Maple Grove, MN | HEI No. 8364_001
December 10, 2019

FROM PTMAPP TO PROJECTS

Project Scale Prioritization & Planning for Ravine Stabilization in Nicollet County

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1 INTRODUCTION

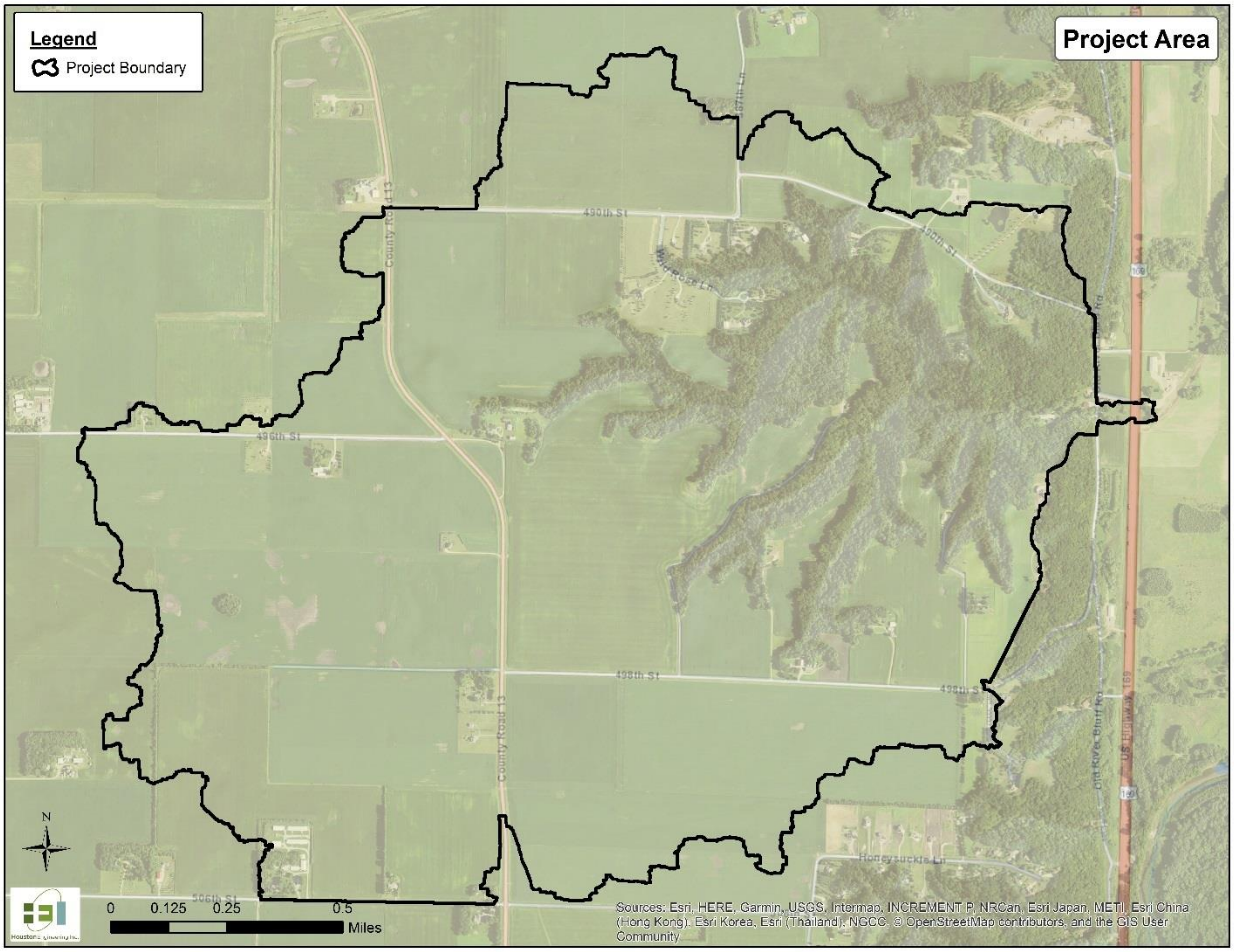
In 2016, Nicollet County underwent the process of developing a countywide dataset identifying field-scale locations of feasible best management practices (BMPs) and conservation practices (CPs). The process was done by using the Prioritize, Target, and Measure Application (PTMApp). The resulting data includes suitable locations for BMPs and CPs as well as anticipated cost and benefit (sediment and nutrient reduction) data for each practice. The resulting targeting and cost effectiveness data will be used by local government unit (LGU) staff to implement the most efficient and effective practices to meet local water quality goals.

Following the development of the countywide PTMApp dataset, the Nicollet County Soil and Water Conservation District (SWCD) began using the data to evaluate BMP and CP implementation within the county. In the fall of 2016, the Nicollet SWCD applied for and received a Board of Water and Soil Resources (BWSR) Accelerated Implementation Grant (AIG) focused on using the newly acquired PTMApp data to identify projects for implementation in a specific ravine watershed. The project area is located along the western edge of the Minnesota River valley bluff, between St. Peter and Mankato, MN, and is located on either side (north and south) of Nicollet County Road 28 between US Highway 169 and Nicollet County Highway 13 (project area). The project area is shown in **Figure 1**.

After receiving the BWSR AIG funds, the Nicollet County SWCD retained Houston Engineering, Inc. (HEI) to:

1. Assess contributing hydrology to ravine(s) within the study area as well as hydraulic and erosion issues within the ravines and along County Road 28;
2. Assess water quality issues that result from ravine erosion and that relate to the Nicollet SWCD Local Water Management Plan and the Minnesota River Turbidity Total Maximum Daily Load (TMDL);
3. Use the stakeholder input, modeling, and site assessment to prioritize erosion and water quality issues within the study area; and
4. Develop and evaluate BMP and CP implementation alternatives that can be prioritized and used to apply for implementation project funding.

Figure 1. Project area location.

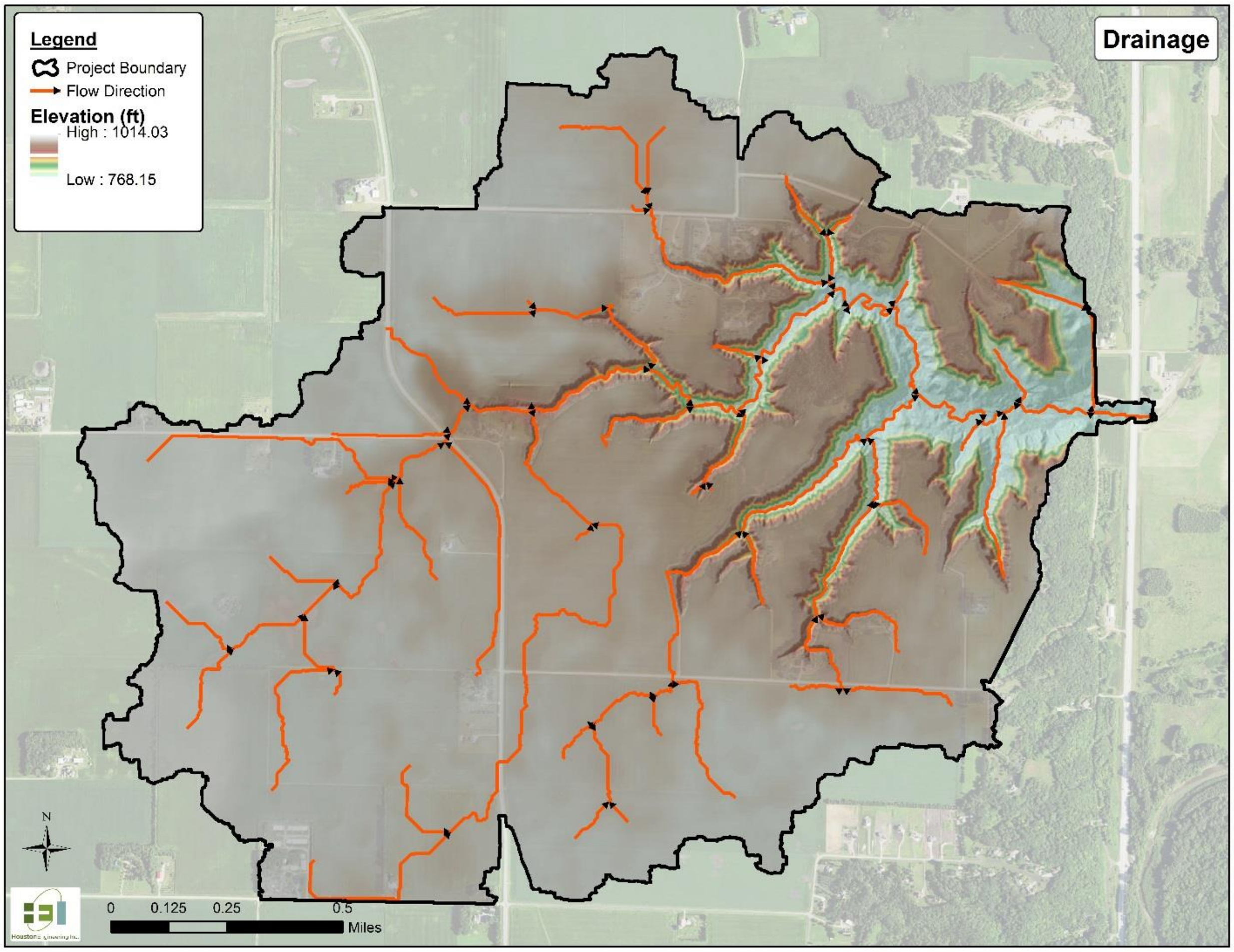


1.1 SITE DESCRIPTION

As shown in **Figure 1**, the project area is located along the western edge of the Minnesota River bluff, between the cities of St. Peter and Mankato. The Minnesota River bluff is characterized by numerous individual subwatersheds that drain west to east, down the bluff through ravine systems, and eventually under US Highway 169 (US 169) to the Minnesota River. The lands to the west of the bluffs are almost entirely agricultural and contain various drainageways, including public and private ditches and drain tile systems.

The general drainage patterns for the project area are shown in **Figure 2**.

Figure 2. Project area drainage.



1.2 PROJECT GOALS & TECHNICAL OBJECTIVES

A key initial step in a project is to develop project goals and technical objectives, based on the project purpose and stakeholder input. On November 13, 2017, HEI met with Nicollet County SWCD staff and local stakeholders (local government officials, agency officials, and project area landowners). The following sections outline the project goals and technical objectives, as determined through this meeting.

1.2.1 PROJECT GOALS

Project goals are established at the beginning of a project to ensure that all the stakeholders involved understand and agree with the desired outcome of the project. A narrative project goal describes the desired outcomes for a project. A concept or design alternative, developed as part of the project, must be able to attain the project goal to be considered feasible.

The primary goal of this project is to target and accelerate the implementation of projects that will reduce sediment and nutrient pollution to the Minnesota River either by overland contribution or through ravine erosion. Secondary goals, to be achieved through the success of the primary goal, include the reduction of road maintenance along the bluff and the general reduction of loss of private land surrounding the ravines.

1.2.2 TECHNICAL OBJECTIVES

Technical objectives are established as a series of criteria needed to obtain the project goal(s). One or more technical objectives are needed to support the project goal(s). Technical objectives are specific, measurable, actionable, realistic, and time-bound conditions that are established and used to accomplish the goal(s).

The technical objectives for this project are:

1. Gather appropriate data to inform the study area analysis and model development process, then use the results, along with past project prioritization methodology, to guide the targeting and prioritization of project locations;
2. Identify targeted project locations based on a defined set of design criteria to finalize the targeting and prioritization;
3. Use stakeholder engagement to help gather initial information, identify potential project locations, assist with stewardship, and participate in the development of the potential project concepts; and
4. Combine all the information to develop up to three conceptual BMP implementation alternatives for each final priority location. Implementation alternatives will focus on addressing reduction in runoff volumes/flow, erosion potential, and pollutant loading.

1.3 KEY ISSUES

1.3.1 SEDIMENT/NUTRIENT LOADING TO THE MINNESOTA RIVER

High levels of suspended sediment flow through the Minnesota River Basin and subsequently into the Mississippi River. The Minnesota River contributes approximately 75% of the total suspended solids (TSS) load in the Mississippi River between the Twin Cities and Lake Pepin (MPCA, 2015).

Sediment erosion in the Minnesota River Basin and its tributaries comes from four main sources (MPCA, 2019):

- Bluffs and streambanks erosion;
- Upland soil surface erosion from areas of exposed soil;
- Urban areas and other developed land uses; and
- Ravine and gully erosion.

This project allows for the targeting of improvements to three of the four sources, (the project area contains no significant urban areas or developed land uses).

The Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River (MPCA, 2015) sets interim milestones to identify the needed level of implementation efforts over specific timeframes and to gauge incremental progress. The strategy presents an interim Minnesota River milestone sediment reduction target of 25% by 2020 and a 50% reduction target by 2030.

Evidence of accelerated sediment and nutrient transport from the project area to the Minnesota River can be seen at the outlet of the project area, near US 169. Each year, the Minnesota Department of Transportation (MnDOT) removes sediment deposition from the channel to the east of the highway, to keep the channel conveyance open and reduce potential highway flooding. The channel and removed sediment pile, as of June 2019 is shown in **Figure 3**.

Figure 3. Sediment deposition and pile of removed sediment at the project area outlet near US 169.

1.3.2 RAVINE EROSION & MASS WASTING

The ravine system within the project area has experienced continued erosion and mass wasting events. Erosion is occurring throughout the ravine system but is particularly severe in several types of locations where:

- significant vegetation has not been established to reduce overland flow rates and therefore sheer stress;
- changes in slopes become more dramatic (generally known as head cuts); and
- unprotected tile drains outlet at the head of a ravine.

Mass wasting events tend to occur near the ravine/upland edges or along ravine erosion head cut walls. Mass wasting is most often caused or exacerbated by groundwater seepage. Examples of ravine erosion and mass wasting in the project area are shown in **Figure 4**.

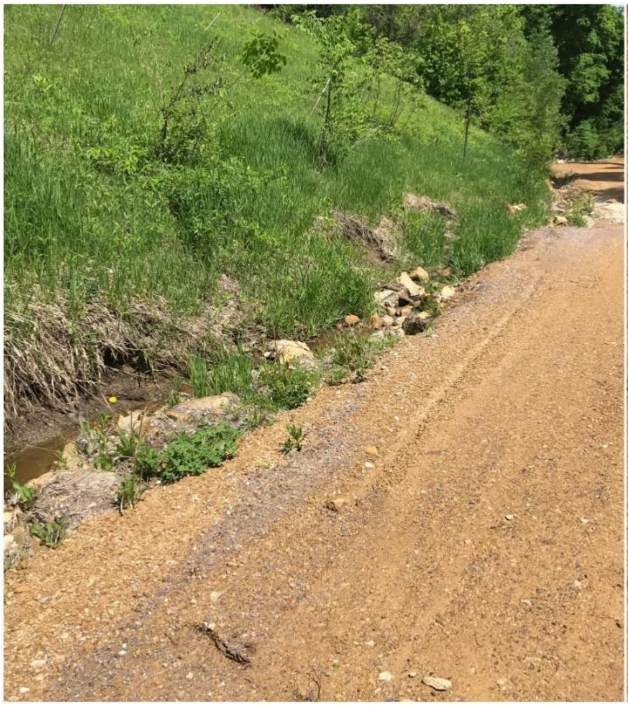
Figure 4. Ravine erosion at a head cut (left) and mass wasting along a ravine wall (right).

1.3.3 DITCH EROSION

All along the western edge of the Minnesota River Valley there are multiple roads that connect the agricultural lands above the bluff with the valley below. Businesses and residents on top of the bluff rely on these roads to access US 169. The project area includes one such road along its north edge, 490th Street (CR 28). This road is very steep, and Belgrade Township has indicated that erosion of the roadway and the ditch system requires significant maintenance. In the past, the township had considered closing the road in the winter months to reduce the maintenance costs. Erosion within the roadway ditch (particularly the north ditch) is significant as well as erosion on the road itself. Reducing ditch and roadway erosion has been identified as a secondary goal for the project.

Along with overland flow entering the ditch system, groundwater seepage has been identified within the roadway. Groundwater seepage is pushed up through the roadway, causing a loosening the compaction of the road surface (gravel) and adding to the roadway/ditch erosion issues. The ditch erosion and groundwater seepage are shown in **Figure 5**.

Figure 5. Ditch erosion along the northern side 490th Street (CR28) (left) and groundwater seepage within the roadway (right).



1.3.4 HIGH FLOWS AND BANK EROSION

Changes in hydrology and hydraulics in the project area uplands have a cumulative effect downstream near the outlet. Anecdotal information from landowners has indicated that the peak flows and overall runoff volume in the downstream portion of the project area during have increased in intensity over the past 10 years. Landowners have indicated that much larger flows are reaching the project area outlet much quicker than in the past. These increased flows are causing substantial bank erosion and channel migration throughout the bottom of the ravine system. A landowner near the outlet indicated that they have lost significant portions of their land along the channel during these large events and have been forced to bring in fill to replace the land lost. Examples of the extent to which this erosion is occurring are shown in **Figure 6**.

Figure 6. Bank erosion near the project area outlet.

2 MODELING AND ANALYSIS METHODOLOGIES

To identify and target potential projects within the project area, several different analyses were used:

- Hydrologic and hydraulic (H&H) modeling was completed to evaluate potential project impacts on runoff volumes and peak flows within the project area;
- Geotechnical and field analysis was completed to evaluate potential project sites and to gauge the extent of erosion impacts in the project area; and
- Water quality analysis was completed to determine the potential pollutant reduction benefits of potential projects.

Following these analyses, preliminary information was presented to the Nicollet SWCD and the results were used to determined final project alternatives. The following sections detail the three different types of analysis completed.

