TECHNICAL MEMORANDUM

To: Doug Thomas,
Board of Water and Soil Resources

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Cc: Melissa Lewis, Board of Water and Soil Resources
File 4875-027

Subject: Prioritizing, Measuring and Targeting Application (PTMApp)
Methods for Estimating the Benefits of Multiple Best Management and Conservation Practices

Date: February 5, 2015

Project: 4875-027

BACKGROUND

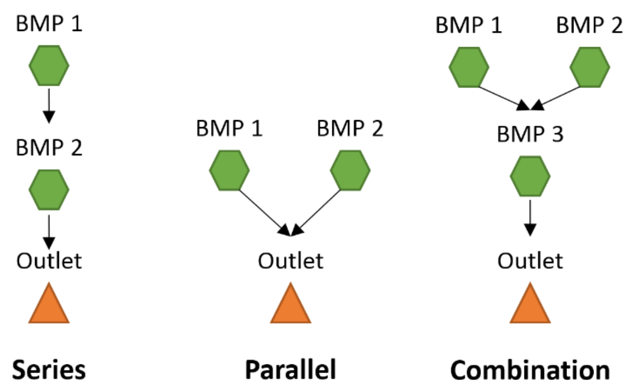
The International Water Institute (IWI) on behalf of the Red River Watershed Management Board, received a 2014 Clean Water Fund Accelerated Implementation Grant from the Board of Water and Soil Resources (BWSR) for the development of the Prioritization, Targeting, and Measuring Water Quality Improvement Application (PTMApp) (referred to as “the Project”). The stated purpose of the Project is to leverage the geospatial data created by the IWI during the completion of their 2012 Accelerated Implementation Grant (AIG) by developing, testing, and deploying an operational application for prioritizing subwatersheds and targeting fields for the implementation of nonpoint source Best Management Practices (BMPs) and Conservation Practices (CPs) based on water quality. The 2012 AIG developed methods to identify the delivery of total nitrogen, total phosphorus, and sediment to downstream water resources. The methods from the 2012 AIG grant will be adapted for the development of PTMApp. The PTMApp is also being developed, in part, to “measure” the effectives of BMPs and CPs in reducing nutrient and sediment loads. Measure means estimate the load reduction benefits.

This Technical Memorandum (TM) is one of several prepared to describe development issues and proposed direction to BWSR. These TMs serve as a communication tool to discuss, resolve and obtain concurrence with BWSR staff and others about application development. The purpose of this TM is to describe the technical methods proposed to estimate the pollutant reduction benefits (i.e., BMP and CP effectiveness) within PTMApp for multiple practices placed on the landscape. These BMPs and CPs are located in series (i.e., located from upstream to downstream order). The IWI and HEI intend to use these methods within PTMApp to “measure” BMP and CP implementation scenarios. Measure is defined here to mean the estimated combined reduction in downstream load.

PROPOSED METHODS FOR MODELING TREATMENT TRAINS

A treatment train is defined as two or more BMPs and CPs which treat a portion of the same runoff and load. The estimated treatment effectiveness of the BMPs and CPs are interdependent; i.e., the load arriving at a BMP or CP if modified by one located upstream. BMP treatment trains can occur in series and parallel, as well as a combination of series and parallel (see **Figure 1)**. **Figure 1** defines the range of potential interdependence[1] of BMPs and CPs.

Figure 1. Type of BMP treatment trains within a catchment.



The fundamental technical challenge when estimating the combined effectiveness (i.e., load reduction) of a treatment train in a geospatial environment lies in the ability to know the number and types of BMPs and CPs located upstream from a specific BMP/CP (i.e., network topology).

