area greater than 5 and less than 100 acres. The tile flow path was assumed to follow the surface flow accumulation raster and the field boundary polygon search to find the flow accumulation cell values meeting the greater than 5- and less than 100-acre condition. The bioreactor practice placement polygon was then attributed using this location, rather than the maximum cell value intersecting the practice placement polygon. Drainage water management practice placement polygons were considered “real” only if more than 50% of a field had a slope less than 2%. A drainage water management practice placement polygon was attributed using the largest value within the flow accumulation raster for the portion of the field with a slope equal to or less than 2%. Demonstrating whether ACPF practice placement polygons can be attributed using PTMApp is one of the purposes of this project. One additional future consideration is whether the crop rotation raster from ACPF can be used to parameterize the cover management and practice factors within the RUSLE incorporated into PTMApp. An additional enhancement may be a new treatment group to represent those practices that reduce the LS values within RUSLE. Additional review of the differences between ACPF and PTMApp flow accumulation rasters is also needed. Assuming quality edge of field load monitoring data are available by crop rotation, the default nutrient yield values could be modified.

Figure 10. Diagram showing methods for adjusting total nitrogen loads to subsurface BMPs, primarily bioreactors and saturated buffers.



INGEST ACPF FILE GEODATABASE DOCUMENTATION

Twelve layers obtained from the Headwaters Cedar Creek HUC-12 ACPF products are present within the Processing_ACPF geodatabase (**Table 13**). These twelve layers have been set up with the correct architecture for PTMApp-Desktop and run through benefits analysis. Attributes that predicted nutrient and sediment loading to the practice as well as nutrient and sediment load reduction, potential, and cost efficiencies for implementation are present. The associated benefits tables that contain these loading and load reduction data are outlined in **Table 13** (summarized in **Table 12**). Available data related to each conservation practice also includes volume of water treated, average curve number of contributing practice area, watershed area, volume, or velocity of water delivery for 2-year and 10-year, 24-hour precipitation events (see **Table 12**). Descriptions for all attributes contained within all layers and tables within both the PTMApp base, processing, and planning geodatabases as well as the Processing_ACPF database have been provided for reference in **Appendix C**.

Table 13. Processing_ACPF Geodatabase Benefits Tables.

Table Name	Description
table_ba_bmp_all	Benefits analysis BMP table for all BMPs.
table_BA_BMP_All catchment	Table showing one set of values per BMP treatment group for each watershed.
table_ba_load_red	Table with loading reductions at the resource of concern.
table_ca_bmp_costeff	Table with BMP cost effectiveness data.
table_p_res_catchment	Loading priority resource watershed and/or plan regions table.
table_p_res_catchment_route	Routing calculation table for priority resource watersheds.

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APPENDIX A: PTMAPP GIS DATA CATALOG

Appendix A: Base Data Geodatabase Products

Data Name	Description	Data Type	Source
bound_cnty	County Boundaries	Shapefile - Polygon	MGC
bound_huc10	HUC10 Watershed Boundary	Shapefile - Polygon	USDA
bound_huc12	HUC12 Watershed Boundary	Shapefile - Polygon	USDA
landuse	2011 National Land Cover Database (8 Bit signed integer)	Raster	MRLC
mn_rainfall_10	Iowa Statewide Rainfall - 10yr 24-hr Atlas 14 (32 Bit floating point; Inches X 1000)	Raster	NOAA
mn_rainfall_2	Iowa Statewide Rainfall - 2yr 24-hr Atlas 14 (32 Bit floating point; Inches X 1000)	Raster	NOAA
nhd_flow	NHD Flowline Data	Shapefile - Line	USGS
nwi	National Wetland Inventory	Shapefile - Polygon	USFWS
table_treat	Lookup table to match BMP groups and efficiencies.	Table	PTMApp

Appendix A: Planning Geodatabase Products

Data Name	Description	Data Type	Source
bound_1w1p	Plan boundary	Shapefile - Polygon	User
p_res_pts	Priority resource point locations	Shapefile - Line	User