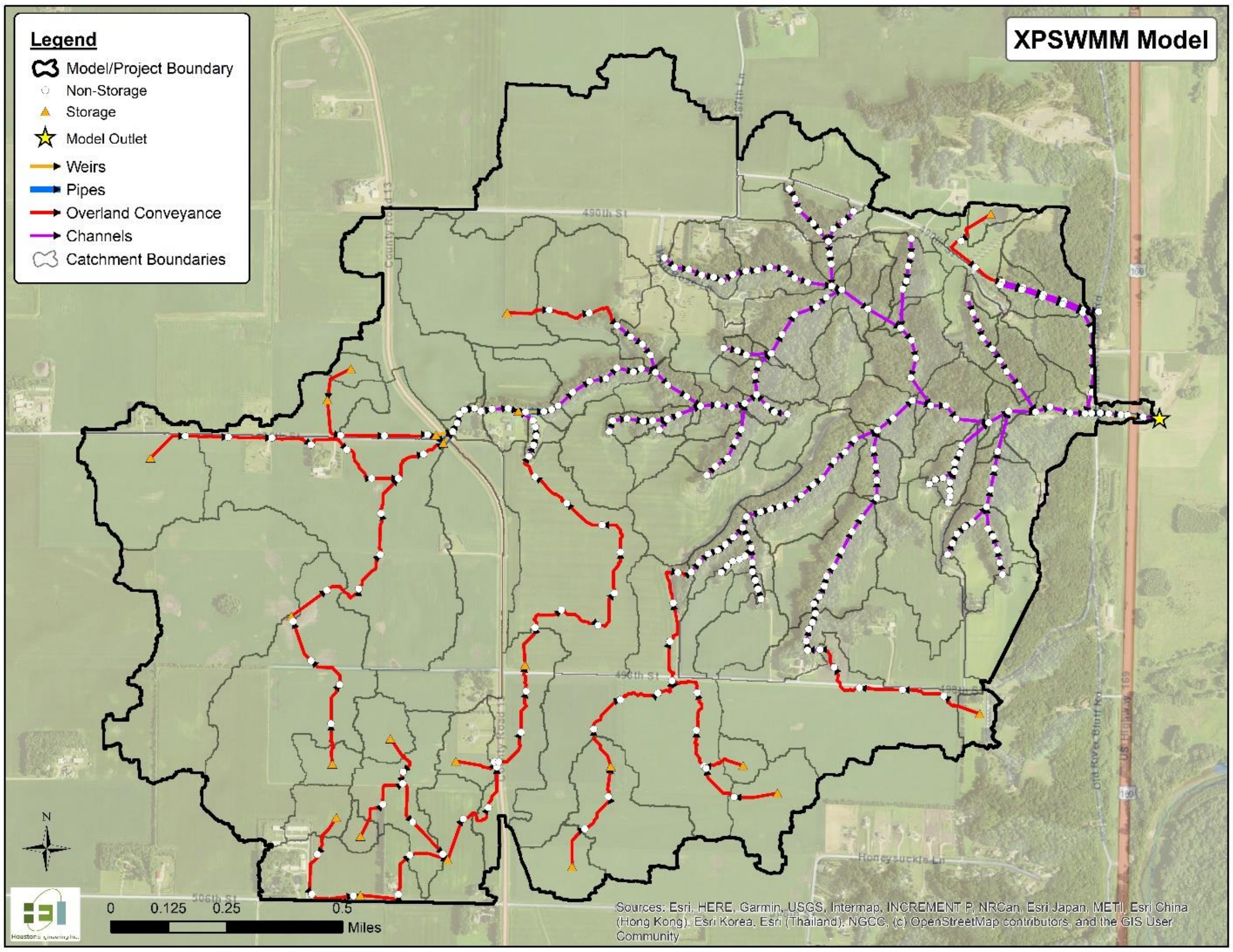
2.1 HYDROLOGIC & HYDRAULIC ANALYSIS

While the initial countywide PTMApp data does provide some information about runoff and peak flow, an H&H model is much more useful in evaluating the potential impacts that a new project will have on peak flows and overall volume passing through the ravine system. An existing conditions H&H model is built and then modified to create scenario models representative of the potential projects. The results from the scenario models are compared to the existing condition model results to evaluate the H&H impact of the projects.

2.1.1 ANALYSIS TOOL

An XPSWMM H&H model (model) was developed for the project area. A general overview of the model and its extents are shown in **Figure 7**. The model was developed using a significant amount of the existing countywide PTMApp data as the basis for the model network. This included catchment boundaries as well as various hydrologic and hydraulic data inputs. The hydrology is modeled using the SCS Method, using data directly from the PTMApp results (i.e. curve number and travel time grids). The hydraulic network for the model is based on the flow accumulation mapping from the PTMApp results and channel cross sections and storage curves were developed using the hydrologically conditioned digital elevation model (hDEM). Culvert crossings were developed based on information obtained during site visits (discussed further in **Section 2.2**).

Figure 7. XPSWMM model overview for the project area.



Synthetic storm events were used to compare project alternative impacts. Often, projects are designed based on these synthetic events, most often the 10-year, 24-hour or the 25-year, 24-hour. The synthetic storm events used in the project area model, along with their relative rainfall depths, are shown in **Table 1**. The storm events have a duration of 24 hours and use an MSE3 distribution.

Table 1. Rainfall events used in the H&H modeling.

Rainfall Type	Duration (hrs)	Event Name	Atlas 14 Total Depth (in)
MSE3	24	2-year	2.85
		10- year	4.24
		25-year	5.27
		100- year	7.09

2.1.2 EXISTING PEAK FLOWS

Once the model was developed and checked for quality assurance/quality control (QA/QC), it was primarily used to evaluate peak flow and runoff volumes at various locations throughout the project area. Peak flow and runoff volumes were examined at two key locations: the overall project area outlet and at the outlet of the site of proposed project alternative. The overall project area outlet is shown in **Figure 7**.

Analyzing the peak flows and volumes passing through the project area outlet is important because they are directly related to the issues described in **Section 1.3.4** and are a good overall metric for the way the watershed reacts to projects and practices applied to it. Regarding pollutants, evaluating impacts at the project area outlet also gives the best estimates of the project alternative impacts on water quality benefit to the Minnesota River.

The existing outflow hydrographs at the project area outlet, for the various rainfall events in **Table 1**, are shown in **Figure 8**. The peak flows and runoff volumes for these events are shown in **Table 2**.

Figure 8. Existing condition outflow hydrographs at the project outlet, for the various rainfall events.

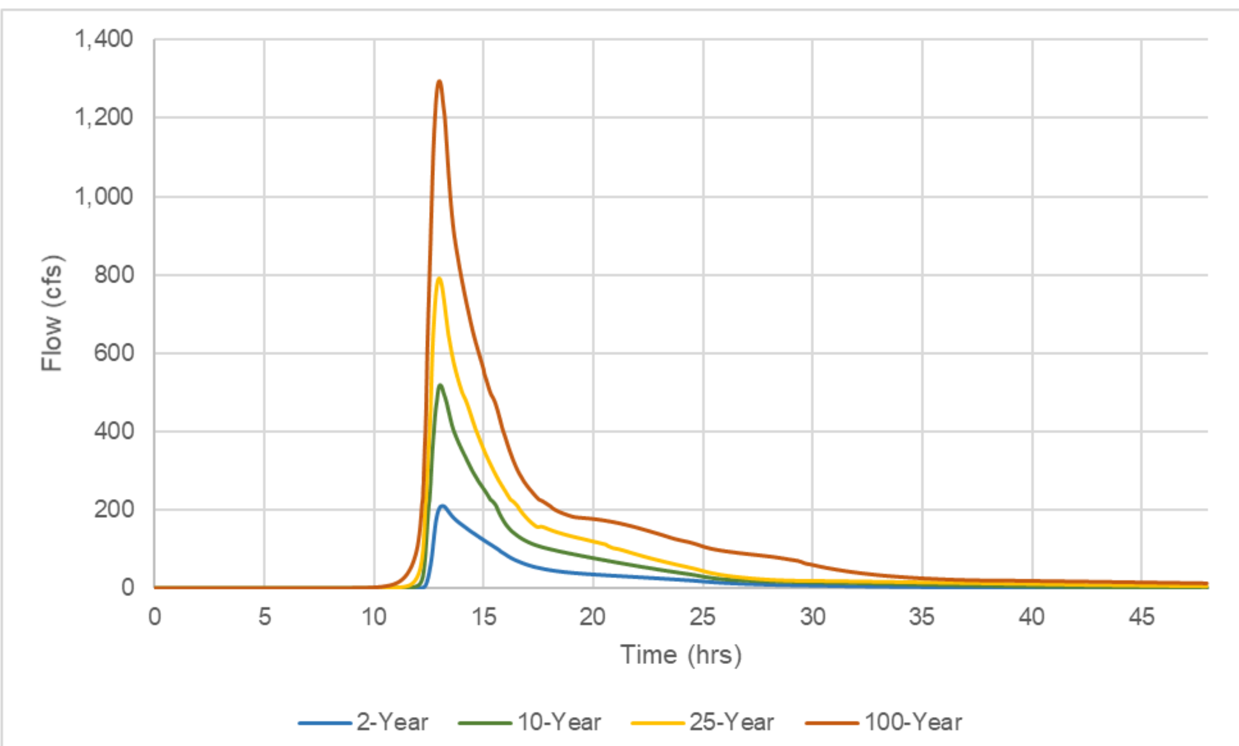


Table 2. Existing condition peak flows and outflow volumes at the project outlet, for the various rainfall events.

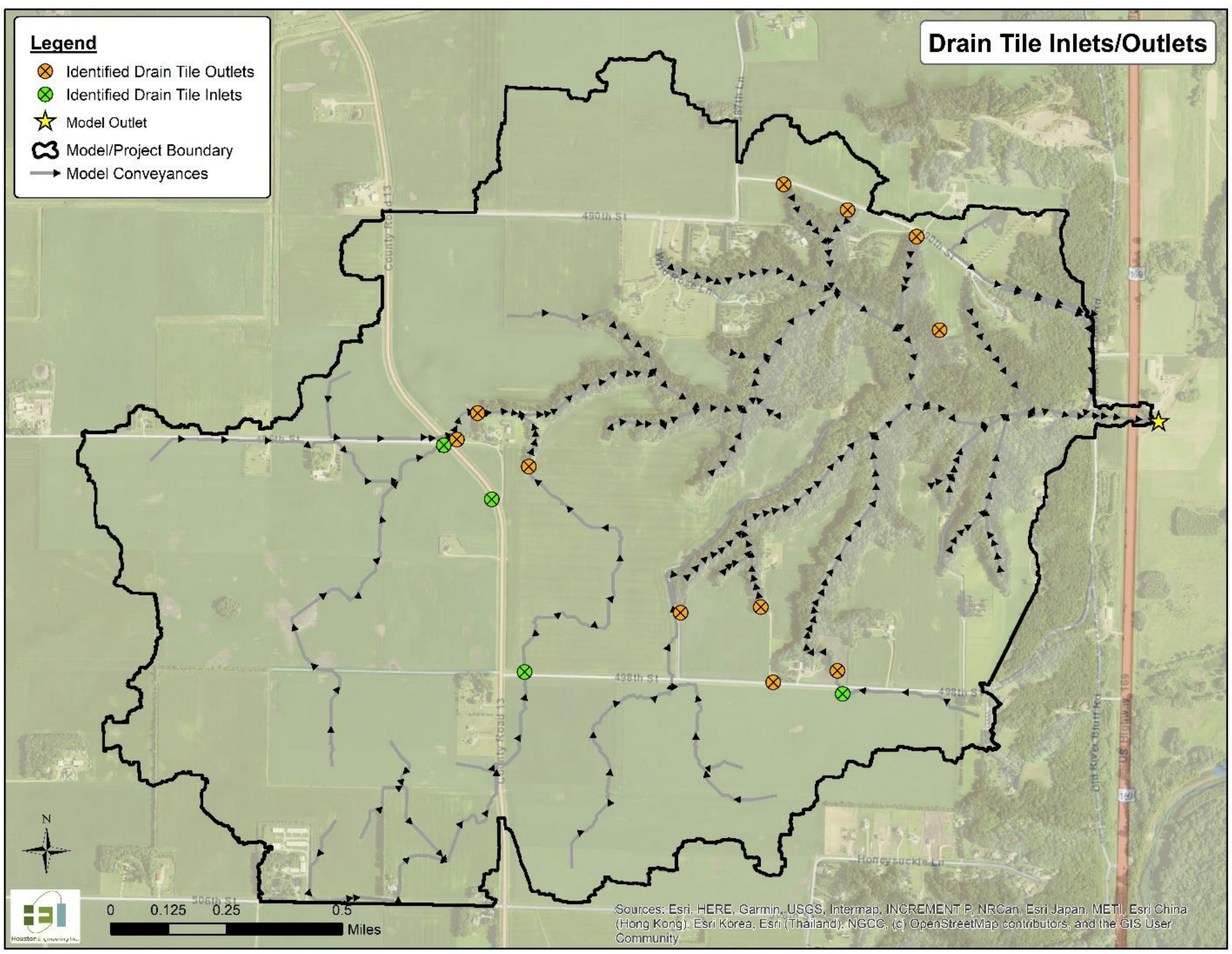
Event Name	Peak Outflow (cfs)	Outflow Volume (ac-ft)
2-year	210.3	77.85
10- year	519.0	172.64
25-year	791.3	260.38
100- year	1,294.9	447.79

These values form the baseline by which the alternative projects are evaluated as related to H&H impacts. Additionally, peak outflow and outflow volume impacts are also evaluated at the alternative project site. These existing condition results and comparisons are described in the individual alternative project discussion in **Section 3**.

2.1.3 MODELING LIMITATIONS

While efforts were made to ensure modeling accuracy (i.e. field verification of uncertain model elements), one significant uncertainty remains. During field visits with SWCD staff, multiple drain tile outlets at the head of ravines were identified as well as multiple field tile inlets along the edges of upland agricultural fields. The drain tile inlets and outlets, identified during field visits, are shown in **Figure 9**.

Figure 9. Field identified drain tile inlet and outlet locations.



The presence of these drain tiles indicates that there is significant tile drainage being routed from the surrounding area into the project area ravine system. Discussion with SWCD staff indicates that some of the drain tiles are likely mains with multiple inlets upstream. It is also possible that these drain tiles capture and route infiltrated agricultural water from beyond the project area, as it is identified in **Figure 9**. There was not enough information available from SWCD staff, regarding the extent and location of the drain tile system, to incorporate into the modeling. Therefore, these drain tile inflows are not accounted for in the modeling. The impacts these drain tiles would have on the modeling results depends highly on factors such as the soil infiltration rates into the tiles, the drainage area the tiles cover, and tile size/slope. While it is unlikely that the drain tile inflows would contribute significantly to the peak flow modeling results, the overall runoff volume would certainly be impacted. In general, the resulting hydrograph could be expected to show more volume, passing through over a longer period. It is recommended that the lack of inclusion of drain tile flow in the modeling be considered when evaluating alternatives in the project area.

2.2 GEOTECHNICAL & FIELD ANALYSIS

- Various site visits were completed during the project. Site visits were completed for multiple purposes:
- To meet local landowners and discuss erosion issues on the upland, within the ravine system, and within the conveyance channel downstream;
- To field verify locations of culvert crossing, drain tile inlets/outlets, and problem locations;
- To qualitatively evaluate soils, geotechnical conditions, and groundwater seepage within the project area; and
- To identify potential project alternative locations.

The following sections describe the results of the site visits with regards to the issues outlined above.

2.2.1 STAKEHOLDER MEETING AND FIELD VISIT

On November 13, 2017, HEI met with Nicollet SWCD staff as well as local stakeholders/landowners. During the meeting, local landowners identified key information about the project area on a map. A significant amount of the information obtained during that meeting was used in the project development. Information obtained included:

- Property owner names;
- Existing erosion and sedimentation issues;
- Existing BMPs and CPs;
- Flood prone areas;
- Tile inlets/outlets;
- Culvert locations; and
- Potential project alternative locations.

Following the meeting, several landowners accompanied HEI and SWCD staff on a field visit to view issues within the project area. These issues primarily included:

- Ravine erosion and mass wasting;
- Channel incision and sloughing near the outlet of the project area; and
- Erosion near tile outlets at the heads of ravines.

The information obtained during this visit was utilized and appears in many figures throughout this report.

2.2.2 CULVERT AND DRAIN TILE VERIFICATION

The hydrologically corrected DEM (hydro-DEM) utilized in the H&H and water quality analysis needs properly identify which direction water if flowing. A major part of this DEM being correct is the inclusion of culverts. On May 29, 2019, HEI and SWCD traveled to the project area to perform additional field checks. The purpose of the field visit was twofold:

- Identify any additional drain tiles inlets/outlets; and
- Field verify culvert locations, sizes, and shapes.

HEI verified culvert locations within the project area and cross checked them against the hydro-DEM. All culverts appear to be accounted for in the hydro-DEM, ensuring that the PTMApp water quality analysis is correct. The field verification of the culverts (size and shape) were utilized to develop the H&H model.

HEI and SWCD staff also identified drain tile inlets/outlets. This is further discussed, relative to the H&H model, in **Section 2.1.3**.