To estimate the load reduction at a BMP or CP both the localized load (from the intervening drainage area between a specific BMP / CP and the next upstream BMP / CP) and the load delivered from upstream BMPs and CPs needs to be known. An example, highlighting this concept, is provided below. The computational steps necessary in a geospatial environment to estimate the combined load reductions can be complex. The approach proposed for use in PTMApp results in a reasonably efficient process by using the annual load rasters (3m x 3m rasters for TP, TN and sediment) for a catchment, where the load values are the mass delivered to the catchment pour point. Once load reductions to the catchment pour points are estimated, they can be "routed" to a downstream resource using pre-computed decay functions. A raster equal to one minus the pollutant reduction effectiveness (i.e. the BMP Delivery Factor) of the BMP / CP is applied to the annual load raster for a catchment. The BMP Delivery Factor is utilized to track the load remaining rather than the load reduced. This methodology eliminates the need for routing loads through BMPs as the routing to the catchment outlet or priority resources is already performed at the raster cell scale. The following section describes how treatment trains (series, parallel, and combinations) are handled within PTMApp.

[1] The treatment effectiveness of BMPs and CPs located in separate catchments are independent, and therefore their combined removal is additives moving downstream.

TREATMENT TRAINS: CALCULATING LOAD REDUCTIONS

The general equations used to estimate the annual load reduction from a treatment train (**Figure 1)** are as follows:

Series
$$L_O = L_{BMP1}d_1d_2 + L_{BMP2}d_2$$

Parallel
$$L_O = L_{BMP1}d_1 + L_{BMP2}d_2$$

Combination
$$L_O = L_{BMP1}d_1d_3 + L_{BMP2}d_2d_3 + L_{BMP3}d_3$$

where L_O is the annual load delivered to the catchment pour point after being reduced by the combined effectiveness of the upstream BMPs, L_{BMPn} is the annual load delivered to BMP n from its upstream drainage area, and d_n is the proportion of the load reaching the n th BMP (BMP n) that is delivered to catchment pour point (i.e., BMP delivery factor). The structure of these equations requires that in order to estimate the overall load reduction at the catchment pour point (or a priority resource), the annual load raster for the catchment of an individual BMP must have the BMP delivery factor applied to the raster. Likewise, if the cell of a raster falls within the drainage area of multiple BMPs (i.e. overlapping BMPs) then the BMP delivery factor are applied multiplicatively.

TREATMENT COST ESTIMATES

The cost of implementing BMPs and CPs will be estimated based upon 2014 U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) payment rates, and are based upon a per unit area basis. The payments used for each BMP treatment category are shown in **Table 1**. These payments do not necessarily reflect the true total cost of installing and maintaining BMPs and CPs. The IWI and HEI suggest updating **Table 1** if better cost estimates become available.

Table 1. Treatment group per unit area cost estimates based upon EQIP rates.

Treatment Group	Reporting Unit	Price, $	Practices included in cost estimate
Storage	CuYd	$310.33	Pond, Sediment Basin, Wetland Restoration
Filtration	acre	$474.07	Conservation Cover, Conservation Crop Rotation, Contour Buffer Strips, Contour Farming, Cover Crop, Field Boarder, Filter Strip
Bio-Filtration	CuYd	$43.87	Denitrifying Bioreactor
Infiltration	ft	$3.95	Terraces
Protection	acre	$2,133.35	Critical Area Planting, Tree & Shrub Establishment
Source Reduction	acre	$30.87	Irrigation Water Mangement, Nutrient Management, Conservation Tillage

APPLYING THE THEORY IN PTMAPP

Within PTMApp the process for applying this theory is as follows:

1. Develop a raster of annual loads delivered to the catchment pour point for the catchment in which the BMP is located;
2. Develop BMP delivery factor rasters, based upon the median and interquartile range of the BMPs estimated effectiveness, for the upstream contributing drainage area for each BMP (i.e. all cells within the catchment given the BMPs BMP delivery factor value) in the catchment;
3. Multiply BMP delivery factor rasters grids together to create an overall BMP delivery factor grid.
4. Multiply the overall BMP delivery factor raster grid by the loading grid to create an applied BMP treatment train loading grid (i.e. the load that is not treated by the BMPs).