Appendix A: Processing Geodatabase Products

Data Name	Description	Data Type	Source
biofiltration	Locations suitable for biofiltration practices.	Shapefile - Polygon	PTMApp
bmp_biofilt	Locations suitable for biofiltration practices. Areas not suitable are nulled. Each suitable location has a unique integer value generated from the binary grid using region groups. (32 bit unsigned integer)	Raster	PTMApp
bmp_filtration	Locations suitable for filtration practices. Areas not suitable are nulled. Each suitable location has a unique integer value generated from the binary grid using region groups. (8 bit unsigned integer)	Raster	PTMApp
bmp_infiltration	Locations suitable for infiltration practices. Areas not suitable are nulled. Each suitable location has a unique integer value generated from the binary	Raster	PTMApp

Data Name	Description	Data Type	Source
	grid using region groups. (8 bit unsigned integer)		
bmp_prot	Locations suitable for protection practices. Areas not suitable are nulled. Each suitable location has a unique integer value generated from the binary grid using region groups. (8 bit signed integer)	Raster	PTMApp
bmp_sred	Locations suitable for source reduction practices. Areas not suitable are nulled. Each suitable location has a unique integer value generated from the binary grid using region groups. (8 bit unsigned integer)	Raster	PTMApp
bmp_storage	Locations suitable for storage practices. Areas not suitable are nulled. Each suitable location has a unique integer value generated from the binary grid using region groups. (8 bit unsigned integer)	Raster	PTMApp
bound_1w1p	Boundary for 1W1P planning area.	Shapefile - Polygon	PTMApp
watershed	Individual hydrologic watershed boundaries.	Shapefile - Polygon	PTMApp
watershedraster	Grid representing the location of watersheds with cell values equal to the catch_id attribute. (8 bit unsigned integer)	Raster	PTMApp
cti	Compound topographic index. Cells are relative dimensionless values. (64 bit double precision)	Raster	PTMApp
curve_num	Curve number raster. (8 bit signed integer)	Raster	PTMApp
ds_fl	Downstream flow length in meters. (32 bit floating point)	Raster	PTMApp
ds_tt	Accumulated downstream travel time in hours. (32 bit floating point)	Raster	PTMApp
fac_surf	Flow accumulation from surface contributing area only. (32 bit floating point)	Raster	User
fac_total	Flow accumulation from fill all. (32 bit floating point)	Raster	User
fdr_surf	Flow direction raster from surface contributing area only. (8 bit unsigned integer)	Raster	User
fdr_total	Flow direction raster from fill all. (8 bit unsinged integer)	Raster	User
fill_dem	DEM from fill on agree DEM in meters. (32 bit floating point)	Raster	PTMApp

Data Name	Description	Data Type	Source
filtration	Locations suitable for filtration practices.	Shapefile - Polygon	PTMApp
hyd_dem	Hydrologically conditioned digital elevation model in meters. (32 bit floating point)	Raster	PTMApp
infiltration	Locations suitable for infiltration practices.	Shapefile - Polygon	PTMApp
ls_factor	Length-Slope factor calculated and used in RUSLE. (32 bit floating point)	Raster	PTMApp
overland_sdr	Delivery ratio of sediment to the flow line as a percent of sediment deliverd to a concentrated flowpation 1 = 100%. (32 bit floating point)	Raster	PTMApp
p_res_watershed	Priority resource hydrologic watershed boundaries and/or plan regions.	Shapefile - Polygon	PTMApp
p_res_pts	Point locations of priority resources and/or plan regions, with water quality goals in attributes.	Shapefile - Point	User
p_res_snap	Watershed outlet point of priority resource and/or plan regions. (8 bit signed integer)	Raster	PTMApp
PeakQ_10yr	Peak flow from upstream contributing drainage area for 10-yr 24-hour event in cubic feet per second. (32 bit floating point)	Raster	PTMApp
PeakQ_2yr	Peak flow from upstream contributing drainage area for 2-yr 24-hour event in cubic feet per second. (32 bit floating point)	Raster	PTMApp
pp_watershed	Outlet pour points for watersheds. Values represent Catch_ID. (32 bit unsigned integer).	Raster	PTMApp
protection	Locations suitable for protection practices.	Shapefile - Polygon	PTMApp
raw_dem	Non-conditioned digital elevation model in meters. (32 bit floating point)	Raster	PTMApp
RO_vol_10yr	Runoff volume from upstream contributing drainage area for 10-yr 24-hour event in cubic feet. (64 bit double precision)	Raster	PTMApp
RO_vol_2yr	Runoff volume from upstream contributing drainage area for 2-yr 24-hour event in cubic feet. (64 bit double precision)	Raster	PTMApp
runoff_depth_10	Runoff depth associated with the 10-yr 24-hour event in inches. (32 bit floating point)	Raster	PTMApp
runoff_depth_2	Runoff depth associated with the 2-yr 24-hour event in inches. (32 bit floating point)	Raster	PTMApp