2.3 WATER QUALITY ANALYSIS

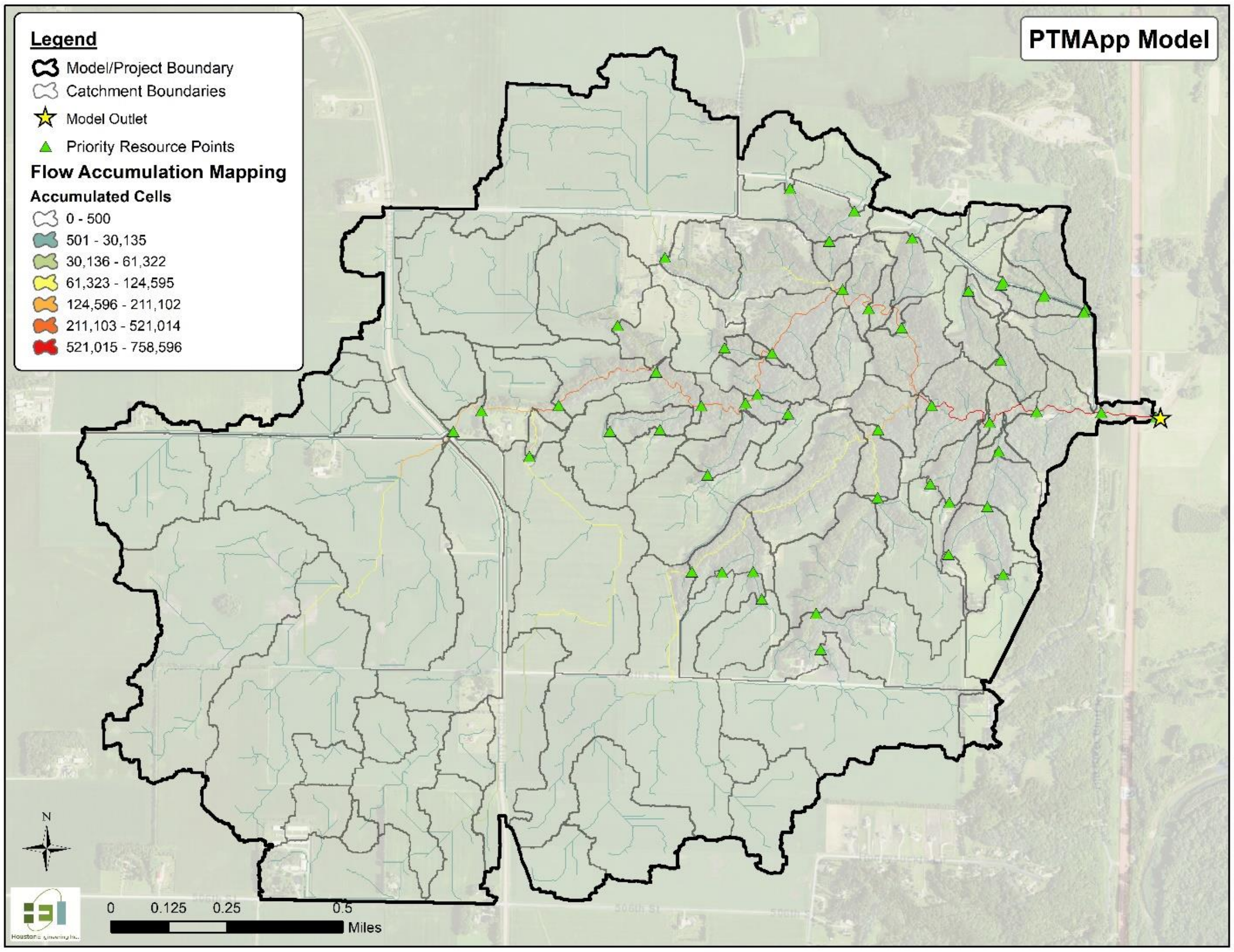
While the XPSWMM model developed can be used to evaluate project alternative impacts to hydrology and hydraulics, additional analysis is needed for water quality impacts such as pollutant loadings and anticipated loading reductions from project alternatives.

2.3.1 ANALYSIS TOOL

As described in **Section 1**, in 2016, Nicollet County developed a countywide PTMApp dataset. Some of the primary uses of PTMApp data are to identify pollutant (sediment, phosphorus, and nitrate) loading to priority resource points, identify suitable BMPs and CPs for implementation, and estimate the annual pollutant loading reductions at priority resource points, following implementation of the BMPs and CPs. In this capacity, PTMApp functions similarly to a water quality model, such as P8. Pollutant loading reductions as well as cost (and therefore cost-effectiveness) are estimated in PTMApp for all BMPs and CPs identified by the program's analysis. For non-PTMApp identified projects, other methods can be used to estimate pollutant loading and cost-effectives using additional PTMApp data. These typically involve assuming about how much of a pollutant reaching the project alternative is removed annually. PTMApp was used as the water quality analysis tool for the project area.

A general overview of the model and its extents are shown in **Figure 10**. PTMApp can be run quickly on an area as small as the project area. Therefore, the PTMApp inputs from the original countywide PTMApp dataset were used along with the project area boundary to rerun a smaller PTMApp dataset. This allowed more priority resource points (i.e. points where results can be extracted) to be added. Additional information about the development of the Nicollet County PTMApp data set can be found in the final implementation report (HEI, 2018) General PTMApp model information can be found on the web at https://ptmapp.bwsr.state.mn.us/.

Figure 10. PTMApp model overview for the project area.



2.3.2 EXISTING POLLUTANT LOADING

The PTMApp dataset provides various useful results, including:

- Annual pollutant (sediment, phosphorus, and nitrogen) loading and yield at the catchment outlet and at priority resource points;
- Estimated runoff peak flows and volumes for various standardized Atlas 14 events;
- Locations for suitable BMPs and CPs, based on Natural Resources Conservation Service (NRCS) placement criteria;
- Annual pollutant load reduction estimates from suitable BMPs and CPs at the catchment outlet and at priority resource points; and
- Practice costs and cost-effectiveness of the BMPs and CPs.

Similar to the H&H model usage described in **Section 2.1**, this project is focused on pollutant loading reductions at both the overall project area outlet and at the outlet of the site of proposed project alternative. Existing annual pollutant loading can be compared to project alternative reductions to report anticipated loading reductions that can be achieved by implementing the project alternative. Pollutant loading reductions at the model outlet represent anticipated loading reductions to the Minnesota River.

An example of pollutant yield at the catchment outlets, for sediment, is shown **Figure 11**. This is the annual sediment yield leaves the catchment. The total amount of pollutant (sediment, phosphorus, and nitrogen) leaving the catchments, for the entire project area, is shown in **Table 3**. The entire set of maps for pollutant yield at the catchment scale can be found in **Appendix A**.

An example of pollutant yield at the model outlet (i.e. reaching the Minnesota River), for sediment, is shown **Figure 12**. This is the annual sediment yield reaches the model outlet. Note that some catchments are identified as “not contributing to the outlet.” This is because sediment leaving these catchments does not reach the model outlet and therefore does not contribute to the model outlet annual yield. The total amount of pollutant (sediment, phosphorus, and nitrogen) reaching the Minnesota River, for the entire project area, is shown in **Table 3**. The entire set of maps for pollutant yield at the model outlet can be found in **Appendix A**.

Because the XPSWMM model developed for this project is much more accurate as estimating H&H results for the project area runoff peak flows and volumes from PTMApp were not used. They were, however, used as a validation on the XPSWMM results. Runoff volumes were found to be similar (within 5%) with XPSWMM runoff volumes typically 3% greater. Peak flows were found to be ~75% greater in the XPSWMM model, as compared to PTMApp. This result is not unusual, given that PTMApp does not have use the complex hydraulic routing functionality found in a dedicated H&H model such as XPSWMM.

Locations for suitable BMPs and CPs identified in PTMApp are shown in **Figure 13**. These were used for discussions about alternative projects.

Pollutant load reductions, BMP/CP costs, and cost-effectiveness results are all included in the PTMApp dataset in the form of tables related to the individual suitable practices. This information is used in discussion of the project alternatives found in **Section 3**.

Table 3. PTMApp estimates of pollutant loading leaving catchments and reaching the Minnesota River for the project area.

Pollutant	Total Leaving Catchments	Total Reaching the Minnesota River
Sediment (tons)	2,154	1,233
Phosphorus (lbs)	351	345
Nitrogen (lbs)	5,879	5,776

Figure 11. Annual sediment yield (tons/acre/year) at the catchment outlets.

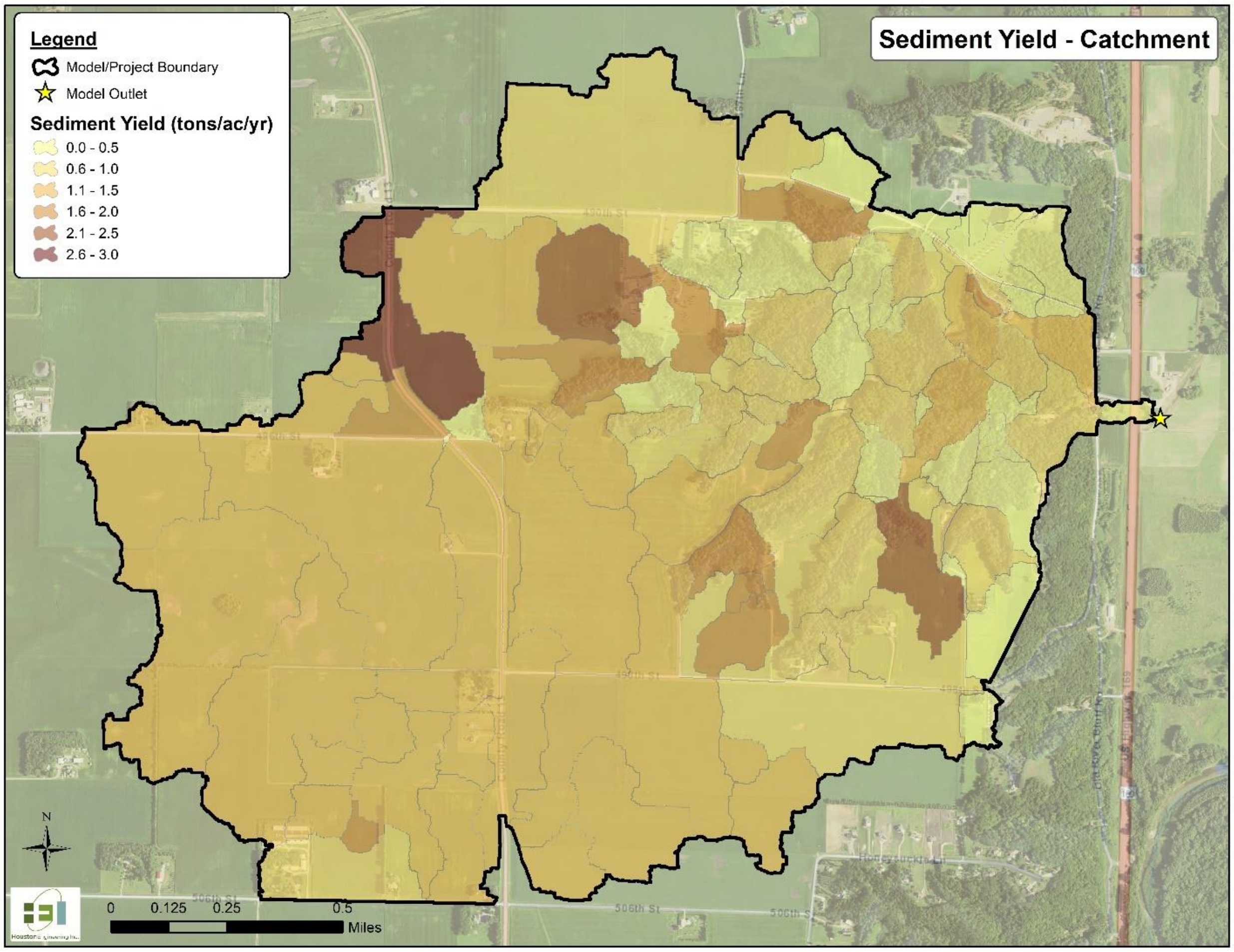


Figure 12. Annual sediment yield (tons/acre/year) at the model outlet.

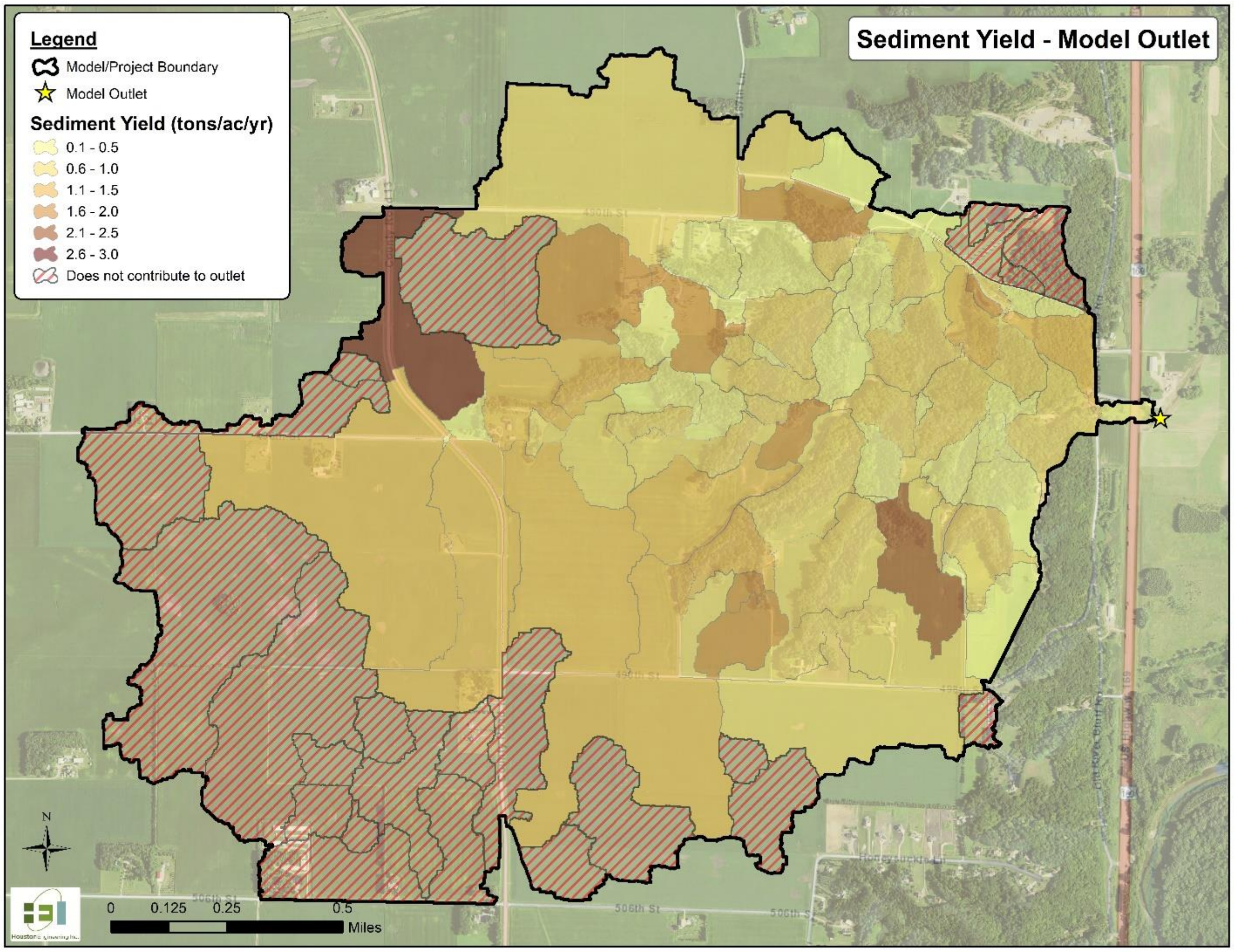
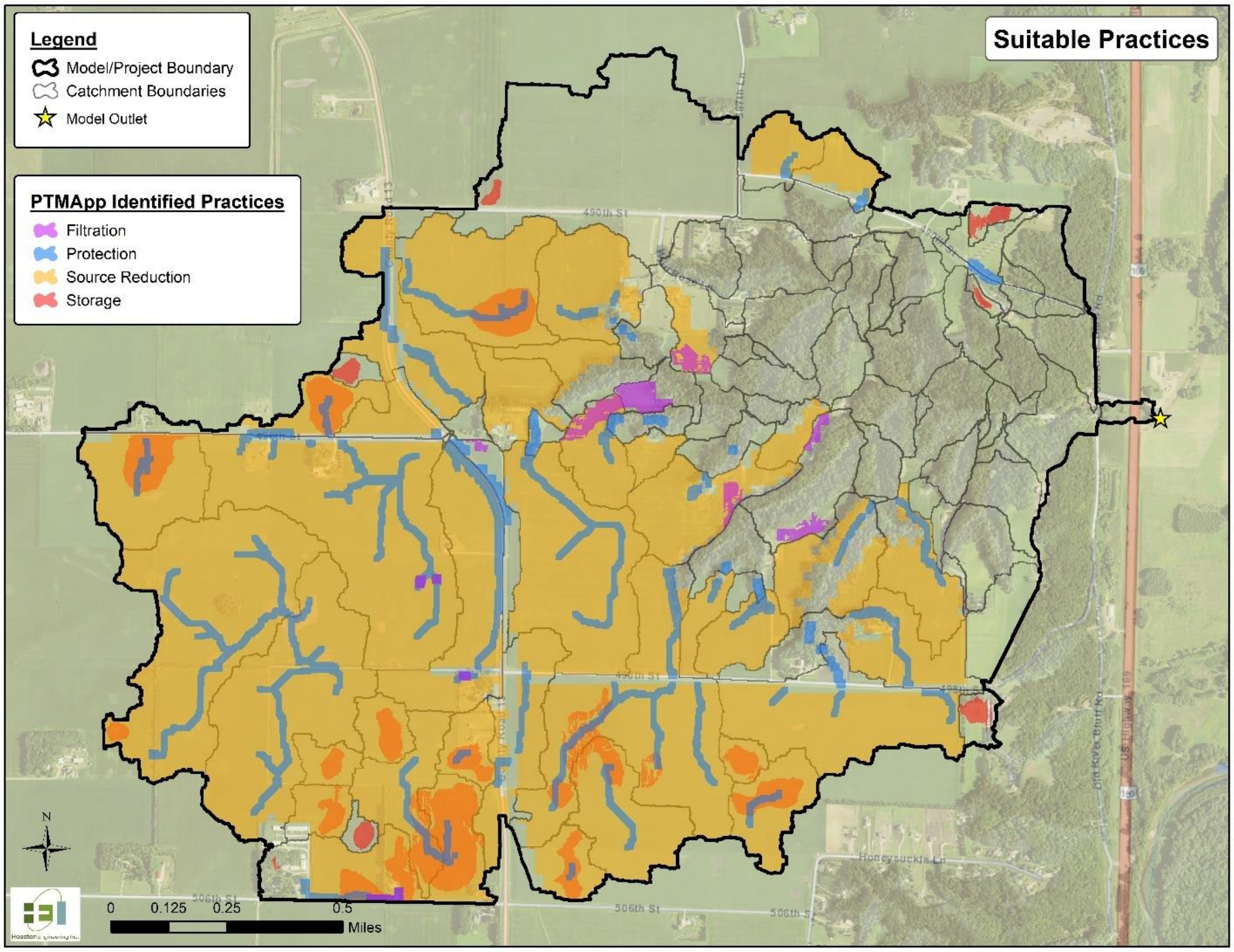


Figure 13. PTMApp-identified suitable best management and conservation practices.