Within PTMApp, IWI and HEI intend to estimate the nutrient and sediment load reductions to areas that receive treatment from BMPs, based upon each BMP's individual effectiveness. Treatment of nutrients and sediment will be estimated by calculating load reductions for the areas treated by each BMP or CP (**Table 2**). For example, Storage practice reductions will be applied to nutrients and sediment delivered to the BMP from its' watershed, whereas Source Reduction practice (e.g. Nitrogen Management Plans) reductions will be applied to the area where the BMP is implemented. For all practice types, costs (per unit area based upon EQIP payment schedule) and benefits (i.e. load reductions) will be estimated relative to catchment pour point or resource of concern. An example calculation is provided to illustrate the proposed treatment train methods for use in PTMApp.

Table 2. Method for applying reductions by treatment group.

	Storage	Filtration	Bio-Filtration	Infiltration	Protection	Source Reduction	User Defined
Method for applying load reductions	Reductions applied to BMP watershed	Reductions applied to BMP watershed	Reductions applied to BMP watershed	Reductions applied to BMP watershed	Reductions applied area where BMP is implemented	Reductions applied area where BMP is implemented	User selects method (from those to left)

EXAMPLE CALCULATION IN THE ROOT RIVER

A catchment with high sediment delivery to the Middle Branch Root River was selected for an example treatment train calculation. Information about the potential locations for various BMPs and CPs is expected to be available either based on the BMP Suitability analysis or the user. The BMP suitability analysis was described in a companion TM titled "Prioritizing, Measuring and Targeting Application (PTMApp) Categorization of Best Management Practices and Conservation Practices for Estimating Pollutant Removal Effectiveness" (December 3, 2014). The treatment potential of each BMP considered in this example is shown in **Table 3**. Note, a portion of the catchment does not receive treatment by these BMPs. For illustration purposes it is assumed there are opportunities for Source Reduction and Filtration practices (show in blue cross hatch on **Figure1**) within the catchment. **Figure 1** shows the potential location for filtration practices. The red boundary in **Figure 1** is an area that is suitable for a source reduction practice. The black line shows the catchment boundary. These boundaries are automatically generated using the desktop ArcGIS toolbar. Catchments are delineated based upon surface hydrology and have an average size of 40 acres.

Table 3. Treatment potential of the individual BMPs.

Treatment Group	Area Treated, acres	Sediment Treatment Effectiveness (Median), %
Filtration	65	76%
Source Reduction	83	76%

The contributing drainage area to each BMP / CP is identified using geospatial processing tools (**Figure 2**) according to the methods outlined in **Table 1**. The grey area within **Figure 2** represents the catchment boundary, the black area the location of source reduction practices within the catchment, the blue line the location of proposed filtration practices and the green area the upstream drainage area contributing runoff to the filtration practices. The individual BMP efficiencies were estimated using the methods described in a companion TM titled "Prioritizing, Measuring and Targeting Application (PTMApp) Categorization of Best Management Practices and Conservation Practices for Estimating Pollutant Removal Effectiveness" (December 3, 2014). For this example calculation the median efficiencies were used for each BMP. These BMP efficiencies were then converted to a BMP Delivery Ration (described above) and applied to the areas of the watershed treated, assuming multiplicative reductions (**Figure 3**). The treatment train scenario indicated that the practices would result in a 13 Tons/year reduction in sediment delivered to the downstream resource and a total EQIP cost of $6,300, giving a treatment cost of $485/ton/year (**Figure 4**). To better illustrate how these calculations are performed, a 5 row X 7 column set of values were extracted from the treatment effectiveness, BMP Delivery Factor and RUSLE sediment yield rasters to so the measured yield remaining after the treatment was applied (**Figure 5**).

Figure 1. Targeted catchment showing opportunities for BMPs.