Data Name	Description	Data Type	Source
rusle_c	RUSLE - Cover management factor. Values typically 0.002 to 0.2 (32 bit floating point)	Raster	User
rusle_kw	RUSLE - Soil erodibility factor. Values typically 0.05 to 0.4 (32 bit floating point)	Raster	User
rusle_m	RUSLE - m-weight factor. Typically assinged to a value of 1 unless local knoweldge available (8 bit signed integer)	Raster	User
rusle_p	RUSLE - Support practice factor. Typically assinged to a value of 1 unless local knoweldge available (8 bit signed integer)	Raster	User
rusle_r	RUSLE - rainfall-runoff erosivity factor. (32 bit floating point)	Raster	User
Sed_mass	Sediment mass leaving the landscape adjusted by calibration factor (tons/acre/year). (64 bit double precision)	Raster	PTMApp
Sed_mass_fl	Sediment mass delivered to the watershed outlet (tons/acre/year). (32 bit floating point)	Raster	PTMApp
Sed_mass_fl_acc	Sediment mass delivered to the watershed outlet and accumulated to the watershed outlet (tons/year). (64 bit double precision)	Raster	PTMApp
Sed_mass_fl_rank	Rank of sediment reaching the flow line. (32 bit foating point)	Raster	PTMApp
Sed_mass_rank	Rank of sediment leaving the landscape. (32 bit foating point)	Raster	PTMApp
Sed_mass_raw	Sediment mass leaving the landscape (tons/acre/year). (64 bit double precision)	Raster	PTMApp
slope	Slope of the raw DEM as a percent. (32 bit floating point)	Raster	PTMApp
sourcreduction	Locations suitable for Source Reduction practices.	Shapefile - Polygon	PTMApp
spi	Stream power index. (32 bit floating point)	Raster	PTMApp
spi_ranks	Rank of the SPI file. (32 bit floating point).	Raster	PTMApp
sssurgo_cpi	SSURGO - Crop Productivity Index. (8 bit signed integer)	Raster	User
ssurgo_dtgw	SSURGO - Depth to groundwater. (8 bit unsigned integer)	Raster	User
ssurgo_hs	SSURGO - Hydric Soils (binary). (8 bit signed integer)	Raster	User
storage	Locations suitable for Storage practices.	Shapefile - Polygon	PTMApp
table_adj_watershed	Adjoint watershed table.	Table	PTMApp
table_adj_watershed_route	Routing calculation table for adjoint watersheds.	Table	PTMApp