2.3.3 MODELING LIMITATIONS

Like the XPSWMM model, there are some limitations to the PTMApp dataset. PTMApp is not a traditional "model" in the sense that XPSWMM is. XPSWMM models allow the user to run different any number of different time-varying rainfall events through the model and extract results at any point throughout the model network. PTMApp is not a time-series model, but rather a tool to estimate annual averages. Pollutant loading is based on average annual yields (using the Revised Universal Soil Loss Equation, or RUSLE) and a simple first order decay during pollutant transport. These are combined to estimate pollutant loading at priority resource points within the project area. Therefore, pollutant loading and reduction values can only be extracted at priority resource points, not anywhere in the model network. To attempt to account for that, many priority resource points were added during the project area specific PTMApp rerun. PTMApp is unique in that it not only identifies suitable BMPs and CPs, but also estimates annual average load reductions at these practices. While PTMApp makes some assumptions about the percent reduction at these practices based on loading to the practice, the range of reduction percentages are largely based on statistical research performed during the development of the tool. Likewise, practice costs are based on the unit costs used in the tool and are the same for all practices within a treatment group. As a result, the reductions achieved by practices, the cost of the practice, and therefore the cost-effectiveness are all highly dependent upon these settings. The settings used were the same as those used in the Nicollet County countywide dataset.

3 ALTERNATIVE DEVELOPMENT

Following several discussions with the Nicollet SWCD and multiple site visits, HEI developed some preliminary project scenarios and presented the results to the SWCD staff. These scenarios were intended to both demonstrate how the hydrology and hydraulics of the project area function and to give some perspective on potential projects and their estimated costs and benefits. These initial scenarios included:

- Elimination of all upland flow to the ravine system. This scenario was intended to demonstrate the hydrologic contribution of the upland area versus the ravine area;
- Various regional storage systems located at the heads of ravines;
- Implementation of various BMPs identified as suitable through PTMApp analysis, including filtration, protection, and storage treatment practices; and
- Implementation of source reduction CPs identified as suitable by PTMApp analysis. This analysis included all identified practices as well as practices on properties identified by the SWCD as likely adopters.

On May 23, 2019, HEI met with the SWCD staff to present the initial scenarios and determine final project alternatives. The discussion with the SWCD included presenting estimated H&H and water quality benefits of the potential scenarios as well as discussion about the feasibility of projects. The presentation materials used for this discussion are included as **Appendix B**.

Following the discussion, the Nicollet SWCD decided on six project alternatives to focus on. The final project alternatives are shown in **Figure 14**.

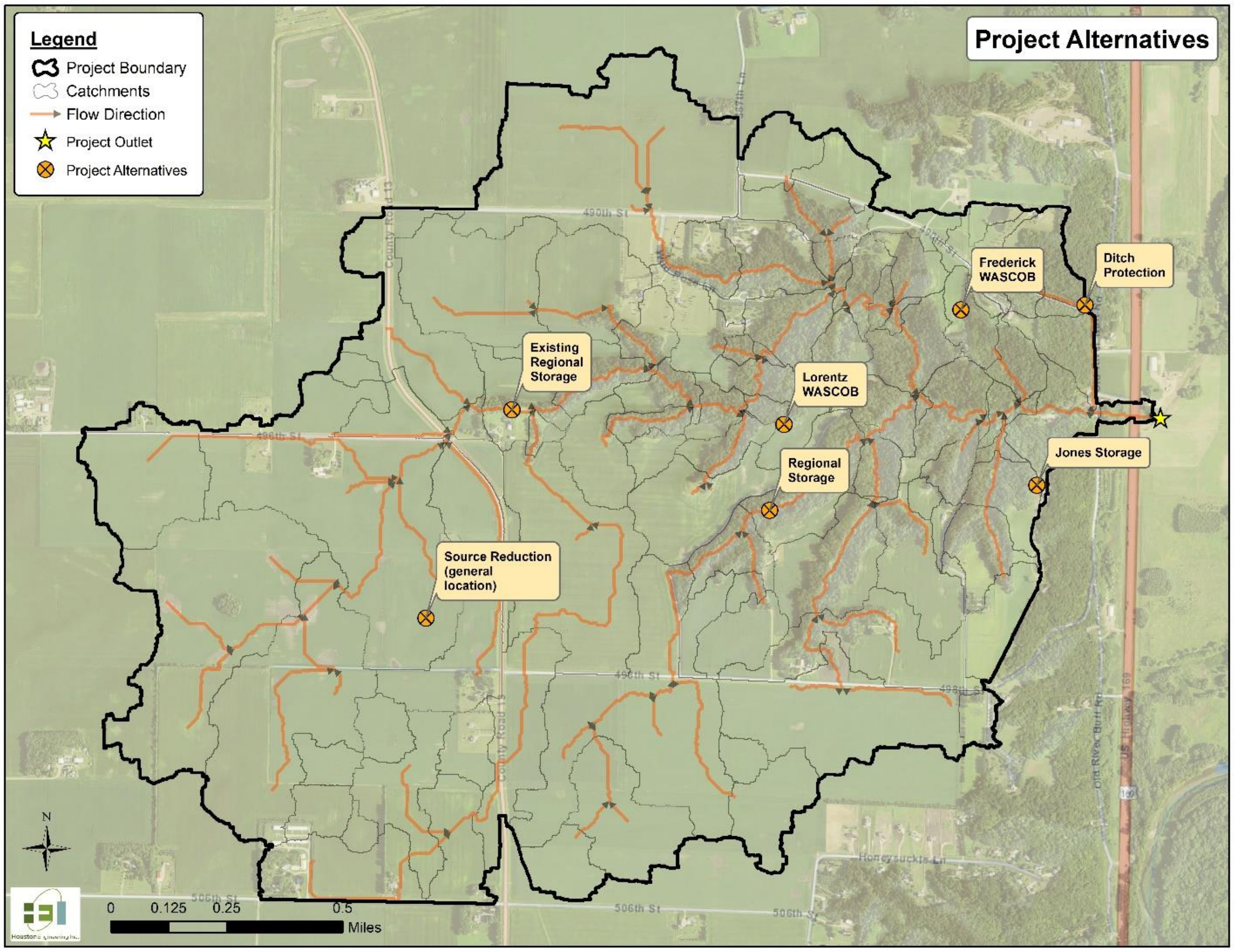
The following sections describe each of the six project alternatives. Each project alternative section contains the following information:

- **Conditions and Issues:** This section describes the problems and concerns at the site and the project alternative selected for the site.
- **Concept Design & Analysis Results:** This section describes the project alternative concept design used for analysis and analysis results at multiple locations:
    - *Site Outlet Analysis* – analysis and benefits immediately downstream of the project alternative.
    - *Project Area Outlet Analysis* – analysis and benefits at the project area outlet (i.e. the Minnesota River).

The site outlet and project area outlet analyses are each presented as their own one-page sheet. These sheets include the following information:

- A brief description of the project alternative;
- A map of the project alternative, relative to the analysis outlet, showing the drainage capture and flow lines;
- A hydrograph of the estimated project impacts to the peak flow and runoff volume;
- A table summarizing the estimated H&H and water quality benefits, costs, and cost-effectiveness; and
- Any assumptions made in the modeling.

Figure 14. Final project alternative sites.



3.1 FREDERICK WASCOB

3.1.1 CONDITIONS & ISSUES

The location of the project alternative is shown in **Figure 14**. The landowner concern at this site is the continuous knickpoint migration of the ravine on the east side of their property. Erosion within the ravine continues to cut the ravine back, upwards towards the bluff. As this happens, trees and other vegetation within the ravine are lost, continuing to destabilize the soils. The erosion is shown in **Figure 15**, taken during a site visit in the fall of 2017. It is difficult to know how much of the ravine has eroded over time, and at what rate, but anecdotal evidence from the landowners indicates that the erosion has been significant and has become more apparent in the past several years. The landowners attended the original stakeholder group that met on November 13, 2017, to discuss issues in the project area with the SWCD. The landowners indicated that they would be willing to implement a storage practice on their agricultural field above the ravine if it would help mitigate peak flows to, and therefore erosion within, the ravine.

Figure 15. Ravine erosion to the east of the Frederick property.

3.1.2 CONCEPT DESIGN & ANALYSIS RESULTS

A water and sediment control basin (WASCOB) was selected for this project alternative. The WASCOB would capture approximately 4.7 acres of drainage runoff from the agricultural field, settle out pollutant, and slowly discharge the runoff under the driveway into the ravine.

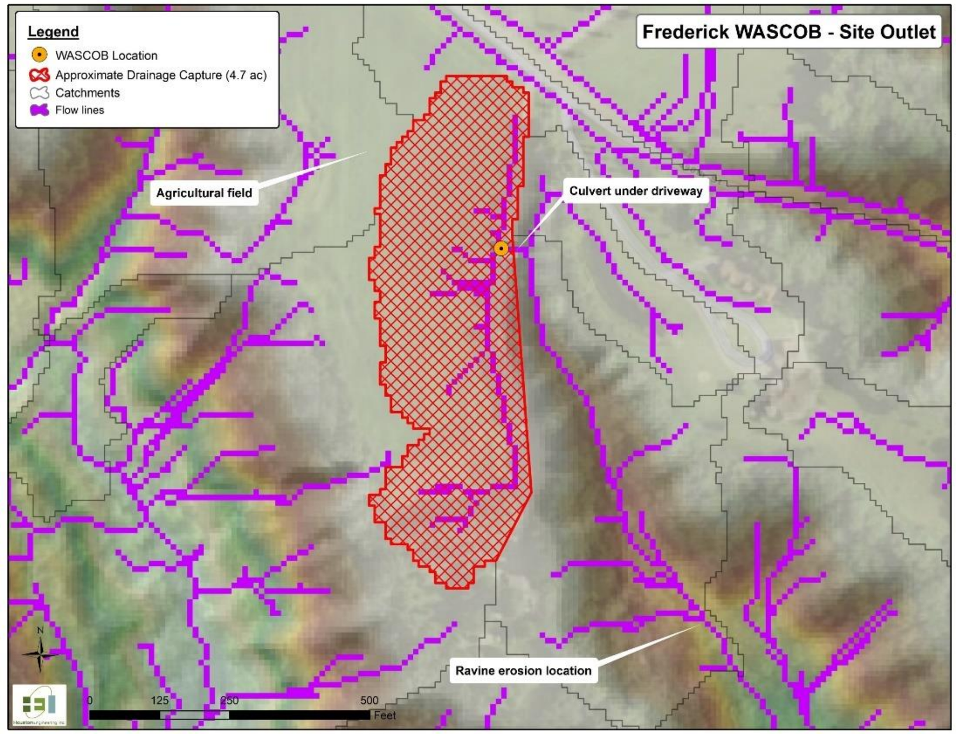
Other considerations for the final design of this project include:

- To reduce the peak discharge to the ravine, the driveway culvert, which acts as the WASCOB control structure, should be reduced in size and the WASCOB should be sized appropriately to store runoff without overtopping the driveway.

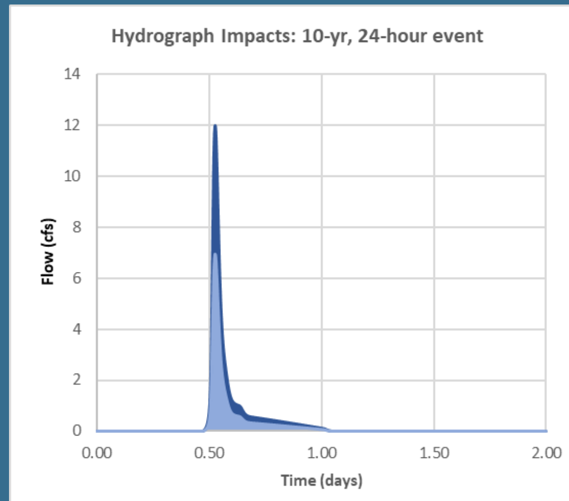
The analysis results for the site outlet and project area outlet are shown in the following one-page sheets.

Frederick WASCOB

WASCOB installed on the west side of the Fredericks' driveway to partially capture field runoff before passing through the culvert, under the driveway, and into the adjacent ravine that is experiencing erosion.



Site Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	12.0
Existing Runoff Volume (ac-ft)	1.4
Scenario Peak Flow (cfs)	6.9
Scenario Runoff Volume (ac-ft)	0.8
Peak Flow Reduction (%)	42%
Runoff Volume Reduction (%)	42%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	13
Existing Annual Total Phosphorus Load (lbs)	2
Existing Annual Total Nitrogen Load (lbs)	37
Scenario Annual Sediment Load (tons)	7
Scenario Annual Total Phosphorus Load (lbs)	1
Scenario Annual Total Nitrogen Load (lbs)	22
Annual Sediment Reduction (%)	42%
Annual Total Phosphorus Reduction (%)	42%
Annual Total Nitrogen Reduction (%)	42%
Cost	
Cost of Implementation	$24,000
Cost Effectiveness	
Sediment ($/ton)	$4,549
Total Phosphorus ($/lb)	$28,548
Total Nitrogen ($/lb)	$1,539

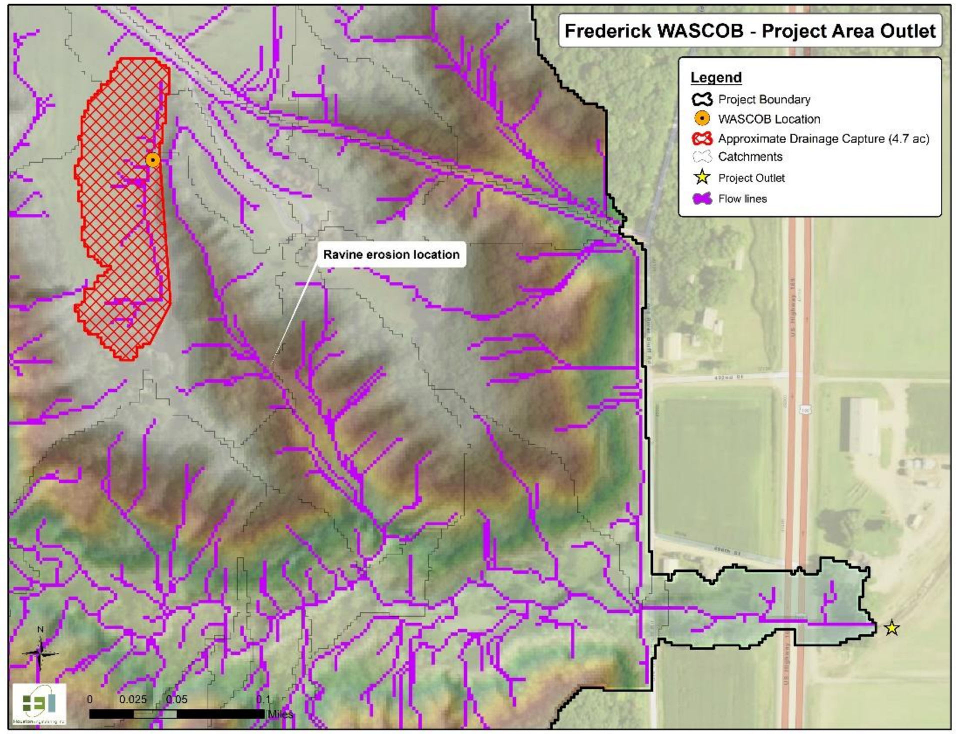


Assumptions

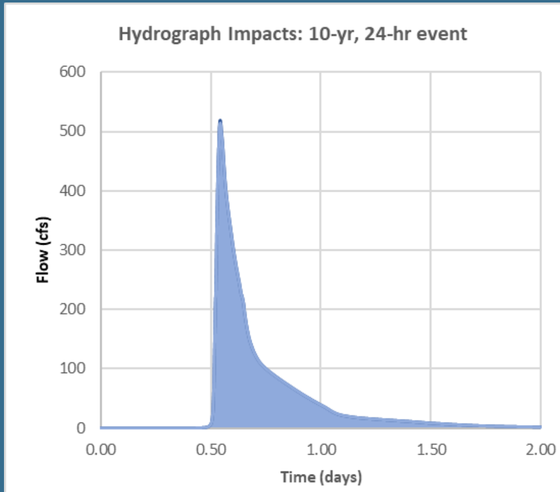
- The WASCOB is designed and developed to capture the 10-year, 24-hour storm event.
- In the H&H analysis, the portion of the catchment labeled "Approximate Drainage Capture" was removed from the model to simulate the capture.
- In the water quality analysis, the catchment pollutant loading was reduced by the fraction of the catchment captured.
- Costs are based on estimates from the SWCD combined with engineering costs and a margin of safety.

Frederick WASCOB

WASCOB installed on the west side of the Fredericks' driveway to partially capture field runoff before passing through the culvert, under the driveway, and into the adjacent ravine that is experiencing erosion.



Project Area Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	519.0
Existing Runoff Volume (ac-ft)	172.6
Scenario Peak Flow (cfs)	514.1
Scenario Runoff Volume (ac-ft)	172.1
Peak Flow Reduction (%)	1%
Runoff Volume Reduction (%)	0%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,226
Scenario Annual Total Phosphorus Load (lbs)	344
Scenario Annual Total Nitrogen Load (lbs)	5,755
Annual Sediment Reduction (%)	1%
Annual Total Phosphorus Reduction (%)	0%
Annual Total Nitrogen Reduction (%)	0%
Cost	
Annual Cost of Implementation	$24,000
Cost Effectiveness	
Sediment ($/ton)	$3,365
Total Phosphorus ($/lb)	$20,789
Total Nitrogen ($/lb)	$1,121



Assumptions

- The WASCOB is designed and developed to capture the 10-year, 24-hour storm event.
- In the H&H analysis, the portion of the catchment labeled “Approximate Drainage Capture” was removed from the model to simulate the capture.
- In the water quality analysis, the catchment pollutant loading was reduced by the fraction of the catchment captured.
- Costs are based on estimates from the SWCD combined with engineering costs and a margin of safety.