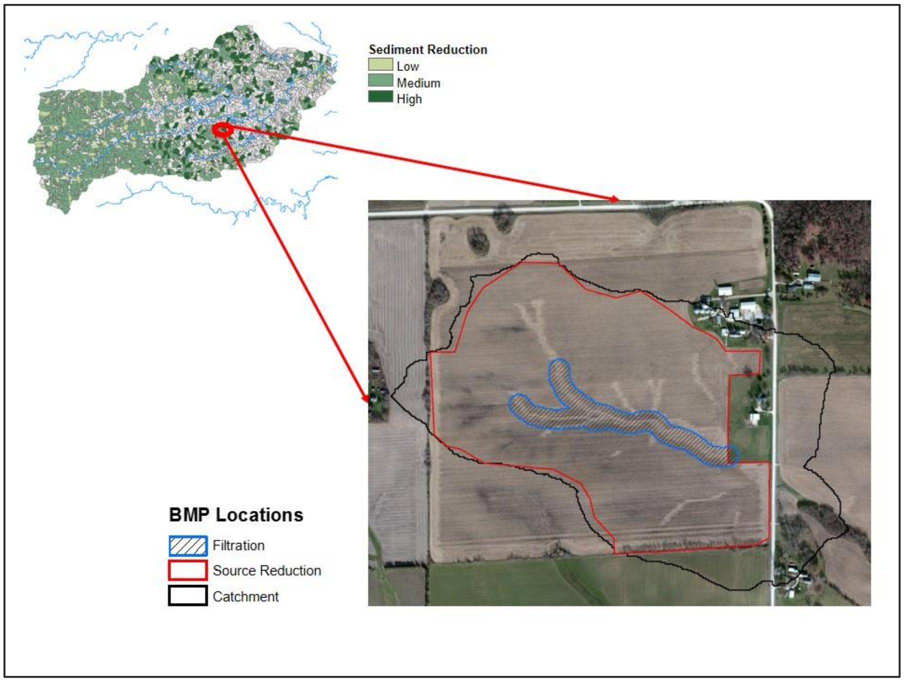


Figure 2. Areas of the watershed treated by the selected BMPs.

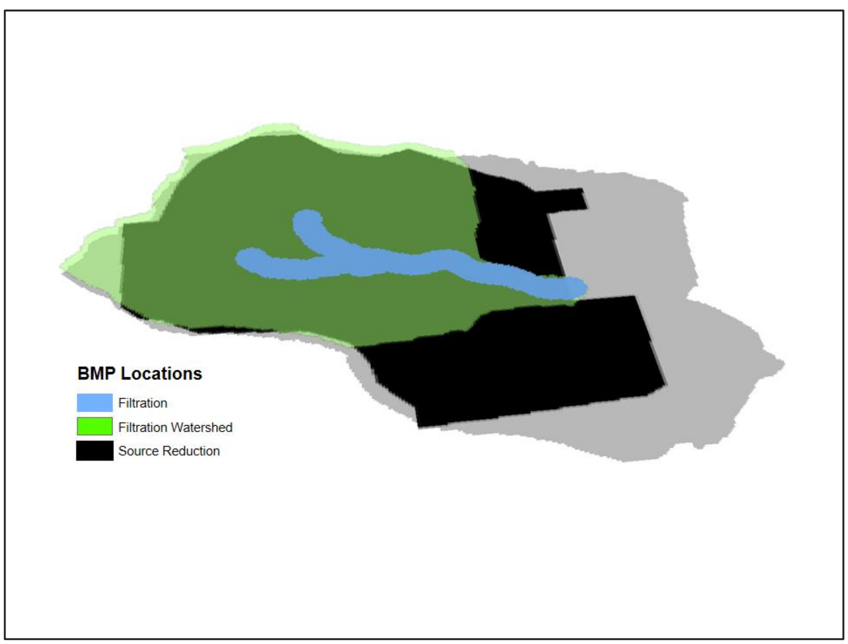


Figure 3. BMP efficiencies applied to the area of the watershed treated by the BMPs for sediment delivered to the downstream resource.