Data Name	Description	Data Type	Source
table_ba_bmp_all	Benefits analysis BMP table for all BMPs.	Table	PTMApp
table_BA_BMP_All Watershed	Table showing one set of values per BMP treatment group for each watershed.	Table	PTMApp
table_ba_load_red	Table with loading reductions at the resource of concern.	Table	PTMApp
table_ca_bmp_costeff	Table with BMP cost effectiveness data.	Table	PTMApp
table_watershed	Watershed table.	Table	PTMApp
table_p_res_watershed	Loading priority resource watershed and/or plan regions table.	Table	PTMApp
table_p_res_watershed_route	Routing calculation table for priority resource watersheds.	Table	PTMApp
table_r_watershed	Ranking watershed table (sediment, TP, TN, WQI), ranking based on 1W1P boundary.	Table	PTMApp
table_r_p_res_watershed	Ranking watershed table (sediment, TP, TN, WQI), ranking based on priority resource boundaries.	Table	PTMApp
TN_mass	TN mass leaving the landscape (lbs/acre/year). (64 bit double precision)	Raster	PTMApp
TN_mass_fl	TN mass delivered to the watershed outlet (lbs/acre/year). (32 bit floating point)	Raster	PTMApp
TN_mass_fl_acc	TN mass delivered to the watershed outlet and accumulated to the watershed outlet (lbs/year). (64 bit doubl precision)	Raster	PTMApp
TN_mass_fl_rank	Rank of nitrogen reaching the flow line. (32 bit floating point)	Raster	PTMApp
TN_mass_rank	Rank of nitrogen leaving the landscape. (32 bit floating point)	Raster	PTMApp
TP_mass	TP mass leaving the landscape (lbs/acre/year). (64 bit double precision)	Raster	PTMApp
TP_mass_fl	TP mass delivered to the watershed outlet (lbs/acre/year). (32 bit floating point)	Raster	PTMApp
TP_mass_fl_acc	TP mass delivered to the watershed outlet and accumulated to the watershed outlet (lbs/year). (64 bit double precision)	Raster	PTMApp
TP_mass_fl_rank	Rank of phosphorus reaching the flow line. (32 bit floating point)	Raster	PTMApp
TP_mass_rank	Rank of phosphorus leaving the landscape. (32 bit floating point)	Raster	PTMApp
tt_grid	Cell to cell travel time in seconds. (32 bit floating point)	Raster	PTMApp
tt_overland	Travel time in hours to the flow line. (32 bit floating point)	Raster	PTMApp
us_fl	Upstream flow length in meters. (32 bit floating point)	Raster	PTMApp

Data Name	Description	Data Type	Source
us_tt	Accumulated upstream travel time in hours. (32 bit floating point)	Raster	PTMApp
WQI_mass_fl_rank	Rank of WQI reaching the flow line. (64 bit doulbe precision)	Raster	PTMApp
WQI_mass_rank	Rank of WQI leaving the landscape. (64 bit doulbe precision)	Raster	PTMApp

1W1P- One Watershed One Plan

BMP - Best Management Practice

DEM - Digital Elevation Model

RUSLE - Revised Universal Soil Loss Equation

SSURGO - Soil Survey Geographic Database

TN - Total Nitrogen

TP - Total Phosphorus

APPENDIX B: BMP OUTPUT SUMMARY STATISTICS FOR CEDAR CREEK WATERSHED TEST AREA

ACPF Layer	PTMApp Treatment Group	Metric	Summary Statistics: Sediment Reduction to Waterway (tons/yr)	Summary Statistics: Total Phosphorus Reduction to Waterway (lbs/yr)	Summary Statistics: Total Nitrogen Reduction to Waterway (lbs/yr)
GrassedWaterways071000060202	Protection	Count	3,427	3,427	3,427
		Min	0	0	0
		Max	61	3	34
		Avg	2	0	8
		Std. Dev.	3	0	7
Bioreactor071000060202	Biofiltration	Count	112	112	112
		Min	0	-4	0
		Max	33	0	273
		Avg	4	0	7
		Std. Dev.	6	1	31
CBS071000060202	Filtration	Count	112	112	112
		Min	0	0	0
		Max	54	22	834
		Avg	9	4	78
		Std. Dev.	12	4	108
Depressions071000060202	Storage	Count	1,233	1,233	1,233
		Min	0	0	0
		Max	1,829	255	1,753
		Avg	53	8	50
		Std. Dev.	144	22	139
DrainageMgmt071000060202	Storage	Count	126	126	126
		Min	0	0	0
		Max	4,163	539	2,313
		Avg	109	15	79
		Std. Dev.	396	52	239
NRW071000060202	Storage	Count	42	42	42
		Min	5	0	0
		Max	569	64	281
		Avg	104	12	51
		Std. Dev.	130	15	72
RiparianFunctionDRV071000060202	Protection	Count	32	32	32
		Min	0	0	0
		Max	5	0	3
		Avg	0	0	1
		Std. Dev.	1	0	1
RiparianFunctionMSB071000060202	Filtration	Count	26	26	26
		Min	0	1	13