3.2 LORENTZ WASCOB

3.2.1 CONDITIONS & ISSUES

The location of the project alternative is shown in **Figure 14**. As with many ravines in the project area, erosion within this ravine is exacerbated by overland runoff and drain tile inflow into the ravine head. It is unknown how much erosion has occurred within this ravine over time, and at what rate erosion is occurring. The landowner was not present at the initial stakeholder meeting in 2017, however the SWCD has indicated that the landowner may be open to working with the SWCD to install CPs or BMPs on their land.

3.2.2 CONCEPT DESIGN & ANALYSIS RESULTS

A WASCOB was selected for this project alternative. The WASCOB would capture approximately 6 acres of drainage runoff from the agricultural field and slowly discharge the runoff, through a control structure, into the adjacent ravine.

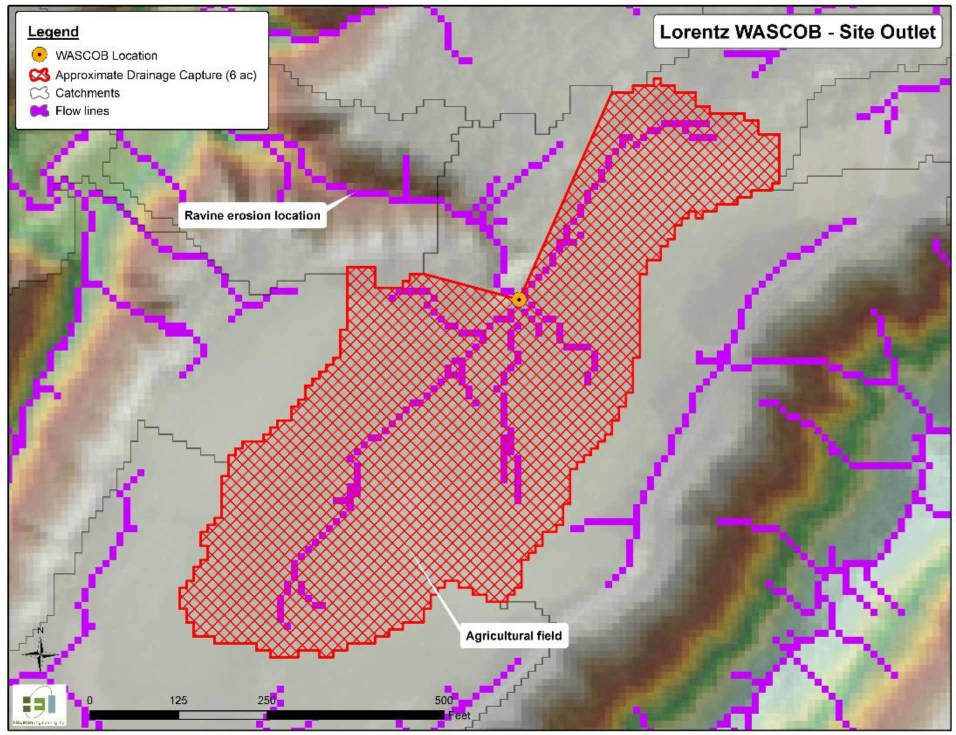
Other considerations for the final design of this project include:

- The SWCD has not discussed the installation of this WASCOB with the landowner. Willingness should be confirmed prior to final designs.

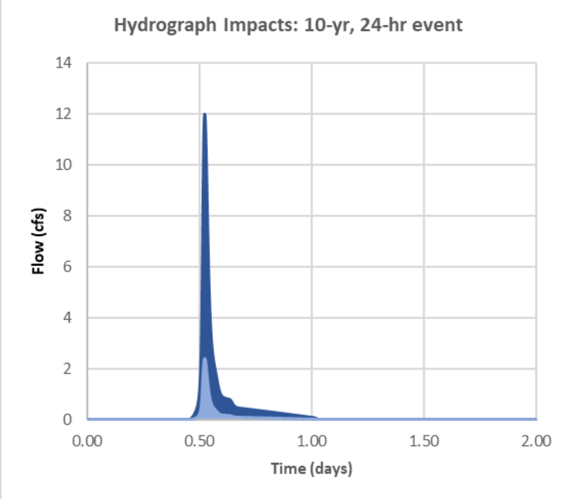
The analysis results for the site outlet and project area outlet are shown in the following one-page sheets.

Lorenzt WASCOB

WASCOB installed on the north edge of the agricultural field to partially capture field runoff before dropping into the adjacent ravine that is experiencing erosion.



Site Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	12.0
Existing Runoff Volume (ac-ft)	1.2
Scenario Peak Flow (cfs)	2.4
Scenario Runoff Volume (ac-ft)	0.2
Peak Flow Reduction (%)	80%
Runoff Volume Reduction (%)	80%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	13
Existing Annual Total Phosphorus Load (lbs)	2
Existing Annual Total Nitrogen Load (lbs)	43
Scenario Annual Sediment Load (tons)	3
Scenario Annual Total Phosphorus Load (lbs)	0
Scenario Annual Total Nitrogen Load (lbs)	9
Annual Sediment Reduction (%)	80%
Annual Total Phosphorus Reduction (%)	80%
Annual Total Nitrogen Reduction (%)	80%
Cost	
Annual Cost of Implementation	$24,000
Cost Effectiveness	
Sediment ($/ton)	$2,274
Total Phosphorus ($/lb)	$13,882
Total Nitrogen ($/lb)	$699

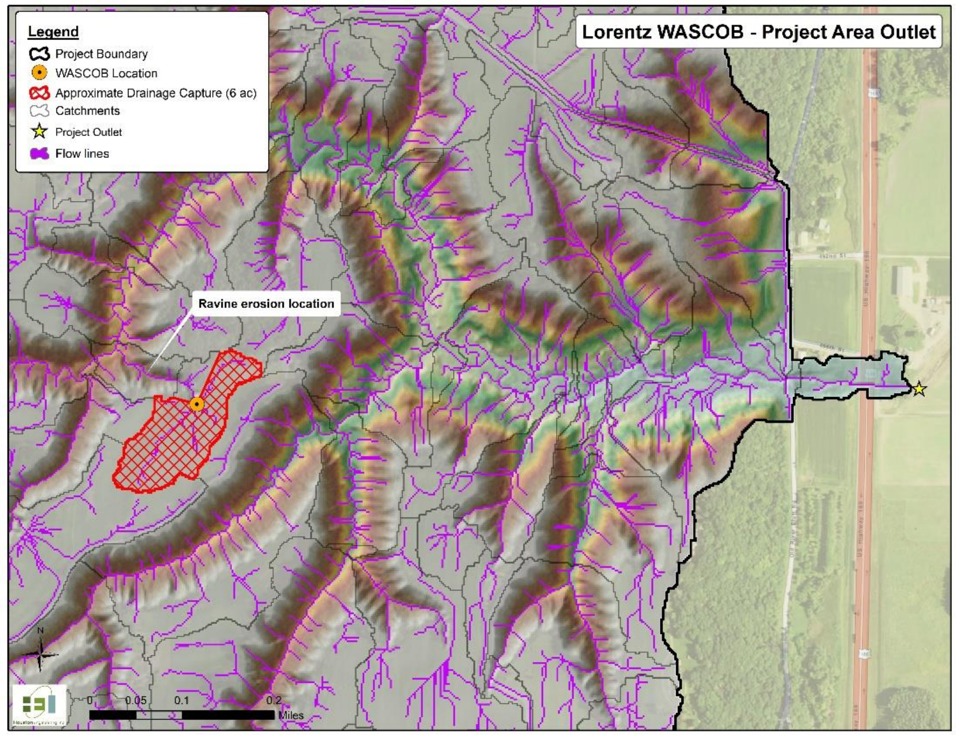


Assumptions

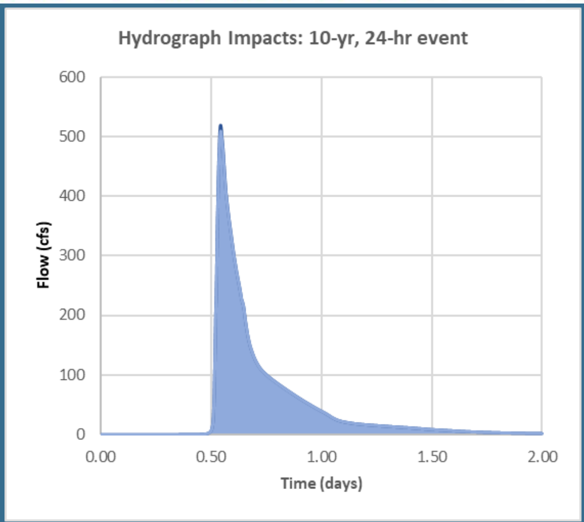
- The WASCOB is designed and developed to capture the 10-year, 24-hour storm event.
- In the H&H analysis, the portion of the catchment labeled "Approximate Drainage Capture" was removed from the model to simulate the capture.
- In the water quality analysis, the catchment pollutant loading was reduced by the fraction of the catchment captured.
- Costs are based on estimates from the SWCD combined with engineering costs and a margin of safety.

Lorenzt WASCOB

WASCOB installed on the north edge of the agricultural field to partially capture field runoff before dropping into the adjacent ravine that is experiencing erosion.



Project Area Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	519.0
Existing Runoff Volume (ac-ft)	172.6
Scenario Peak Flow (cfs)	509.1
Scenario Runoff Volume (ac-ft)	171.7
Peak Flow Reduction (%)	2%
Runoff Volume Reduction (%)	1%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,230
Scenario Annual Total Phosphorus Load (lbs)	344
Scenario Annual Total Nitrogen Load (lbs)	5,768
Annual Sediment Reduction (%)	0%
Annual Total Phosphorus Reduction (%)	0%
Annual Total Nitrogen Reduction (%)	0%
Cost	
Annual Cost of Implementation	$24,000
Cost Effectiveness	
Sediment ($/ton)	$9,616
Total Phosphorus ($/lb)	$56,344
Total Nitrogen ($/lb)	$2,837



Assumptions

- The WASCOB is designed and developed to capture the 10-year, 24-hour storm event.
- In the H&H analysis, the portion of the catchment labeled “Approximate Drainage Capture” was removed from the model to simulate the capture.
- In the water quality analysis, the catchment pollutant loading was reduced by the fraction of the catchment captured.
- Costs are based on estimates from the SWCD combined with engineering costs and a margin of safety.

3.3 REGIONAL STORAGE

3.3.1 CONDITIONS & ISSUES

In 2003, the Nicollet SWCD installed a sediment control basin at the head of the westernmost ravine in the project area. The installed basin is identified on **Figure 14** and a photograph of the install is shown in **Figure 16**. The existing basin captures runoff from the fields and tile in the adjacent cropland to the west and buffers the discharge into the ravine system, substantially reducing the peak flows and volume that passes through the ravine at this location. The Nicollet SWCD requested a project alternative, like the 2003 project, be considered elsewhere in the project area. The regional storage location identified for the project alternative is shown in **Figure 14**. The landowner at this project location was not present at the initial stakeholder meeting, however the SWCD has indicated that the landowner may be open to working with the SWCD to implement a regional storage sediment basin at this location.

Figure 16. *Existing regional storage sediment control basin installed in 2003 (credit: http://www.nicolletswcd.org/MNDOT%20Projects.pdf)*

3.3.2 CONCEPT DESIGN & ANALYSIS RESULTS

A sediment control basin was selected for this project alternative. The basin would capture approximately 192 acres of drainage runoff from the agricultural field and slowly discharge the runoff into the downstream ravine system.

Other considerations for the final design of this project include:

- The SWCD has not discussed the installation of this WASCOB with the landowner. Willingness should be confirmed prior to final designs;

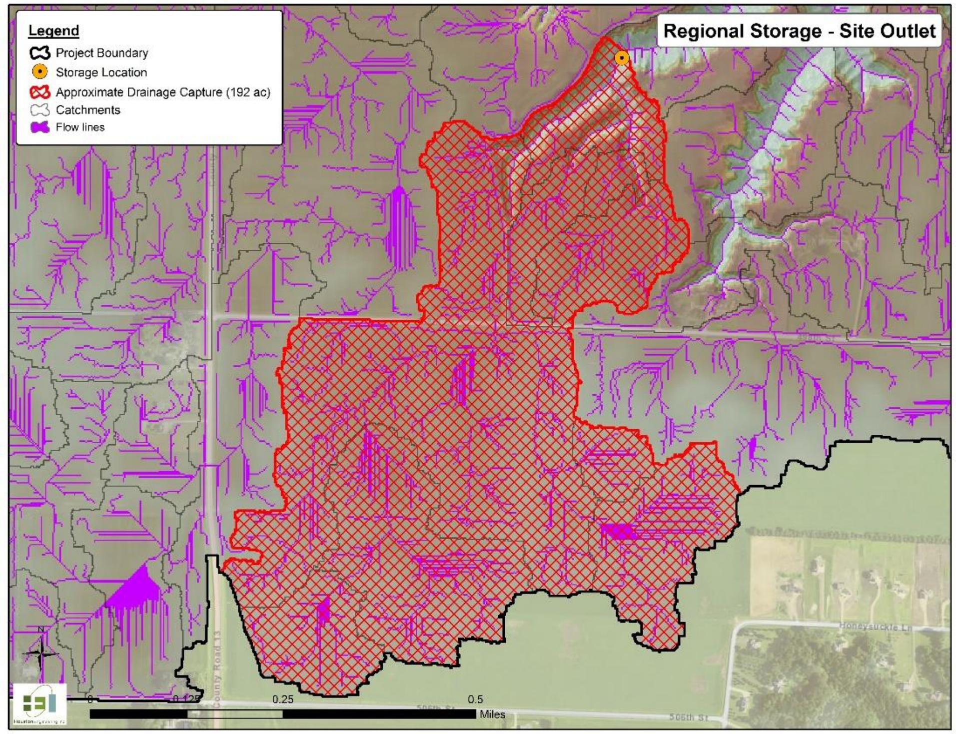
- Portions of the 192-acre contributing drainage area do not contribute during smaller storm events (i.e. agricultural fields to the west have depressional areas that store runoff from smaller events and the runoff would not reach the regional storage basin). This should be considered in the final design;
- The project would require significant geotechnical engineering, as it requires the design and implementation of an earthen dam within the ravine as well as stabilization of the ravine walls within the storage basin. Additional geotechnical survey should be completed to determine the feasibility of this project alternative.

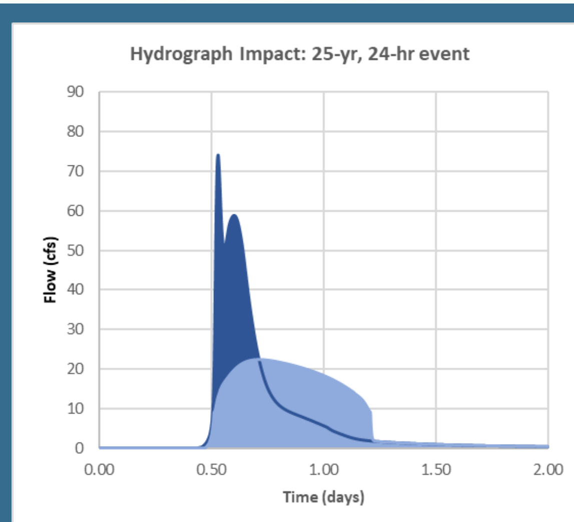
The analysis results for the site outlet and project area outlet are shown in the following one-page sheets.

Regional Storage

Regional storage basin placed at the head of the ravine to capture and mitigate flows from the upland agricultural fields. This project is similar to a previously installed storage basin at the head of a nearby ravine.

Site Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	25-yr, 24-hr
Depth of Rainfall (in)	5.27
Existing Peak Flow (cfs)	74.1
Existing Runoff Volume (ac-ft)	28.3
Scenario Peak Flow (cfs)	22.4
Scenario Runoff Volume (ac-ft)	27.3
Peak Flow Reduction (%)	70%
Runoff Volume Reduction (%)	4%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	159
Existing Annual Total Phosphorus Load (lbs)	42
Existing Annual Total Nitrogen Load (lbs)	790
Scenario Annual Sediment Load (tons)	24
Scenario Annual Total Phosphorus Load (lbs)	21
Scenario Annual Total Nitrogen Load (lbs)	553
Annual Sediment Reduction (%)	85%
Annual Total Phosphorus Reduction (%)	50%
Annual Total Nitrogen Reduction (%)	30%
Cost	
Annual Cost of Implementation	$96,000
Cost Effectiveness	
Sediment ($/ton)	$712
Total Phosphorus ($/lb)	$4,550
Total Nitrogen ($/lb)	$405



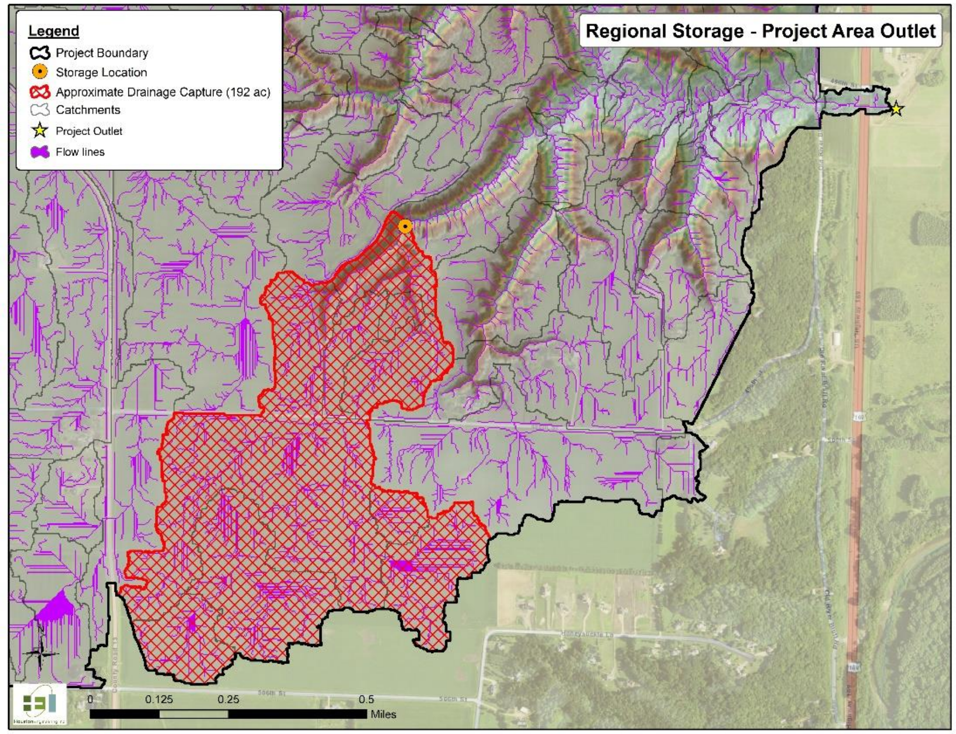


Assumptions

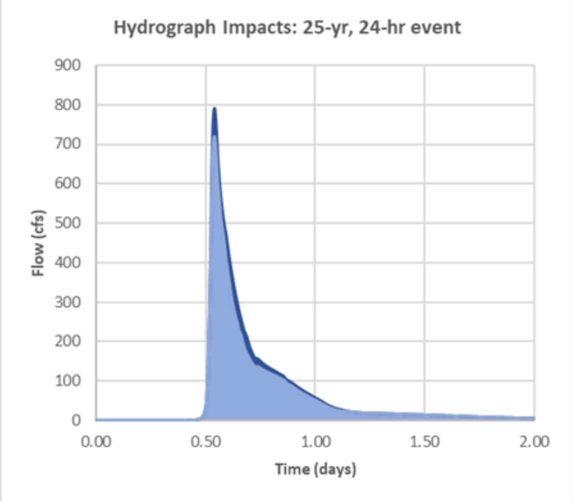
- The pond is designed and developed to capture the 25-year, 24-hour storm event and has an overflow weir as well as a low flow. The modeling of the pond assumed a 12” pipe as a low flow outlet.
- In the water quality analysis, the catchment pollutant loading was reduced based on Recommended pollutant removal efficiencies from the MPCA (https://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_stormwater_ponds). Removal efficiencies assume a wet pond. Installation of a low flow outlet structure (dry pond) would reduce the removal efficiencies. Efficiencies should be re-estimated following the final design of the low flow outlet.
- Costs are based on estimates from the SWCD, from a prior project, combined with engineering costs and a margin of safety.