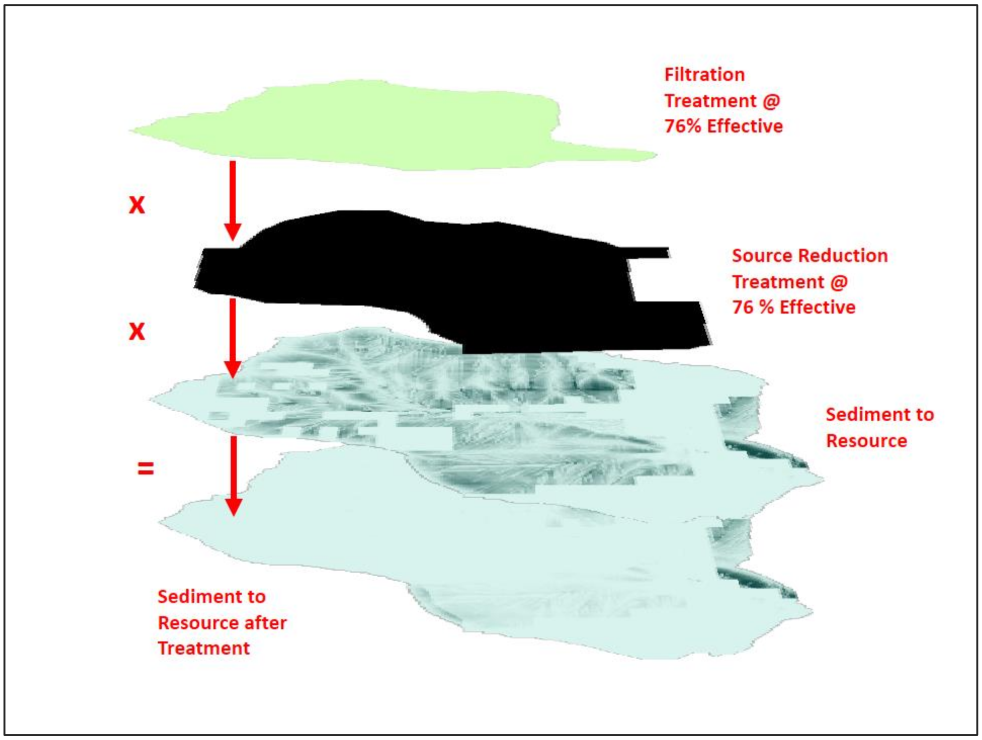


Figure 4. Resulting treatment cost of the treatment train scenario.

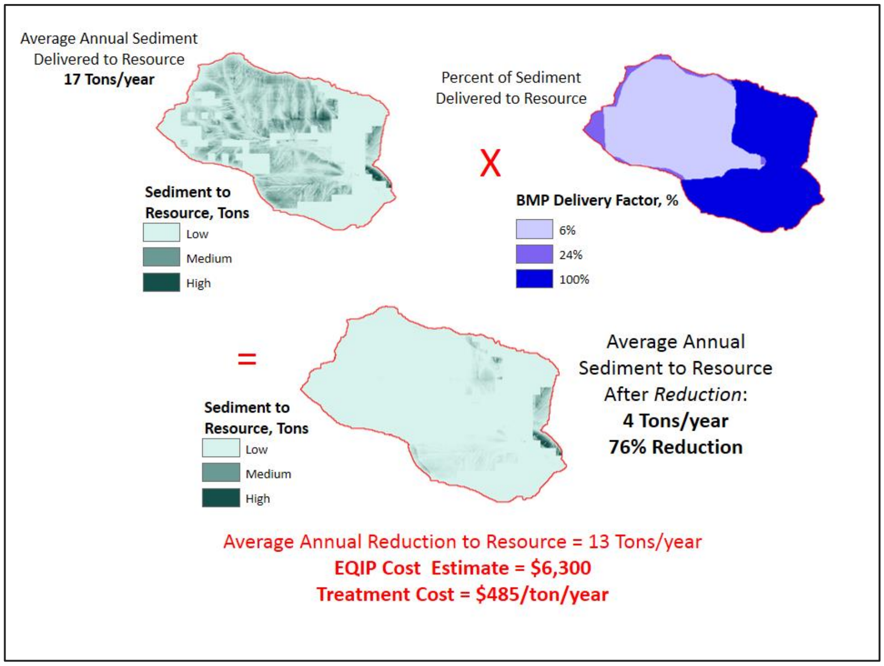


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Figure 5. Illustration of treatment train calculations showing raster cell values that result from applying the BMP Delivery Factor to RUSLE sediment yields.