ACPF Layer	PTMApp Treatment Group	Metric	Summary Statistics: Sediment Reduction to Waterway (tons/yr)	Summary Statistics: Total Phosphorus Reduction to Waterway (lbs/yr)	Summary Statistics: Total Nitrogen Reduction to Waterway (lbs/yr)
		Max	55	56	1,587
		Avg	14	9	232
		Std. Dev.	14	10	297
RiparianFunctionSBS071000060202	Protection	Count	110	110	110
		Min	0	0	0
		Max	7	0	6
		Avg	0	0	0
		Std. Dev.	1	0	1
RipariaFunctionSSG071000060202	Filtration	Count	69	69	69
		Min	0	0	2
		Max	232	109	8,829
		Avg	15	14	618
		Std. Dev.	29	22	1,580
SaturatedBuffer071000060202	Biofiltration	Count	50	50	50
		Min	0	0	0
		Max	49	0	45
		Avg	4	0	4
		Std. Dev.	7	0	9
WASCOBBasin071000060202	Storage	Count	22	22	22
		Min	0	0	0
		Max	48	5	26
		Avg	8	1	3
		Std. Dev.	14	1	7

Table	Summary Statistics			
table_ba_bmp_all	Metric	Sediment Reduction to Waterway (tons/yr)	Total Phosphorus Reduction to Waterway (lbs/yr)	Total Nitrogen Reduction to Waterway (lbs/yr)
	Count	5,887	5,887	5,887
	Min	0	-4	0
	Max	4,163	539	9,127
	Avg	16	4	102
	Std. Dev	92	16	700

Table	Summary Statistics			
table_ba_load_red	Metric	Sediment Reduction to Priority Resource (tons/yr)	Total Phosphorus Reduction to Priority Resource (lbs/yr)	Total Nitrogen Reduction to Priority Resource (lbs/yr)
	Count	5,297	5,297	5,297
	Min	0	0	0
	Max	887	113	9,122
	Avg	5	1	49
	Std. Dev	27	7	553
table_ba_load_red	Metric	Total BMP Cost		
	Count	$4,265.00		
	Min	$5		
	Max	$4,588,478		
	Avg	$ 60,661		
	Std. Dev	$292,220		