Regional Storage

Regional storage basin placed at the head of the ravine to capture and mitigate flows from the upland agricultural fields. This project is similar to a previously installed storage basin at the head of a nearby ravine.



Project Area Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	25-yr, 24-hr
Depth of Rainfall (in)	5.27
Existing Peak Flow (cfs)	791.3
Existing Runoff Volume (ac-ft)	260.4
Scenario Peak Flow (cfs)	719.7
Scenario Runoff Volume (ac-ft)	233.6
Peak Flow Reduction (%)	9%
Runoff Volume Reduction (%)	10%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,103
Scenario Annual Total Phosphorus Load (lbs)	324
Scenario Annual Total Nitrogen Load (lbs)	5,542
Annual Sediment Reduction (%)	10%
Annual Total Phosphorus Reduction (%)	6%
Annual Total Nitrogen Reduction (%)	4%
Cost	
Annual Cost of Implementation	$96,000
Cost Effectiveness	
Sediment ($/ton)	$742
Total Phosphorus ($/lb)	$4,600
Total Nitrogen ($/lb)	$409



Assumptions

- The pond is designed and developed to capture the 25-year, 24-hour storm event and has an overflow weir as well as a low flow. The modeling of the pond assumed a 12" pipe as a low flow outlet.
- In the water quality analysis, the catchment pollutant loading was reduced based on Recommended pollutant removal efficiencies from the MPCA (https://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_stormwater_ponds). Removal efficiencies assume a wet pond. Installation of a low flow outlet structure (dry pond) would reduce the removal efficiencies. Efficiencies should be re-estimated following the final design of the low flow outlet.
- Costs are based on estimates from the SWCD, from a prior project, combined with engineering costs and a margin of safety.

3.4 JONES STORAGE

3.4.1 CONDITIONS & ISSUES

The location of the project alternative is shown in **Figure 14**. The concern at this site is the residential development atop and its potential impact on the runoff to the ravine. Surrounding landowners have indicated that the residential development has increased the runoff to the ravine system and therefore the erosion within the ravine and peak flows downstream. It is unknown how much erosion has occurred within this ravine over time, and at what rate erosion is occurring, particularly due to the new development.

3.4.2 CONCEPT DESIGN & ANALYSIS RESULTS

A stormwater pond was selected for this project alternative. The pond would capture approximately 1 acre of drainage runoff from the residential development and slowly discharge the runoff into the ravine system.

Other considerations for the final design of this project include:

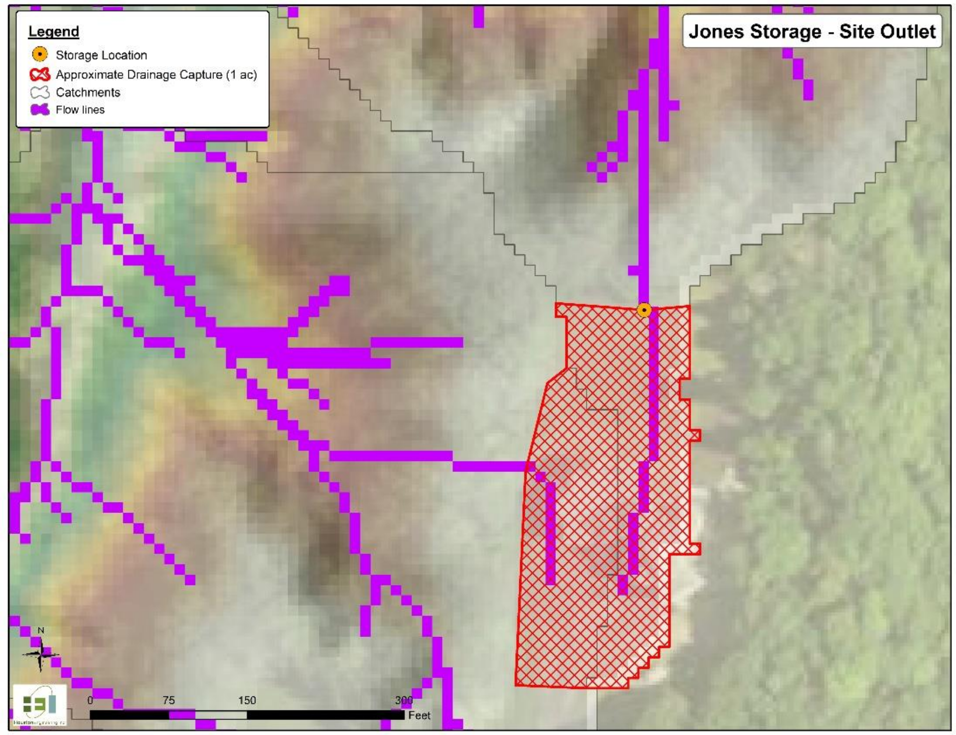
- The SWCD has not discussed the installation of this WASCOB with the landowner. Willingness should be confirmed prior to final designs; and
- The final grading plans of the residential development were not available; therefore, the drainage capture is based on the pre-development LiDAR drainage delineation.

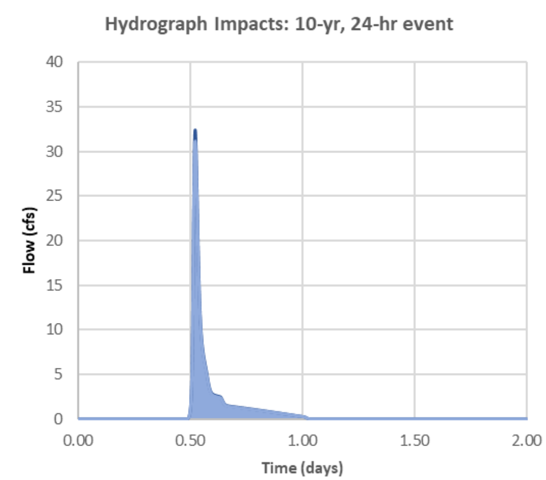
The analysis results for the site outlet and project area outlet are shown in the following one-page sheets.

Jones Storage

Storage pond installed on the north side of the Jones' newly developed property to partially capture impervious runoff before draining to the adjacent ravines.

Site Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	32.4
Existing Runoff Volume (ac-ft)	3.2
Scenario Peak Flow (cfs)	31.2
Scenario Runoff Volume (ac-ft)	3.0
Peak Flow Reduction (%)	4%
Runoff Volume Reduction (%)	4%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	22
Existing Annual Total Phosphorus Load (lbs)	4
Existing Annual Total Nitrogen Load (lbs)	69
Scenario Annual Sediment Load (tons)	21
Scenario Annual Total Phosphorus Load (lbs)	4
Scenario Annual Total Nitrogen Load (lbs)	68
Annual Sediment Reduction (%)	3%
Annual Total Phosphorus Reduction (%)	2%
Annual Total Nitrogen Reduction (%)	1%
Cost	
Annual Cost of Implementation	$24,000
Cost Effectiveness	
Sediment ($/ton)	$35,496
Total Phosphorus ($/lb)	$290,182
Total Nitrogen ($/lb)	$31,585





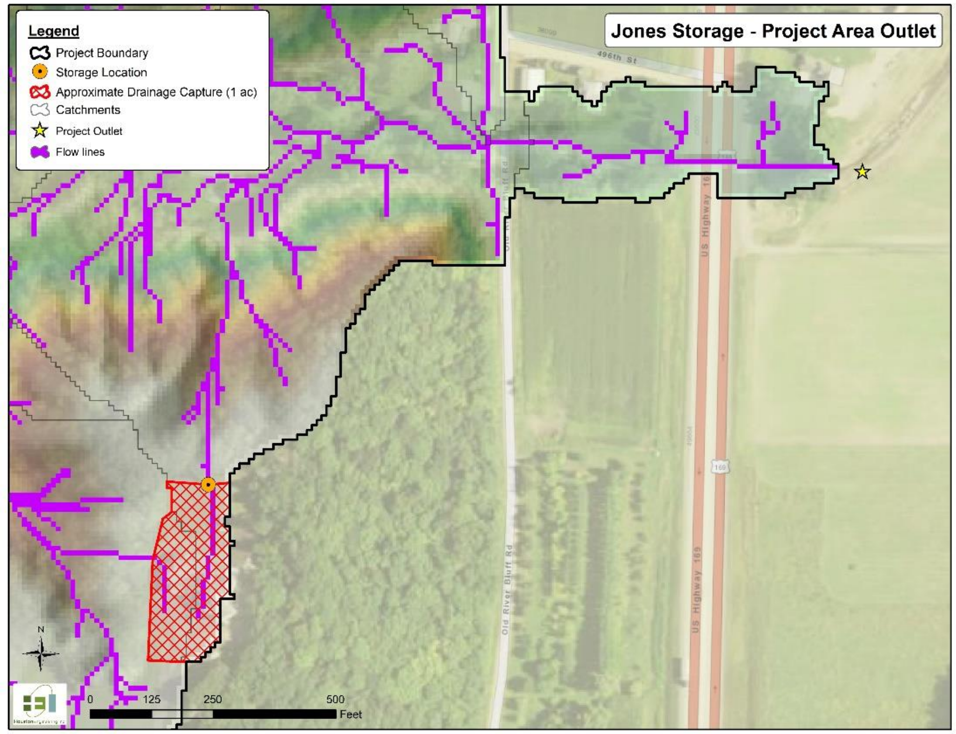
Assumptions

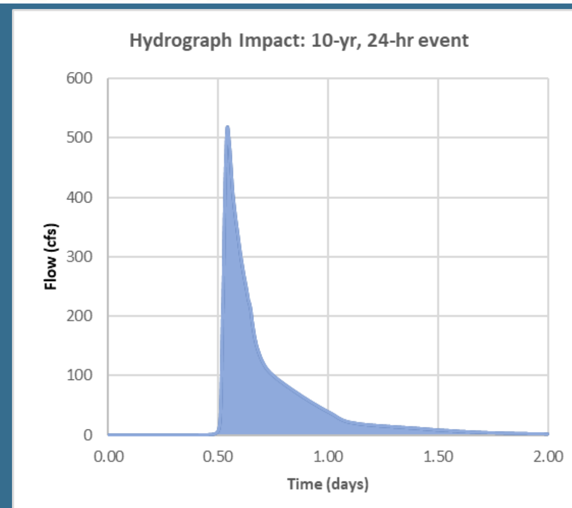
- The storage pond is designed and developed to capture the 10-year, 24-hour storm event.
- In the H&H analysis, the portion of the catchment labeled "Approximate Drainage Capture" was removed from the model to simulate the capture.
- In the water quality analysis, the catchment pollutant loading was reduced based on Recommended pollutant removal efficiencies from the MPCA (https://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_stormwater_ponds). Removal efficiencies assume a wet pond. Installation of a low flow outlet structure (dry pond) would reduce the removal efficiencies. Efficiencies should be re-estimated following the final design of the low flow outlet.
- Costs are based on estimates from the SWCD combined with engineering costs and a margin of safety.

Jones Storage

Storage pond installed on the north side of the Jones' newly developed property to partially capture impervious runoff before draining to the adjacent ravines.

Project Area Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	519.0
Existing Runoff Volume (ac-ft)	172.6
Scenario Peak Flow (cfs)	518.3
Scenario Runoff Volume (ac-ft)	172.5
Peak Flow Reduction (%)	0%
Runoff Volume Reduction (%)	0%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,232
Scenario Annual Total Phosphorus Load (lbs)	345
Scenario Annual Total Nitrogen Load (lbs)	5,775
Annual Sediment Reduction (%)	0%
Annual Total Phosphorus Reduction (%)	0%
Annual Total Nitrogen Reduction (%)	0%
Cost	
Annual Cost of Implementation	$24,000
Cost Effectiveness	
Sediment ($/ton)	$35,496
Total Phosphorus ($/lb)	$290,182
Total Nitrogen ($/lb)	$31,585





Assumptions

- The storage pond is designed and developed to capture the 10-year, 24-hour storm event.
- In the H&H analysis, the portion of the catchment labeled "Approximate Drainage Capture" was removed from the model to simulate the capture.
- In the water quality analysis, the catchment pollutant loading was reduced based on Recommended pollutant removal efficiencies from the MPCA (https://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_stormwater_ponds). Removal efficiencies assume a wet pond. Installation of a low flow outlet structure (dry pond) would reduce the removal efficiencies. Efficiencies should be re-estimated following the final design of the low flow outlet.
- Costs are based on estimates from the SWCD combined with engineering costs and a margin of safety.

3.5 SOURCE REDUCTION

3.5.1 CONDITIONS & ISSUES

One of the most cost-effective ways to reduce runoff and pollutants is to reduce the runoff at its source. In agriculture settings this is often achieved through CPs such as cover crops or no-till/strip-till. Pollutants in the project area come from two primary sources: agricultural land and in-channel/ravine erosion. This project alternative targets the former through source reduction. The general location of the source reduction practices (agriculture) are shown in **Figure 14**. None of the landowners of these areas were present at the initial stakeholder meeting, however the SWCD has indicated that many of these landowners may be open to working with the SWCD to implement source reduction CPs.

3.5.2 CONCEPT DESIGN & ANALYSIS RESULTS

This project alternative consists of a series of source reduction practices applied to multiple agricultural fields within the upland of the ravine system. There are approximately 1,038 acres of upland agricultural fields identified as having source reduction potential.

Other considerations for the final design of this project include:

- The SWCD has not yet discussed conservation practice implementation with the landowners. Willingness should be confirmed prior to final designs;
- The PTMApp analysis that identified the source reduction potential does not consider landowners that may already be implementing these practices. These locations should be field verified;

Because this project alternative does not constitute a specific site, but rather multiple sites, the site outlet analysis has been replaced with an analysis of sediment reduction potential (tons/acre/year) and sediment cost benefit analysis ($/ton/acre/year), based on catchment. This can be used to prioritize and target source reduction practices in the project area. Like other project alternatives, a project area outlet analysis is provided to estimate anticipated benefits at the project area outlet (Minnesota River). The analyses are shown in the following one-page sheets.

Source Reduction

All source reduction practices identified in PTMApp are implemented.

Sediment Reduction Potential

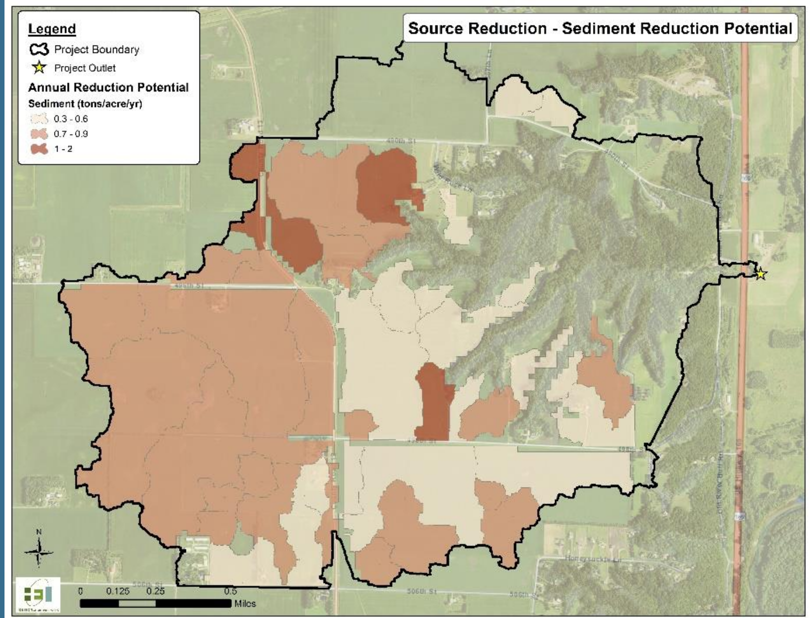
The site outlet sediment reduction potential is determined using PTMApp data. The values represent the practices annual sediment reduction, at the catchment out, normalized by the area of the practice. The value represents the potential annual sediment reduction that could be achieved if source reduction practices were implemented there.