BMP 1: BMP Delivery Factor: Filtration (1 - Efficiency)

24%	24%	24%	24%	24%	100%	100%
24%	24%	24%	24%	24%	24%	100%
24%	24%	24%	24%	24%	24%	100%
24%	24%	24%	24%	24%	24%	24%
24%	24%	24%	24%	24%	24%	24%

BMP2: BMP Delivery Factor: Source Reduction (1 - Efficiency)

24%	100%	100%	100%	100%	100%	100%
24%	24%	24%	100%	100%	100%	100%
24%	24%	24%	24%	100%	100%	100%
24%	24%	24%	24%	24%	100%	100%
24%	24%	24%	24%	24%	24%	24%

x

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Treatment Train: BMP Delivery Factor (Percent untreated)

6%	24%	24%	24%	24%	100%	100%
6%	6%	6%	24%	24%	24%	100%
6%	6%	6%	6%	24%	24%	100%
6%	6%	6%	6%	6%	24%	24%
6%	6%	6%	6%	6%	6%	6%

Raster No. 1 - RUSLE Sediment Yields Delivered to the Catchment Outlet (tons/acre)*

7.3	6.4	5.0	4.9	4.1	5.3	4.4
5.5	5.5	7.3	6.2	4.5	3.1	6.8
8.5	14.2	11.6	10.2	5.8	4.3	2.6
4.7	10.0	13.6	12.9	4.4	3.4	2.3
16.3	15.2	14.8	13.0	8.9	5.4	3.2

* Load delivery is estimated using a sediment delivery ratio and is described by HEI (2015).

x

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RUSLE Yield (tons/acre) Raster After Treatment

0.4	1.5	1.2	1.2	1.0	5.3	4.4
0.3	0.3	0.4	1.5	1.1	0.7	6.8
0.5	0.8	0.7	0.6	1.4	1.0	2.6
0.3	0.6	0.8	0.7	0.3	0.8	0.6
0.9	0.9	0.9	0.7	0.5	0.3	0.2

CONCLUSIONS

This TM describes the technical methods proposed to estimate the pollutant reduction benefits (i.e., BMP and CP effectiveness) within the PTMApp for multiple practices placed on the landscape. While these methods are robust for estimated the load reductions from treatment trains, the geoprocessing needed to complete the calculations is intensive. As such, IWI and HEI still need to evaluate if these methods will be transferable (i.e. due to potential computational limitations) to the web environment. In addition, these methods also assume that 100% of the proposed practices are implemented. In reality, once proposed projects are built they may be partially implemented (i.e. < 100%) or end up being greater in number or extent than originally planned (i.e. > 100%). This difference can be accounted for by rerunning the treatment train scenario with the actual extent of the conservation practice after it has been implemented. Currently, the IWI and HEI do not intend to directly account for different species of Phosphorus and Nitrogen, or different loss pathways (e.g. ground water contamination). Future work should consider the use of existing ground water models (i.e. sensitive groundwater areas) or monitoring data (i.e. for different species of nutrients) to account for this information. The IWI and HEI intend for the methods highlighted above to provide information and data products that can be utilized during 1W1P development to inform the analysis and prioritization of resources and issues impacting resources, setting measurable goals, and developing implementation strategies. In addition, these methods could also be used to tailor the plan after it has been developed. Upon agreement on these methods, the IWI and HEI will assume that the methods meet BWSR's requirements for prioritizing, targeting, and measuring as part of 1W1P development process.

These methods are open to discussion and subject to change based upon BWSRs requirements. Once finalized, the "treatment train" methods will be used for the development of the PTMApp. Future changes to the "treatment train" methods after initial establishment, could result in a need to adjust the overall project scope and timeline. We request that after review of this TM, BWSR submit any comments/preferences necessary to ensure that the "treatment train" methods are suitable for development of the PTMApp.

Acknowledgement

By initializing this TM I concur with the intended direction for application development.

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Board of Soil and Water Resources