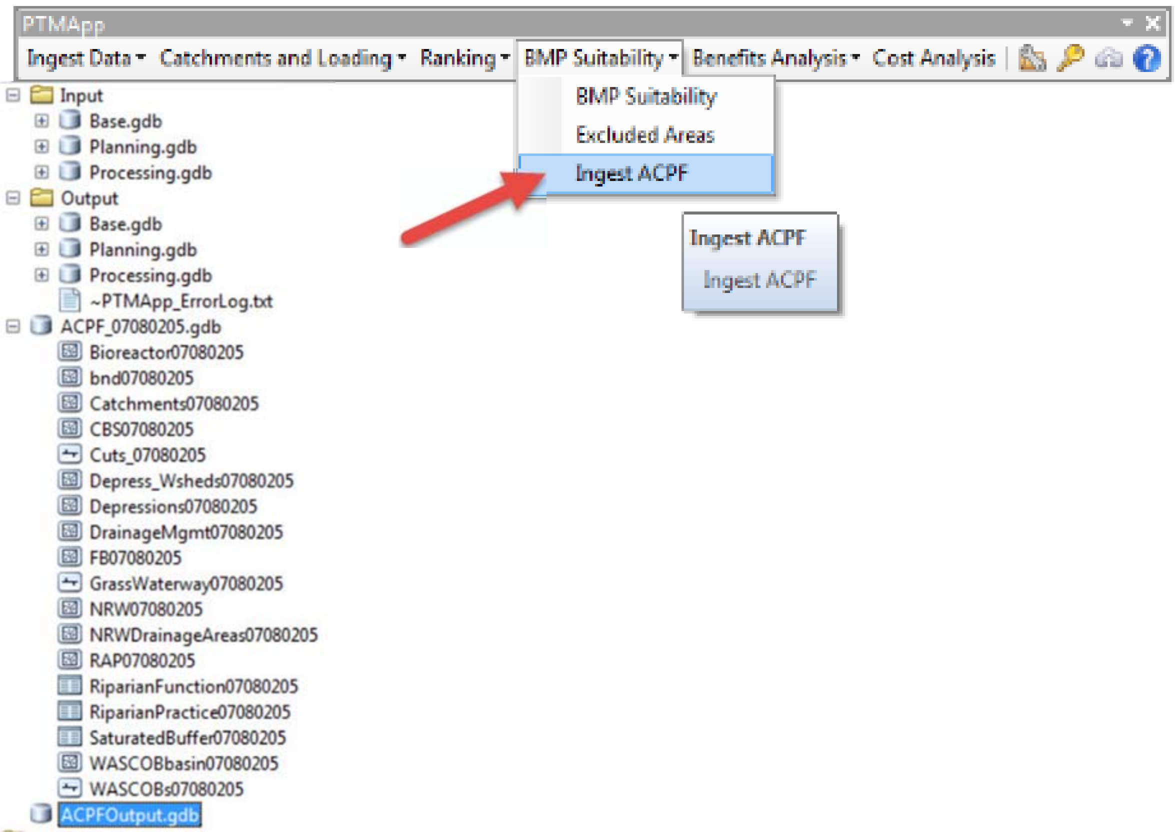
APPENDIX C: USING THE ACPF TOOLBAR

INGEST ACPF

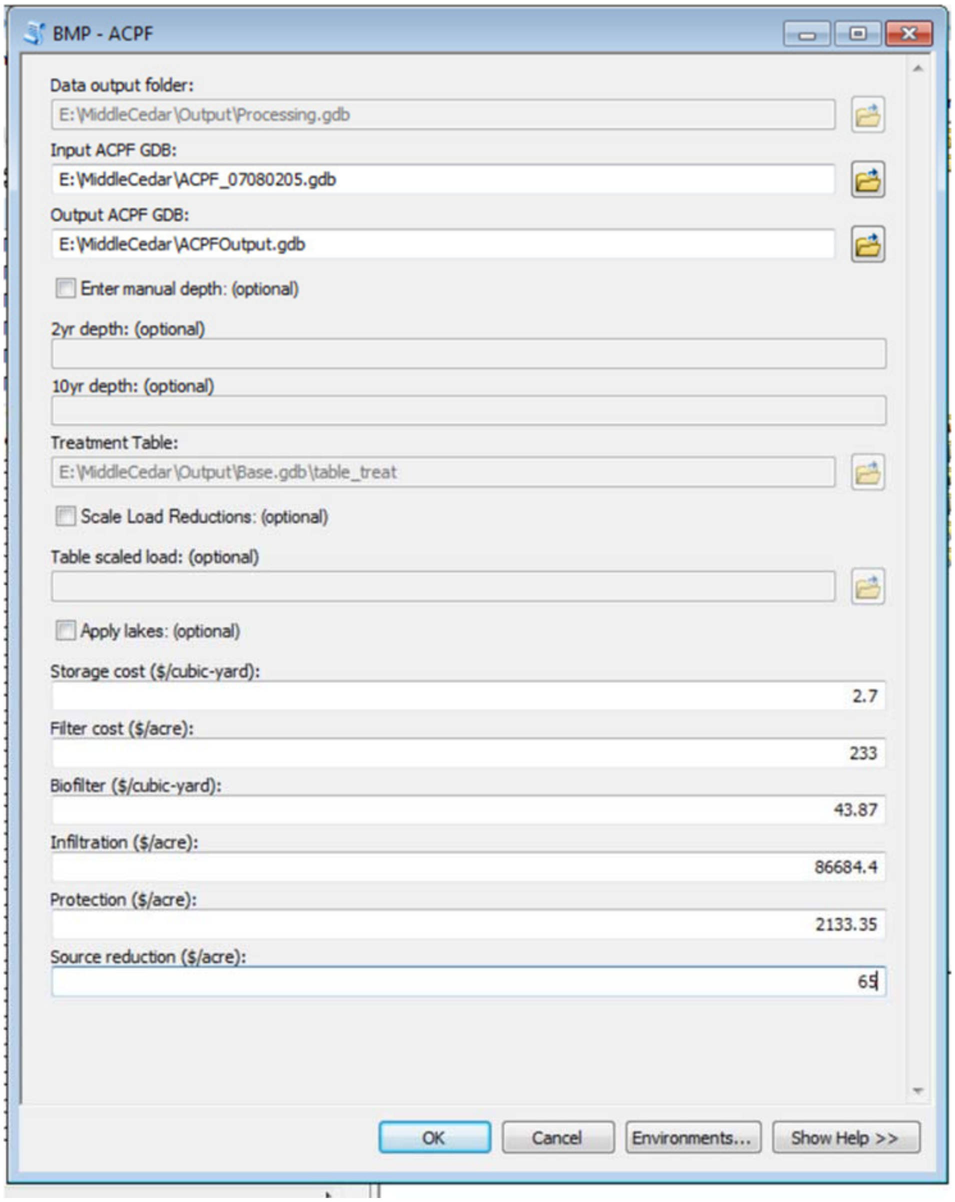
Description

This tool ingests practice polygons that were identified by the ACPF tool into PTMApp. Conservation practice placement opportunities mapped by the ACPF toolset include 13 different practices, including controlled drainage, grassed waterways, water and sediment control basins, and nutrient removal wetlands. The PTMApp attributes ACPF practices locations with water quality benefits, including constituent delivery to the practices and sediment, TN, and TN removal both locally and regionally.

☞ **HOW TO:**



a. Inputs:
   i. Output PTMApp dataset for the study area
   ii. Output ACPF dataset for the study area
   iii. Empty output file geodatabase entitled ACPFOutput.gdb
   iv. 2016 Annualized Life Cycle Cost Estimate by Treatment Type
b. Outputs:
   i. ACPFOutput: Populates geodatabase with feature class for each ACPF practice type attributed with water quality benefits and cost estimates.


BMP - ACPF
Data output folder:
E:\MiddleCedar\Output\Processing.gdb
Input ACPF GDB:
E:\MiddleCedar\ACPF_07080205.gdb
Output ACPF GDB:
E:\MiddleCedar\ACPFOutput.gdb
Enter manual depth: (optional)
2yr depth: (optional)
10yr depth: (optional)
Treatment Table:
E:\MiddleCedar\Output\Base.gdb\table_treat
Scale Load Reductions: (optional)
Table scaled load: (optional)
Apply lakes: (optional)
Storage cost ($/cubic-yard):
2.7
Filter cost ($/acre):
233
Biofilter ($/cubic-yard):
43.87
Infiltration ($/acre):
86684.4
Protection ($/acre):
2133.35
Source reduction ($/acre):
65
OK
Cancel
Environments...
Show Help >>