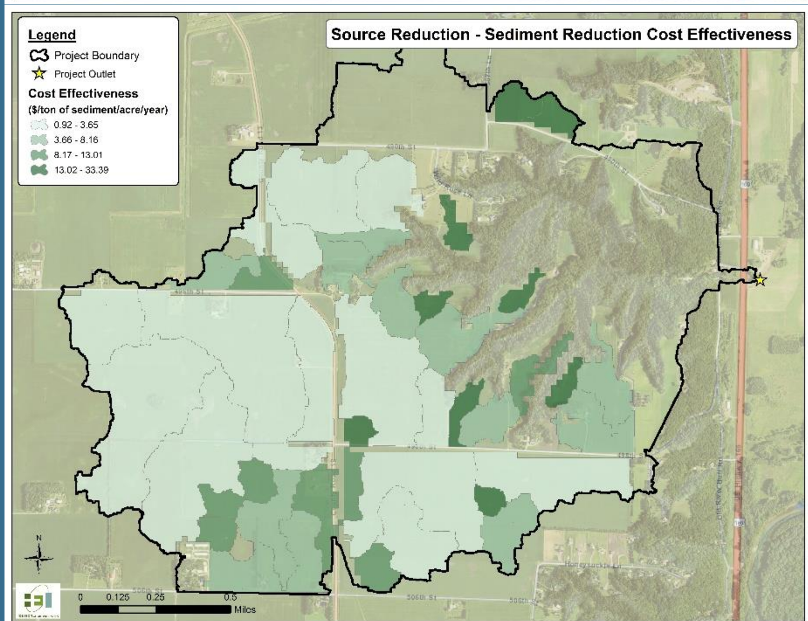
Sediment Cost Effectiveness

The site outlet sediment reduction cost effectiveness is determined using PTMApp data. The values represent the annual cost to implement the practice divided by the annual sediment reduction potential (described above). The mapping indicates which practices are the most cost-effective (i.e. lower numbers) to implement and achieve potential sediment reductions.

Assumptions

- Assumptions
- In the H&H analysis, catchment curve numbers were adjusted to reflect source reduction practices. The analysis is done for the 10-year, 24-hour storm event.
- In the water quality analysis, catchment pollutant loadings and the reduction are extracted directly from PTMApp data.
- Costs are based on estimates from PTMApp as decided during the Nicollet County countywide PTMApp data development.

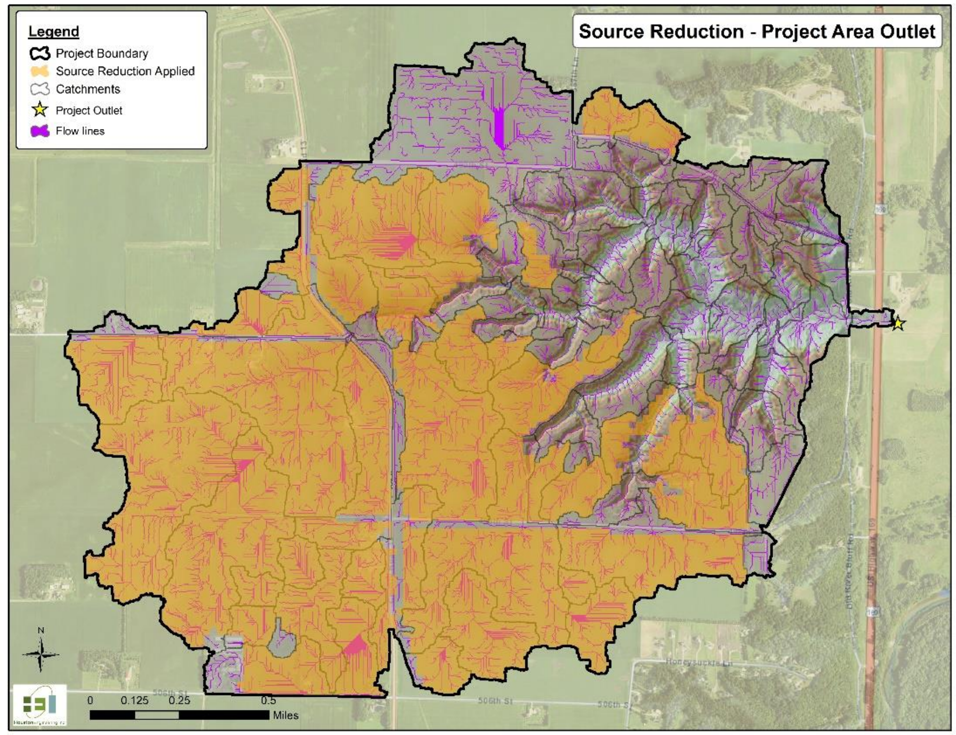


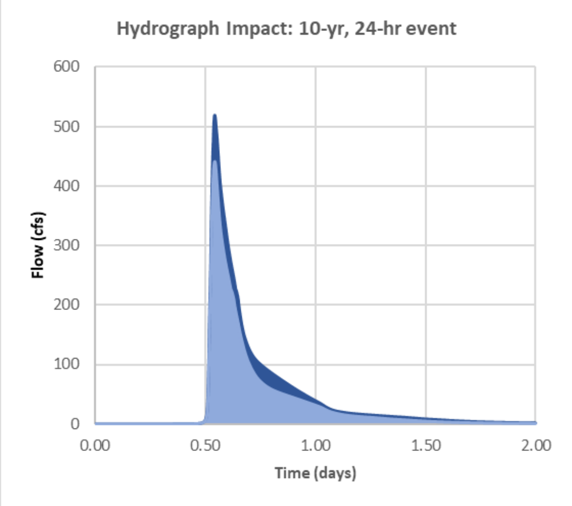


Source Reduction

All source reduction practices identified in PTMApp are implemented.

Project Area Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	519.0
Existing Runoff Volume (ac-ft)	172.6
Scenario Peak Flow (cfs)	441.2
Scenario Runoff Volume (ac-ft)	137.1
Peak Flow Reduction (%)	15%
Runoff Volume Reduction (%)	21%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	845
Scenario Annual Total Phosphorus Load (lbs)	265
Scenario Annual Total Nitrogen Load (lbs)	5,137
Annual Sediment Reduction (%)	31%
Annual Total Phosphorus Reduction (%)	23%
Annual Total Nitrogen Reduction (%)	11%
Cost	
Annual Cost of Implementation	$38,065
Cost Effectiveness	
Sediment ($/ton)	$98
Total Phosphorus ($/lb)	$477
Total Nitrogen ($/lb)	$60





Assumptions

- In the H&H analysis, catchment curve numbers were adjusted to reflect source reduction practices. The analysis is done for the 10-year, 24-hour storm event.
- In the water quality analysis, catchment pollutant loadings and the reduction are extracted directly from PTMApp data.
- Costs are based on estimates from PTMApp as decided during the Nicollet County countywide PTMApp data development.

3.6 DITCH PROTECTION

3.6.1 CONDITIONS & ISSUES

As indicated in **Section 1.3.3**, the north ditch along CR 28 experiences significant erosion issues where the bluff transitions from the upland down to US 169. The erosion results in the transport of sediment and nutrients and poses a significant maintenance issue for Belgrade Township. The erosion within the ditch and along the north side of the roadway is exacerbated by groundwater seepage, evidenced during a site visit. Along with overland flow entering the ditch system, groundwater seepage has been identified within the roadway. Images of the issues are shown in **Figure 5**.

As of the summer of 2015, the township appears to have attempted to lessen the erosion potential and stabilize the ditch by adding riprap to the ditch system, effectively creating a series of check dams along the fall (**Figure 5**, left photo).

It is unknown how much erosion has occurred within the ditch over time, and at what rate erosion is occurring. However, the ditch and roadway has required repeated maintenance throughout the year by the township.

3.6.2 CONCEPT DESIGN & ANALYSIS RESULTS

This project alternative consists of a series of riprap check dams placed along the ditch. The dams are designed to slow the flow of water (and the erosive potential) and to capture eroded sediment behind the dams, preventing pollutant loading from the ditch. Along with the check dams, the ditch would also be revegetation to provide additional stability. This project alternative estimates approximately 50 check dams over 1000 feet of ditch.

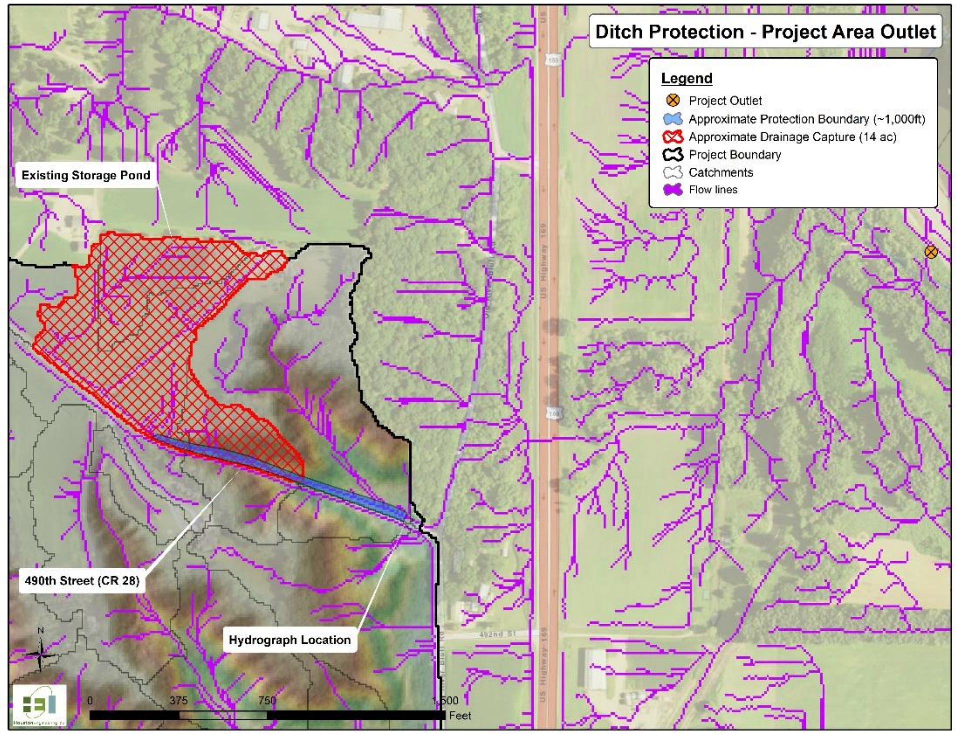
Other considerations for the final design of this project include:

- As of May of 2019, the township appears to have added a significant amount of riprap to the ditch to reduce erosion. The SWCD may want to evaluate the impact this modification has had on the ditch erosion and modify this project alternative in necessary.
- This project alternative does not address the seepage issues in the roadway (see **Section 1.3.3**). Additional geotechnical analysis should be done to determine a potential solution for addressing seepage-related erosion to the roadway.

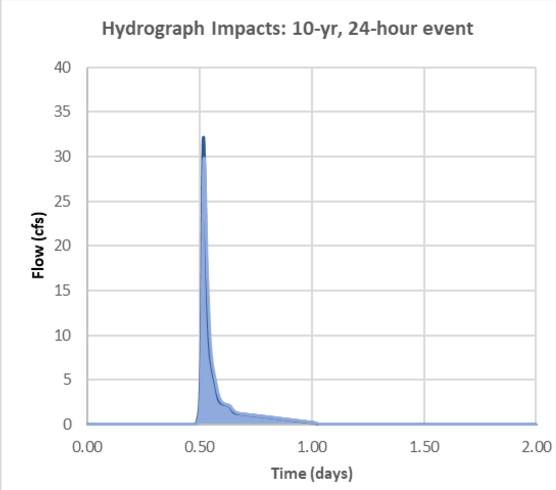
Because this project alternative does not contribute to the same project area outlet as the other project alternatives (i.e. runoff from the ditch enters the Minnesota River via a different route than the project area ravine system), additional analysis was performed to determine impacts to the Minnesota River. Roughness in the ditch channel was modified in the H&H model to simulate the addition of check dams and determine the peak flow reduction. The BWSR Water Erosion Pollution Reduction Estimator was used to estimate the pollutant reduction achieved by protecting the ditch and PTMApp data was used to estimate the potential impacts to the Minnesota River. The analysis is shown in the following one-page sheet.

Ditch Protection

Install erosion protection measures within the north side ditch of 490th Street (CR 28) where the ditch descends the bluff.



Project Area Outlet Results	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	32.2
Existing Runoff Volume (ac-ft)	2.9
Scenario Peak Flow (cfs)	29.8
Scenario Runoff Volume (ac-ft)	2.9
Peak Flow Reduction (%)	7%
Runoff Volume Reduction (%)	0%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	255
Existing Annual Total Phosphorus Load (lbs)	192
Existing Annual Total Nitrogen Load (lbs)	2,608
Scenario Annual Sediment Load (tons)	237
Scenario Annual Total Phosphorus Load (lbs)	184
Scenario Annual Total Nitrogen Load (lbs)	2,493
Annual Sediment Reduction (%)	7%
Annual Total Phosphorus Reduction (%)	4%
Annual Total Nitrogen Reduction (%)	4%
Cost	
Cost of Implementation	$20,434
Cost Effectiveness	
Sediment ($/ton)	$1,167
Total Phosphorus ($/lb)	$2,414
Total Nitrogen ($/lb)	$178



Assumptions

- Assumes 50 Class II riprap check dams are installed along the 1,000 ft of ditch. Dams are assumed to be 6' wide, 3' tall, and have a thickness of 3'.
- In the H&H analysis, the roughness of the ditch channel was changed from 0.02 to 0.06 to simulate the addition of the riprap check dams.
- In the water quality analysis, the BWSR Water Erosion Pollution Reduction Estimator was used to estimate the volume of sediment leaving the ditch annually. PTMApp sediment to TP and sediment to TN ratios where used to estimate TP and TN leaving the ditch annually. PTMApp sediment and nutrient decay methods were used to estimate the benefits to the Minnesota River.
- Material costs are based on riprap volumes, MnDOT Class II costs and the assumption that the top of the next downstream dam will be at the same elevation as the toe of the upstream dam. Costs assume an additional 50% of material costs for install and an additional $10,000 for final engineering. A margin of safety (20%) was also included.

4 DISCUSSION

A summary of the six project alternatives is shown in **Table 4**. The table compares the H&H, water quality, and cost-effectiveness results from the analysis outlined in **Section 3**. The table can be used to compare the benefits of the six project alternatives at both the sites and at the project area outlet.

The following is a summary of the key findings of the project alternative analyses:

- Implementation of source reduction practices in the upland is by far the most cost-effective form of flow and pollutant reduction at both the site outlets and at the project area outlet.
- The regional storage is the second most cost-effective project alternative behind source reduction and provides the second greatest benefits at both the site and project area outlets. Regional storage is also the costliest project and would likely require the most planning, engineering, and coordination to achieve.
- The Jones Storage project alternative provides the least amount of benefit at the site and the project outlets for both H&H and water quality. This is due primarily to the small drainage area that can be captured by the project alternative.
- Both WASCOBs (Frederick and Lorentz) provide very little water quality benefit to the Minnesota River, due in large part to their small drainage capture and distance from the project area outlet. Comparing the two, the Lorentz WASCOB provides slightly more benefit, both at the site and project area outlets, but is less cost-effective at the project area outlet scale.
- The Ditch Protection project alternative has to potential to provide substantial benefit to the Minnesota River, however, efforts by the township as of May 2019 may have alleviated some of the issues.

Table 4. *Summary of project alternative benefits.*

			Frederick WASCOB $24,000	Lorentz WASCOB $24,000	Regional Storage $96,000	Jones Storage $24,000	Source Reduction $38,065	Ditch Protection $20,434
Site Outlet	H&H	Peak Flow Reduction (%)	42%	80%	70%	4%	See Section 3.5.2	Not Applicable
		Runoff Volume Reduction (%)	42%	80%	4%	4%		
	Water Quality	Annual Sediment Reduction (%)	42%	80%	85%	3%		
		Annual Total Phosphorus Reduction (%)	42%	80%	50%	2%		
		Annual Total Nitrogen Reduction (%)	42%	80%	30%	1%		
	Cost Effectiveness	Sediment Cost Effectiveness ($/ton)	$4,549	$2,274	$712	$35,496		
		Total Phosphorus Cost Effectiveness ($/lb)	$28,548	$13,882	$4,550	$290,182		
		Total Nitrogen Cost Effectiveness ($/lb)	$1,539	$699	$405	$31,585		
Project Area Outlet	H&H	Peak Flow Reduction (%)	1%	2%	9%	<1%	15%	7%
		Runoff Volume Reduction (%)	<1%	1%	10%	<1%	21%	<1%
	Water Quality	Annual Sediment Reduction (%)	1%	<1%	10%	<1%	31%	7%
		Annual Total Phosphorus Reduction (%)	<1%	<1%	6%	<1%	23%	4%
		Annual Total Nitrogen Reduction (%)	<1%	<1%	4%	<1%	11%	4%
	Cost Effectiveness	Sediment Cost Effectiveness ($/ton)	$3,365	$9,616	$742	$35,496	$98	$1,167
		Total Phosphorus Cost Effectiveness ($/lb)	$20,789	$56,344	$4,600	$290,182	$477	$2,414
		Total Nitrogen Cost Effectiveness ($/lb)	$1,121	$2,837	$409	$31,585	$60	$178

5 REFERENCES

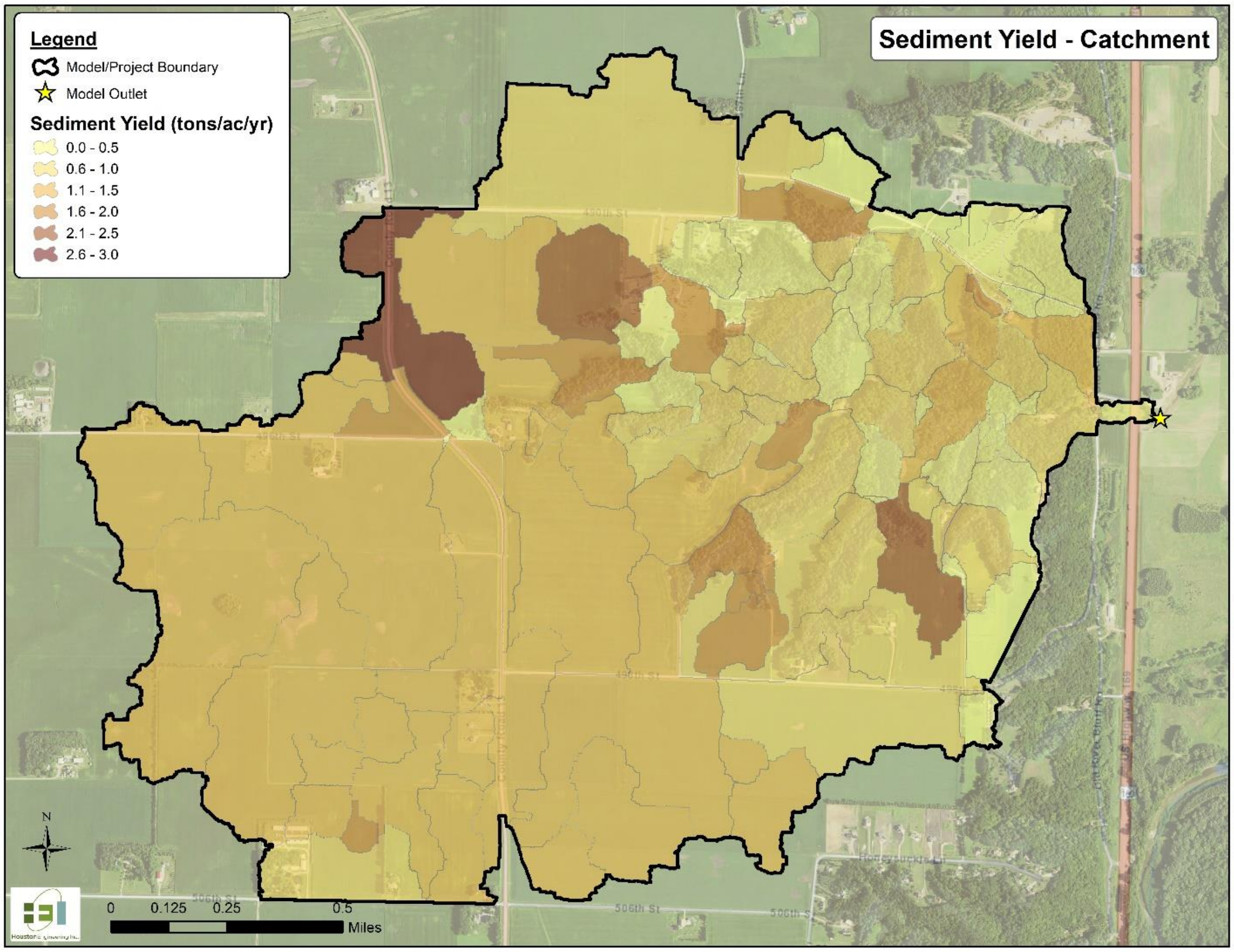
Houston Engineering, Inc. (HEI). 2018. Targeted Implementation Plan for Nicollet County to Improve Surface Water Quality. November 12, 2018.

Minnesota Pollution Control Agency (MPCA). 2015. Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River. January 2015.

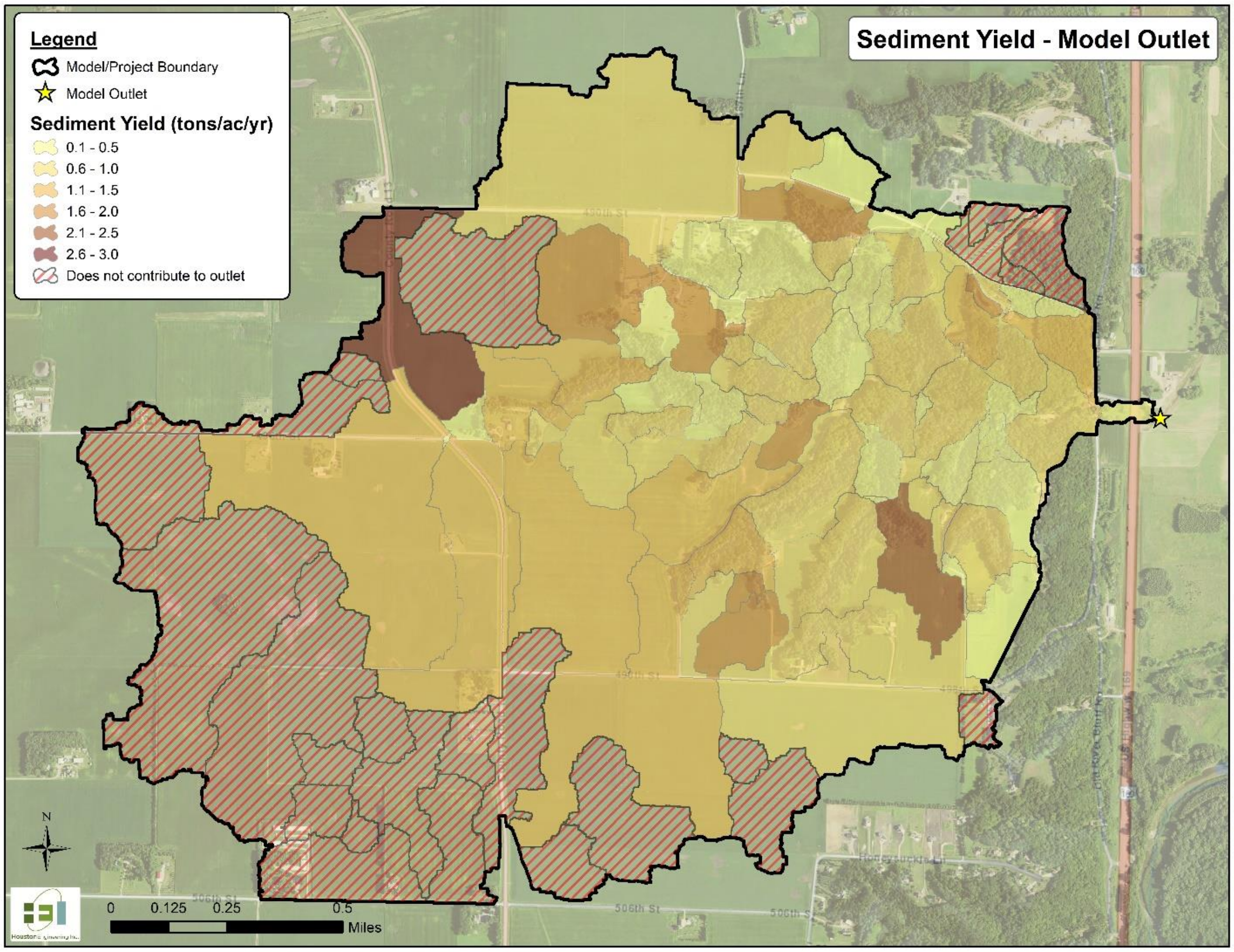
Minnesota Pollution Control Agency (MPCA). 2019. Sediment reduction strategy. Minnesota River and South Metro Mississippi River. Website accessed August 6, 2019. https://www.pca.state.mn.us/water/sediment-reduction-strategy-minnesota-river-basin-and-south-metro-mississippi-river

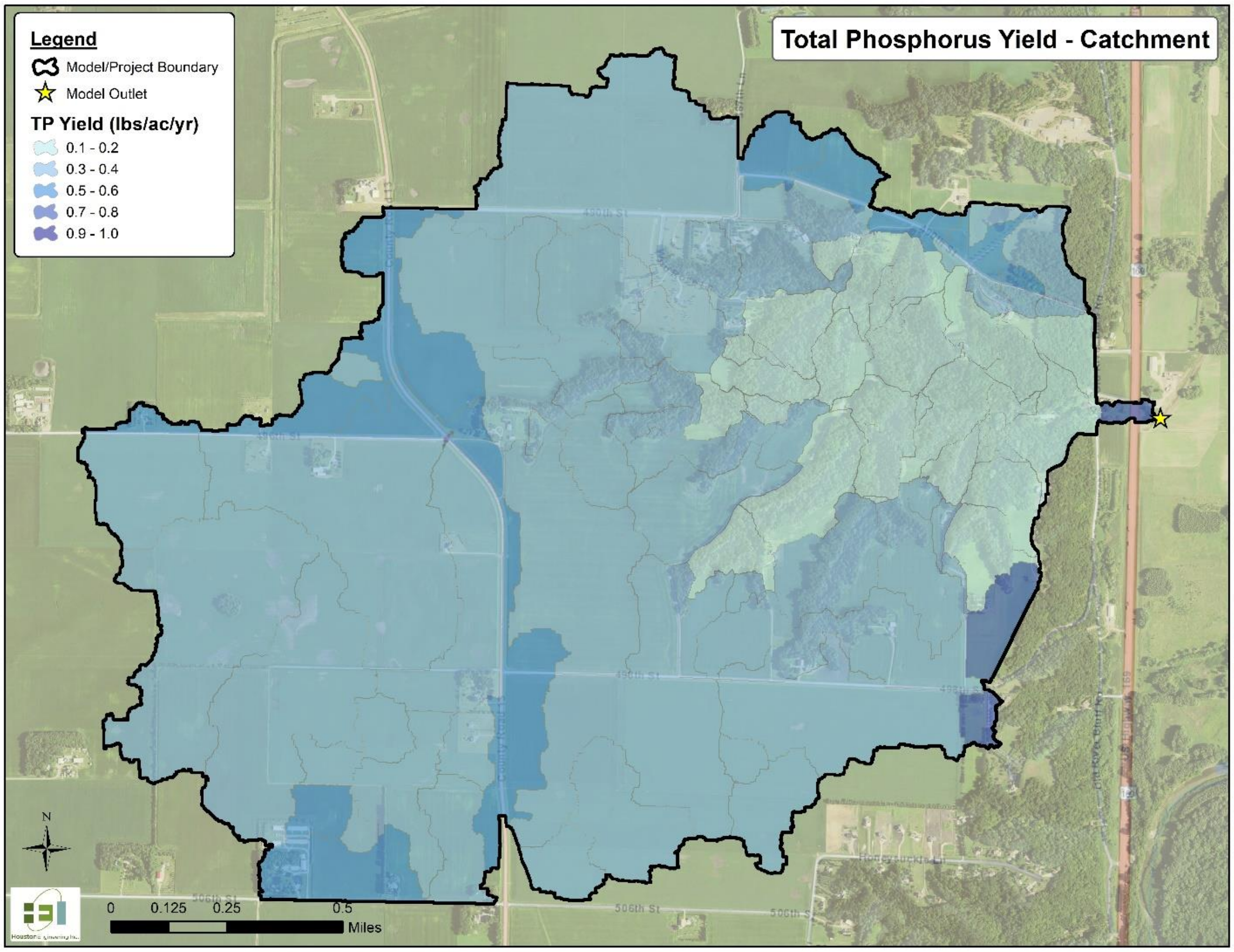
6 APPENDICES

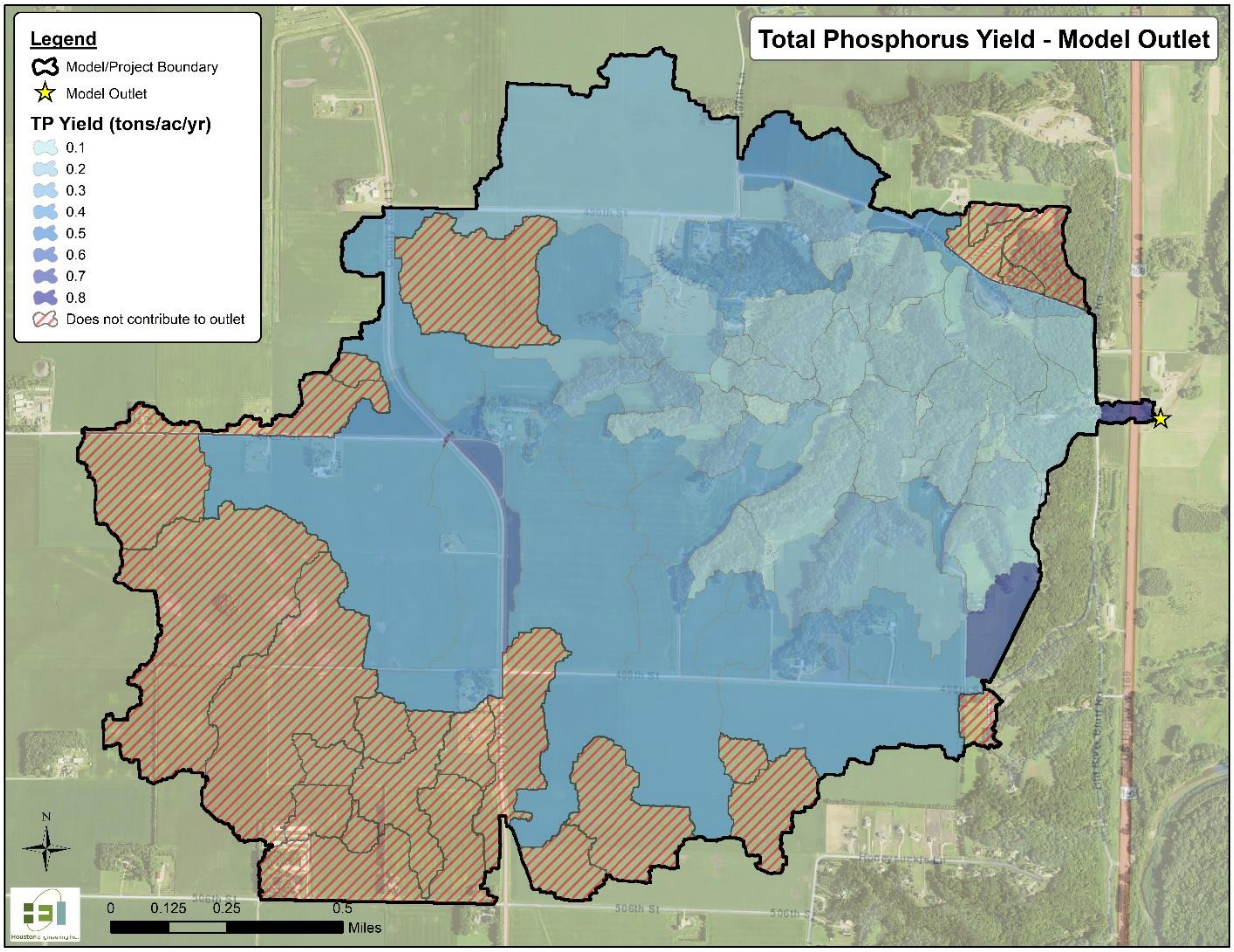
A – PTMAPP RESULTS

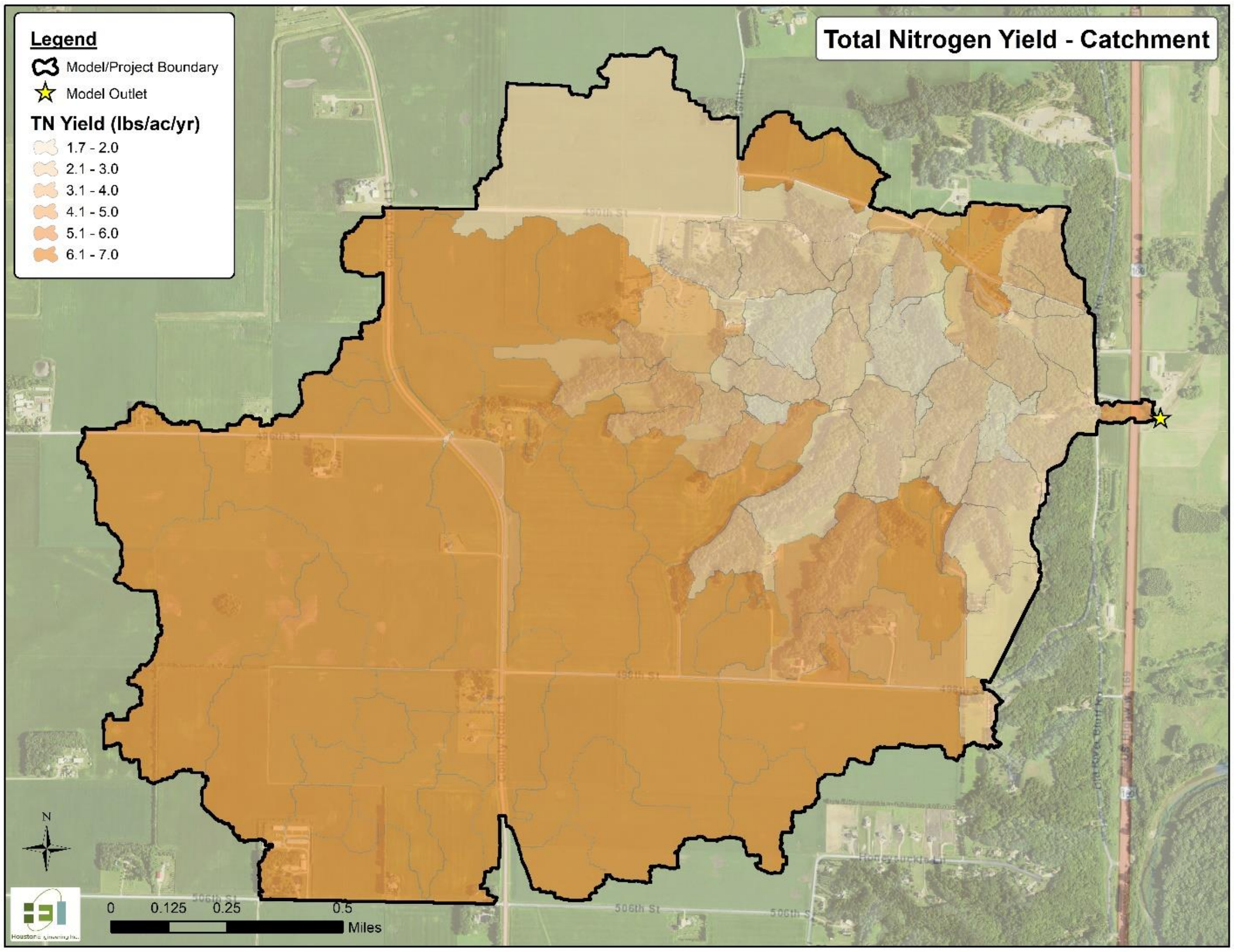


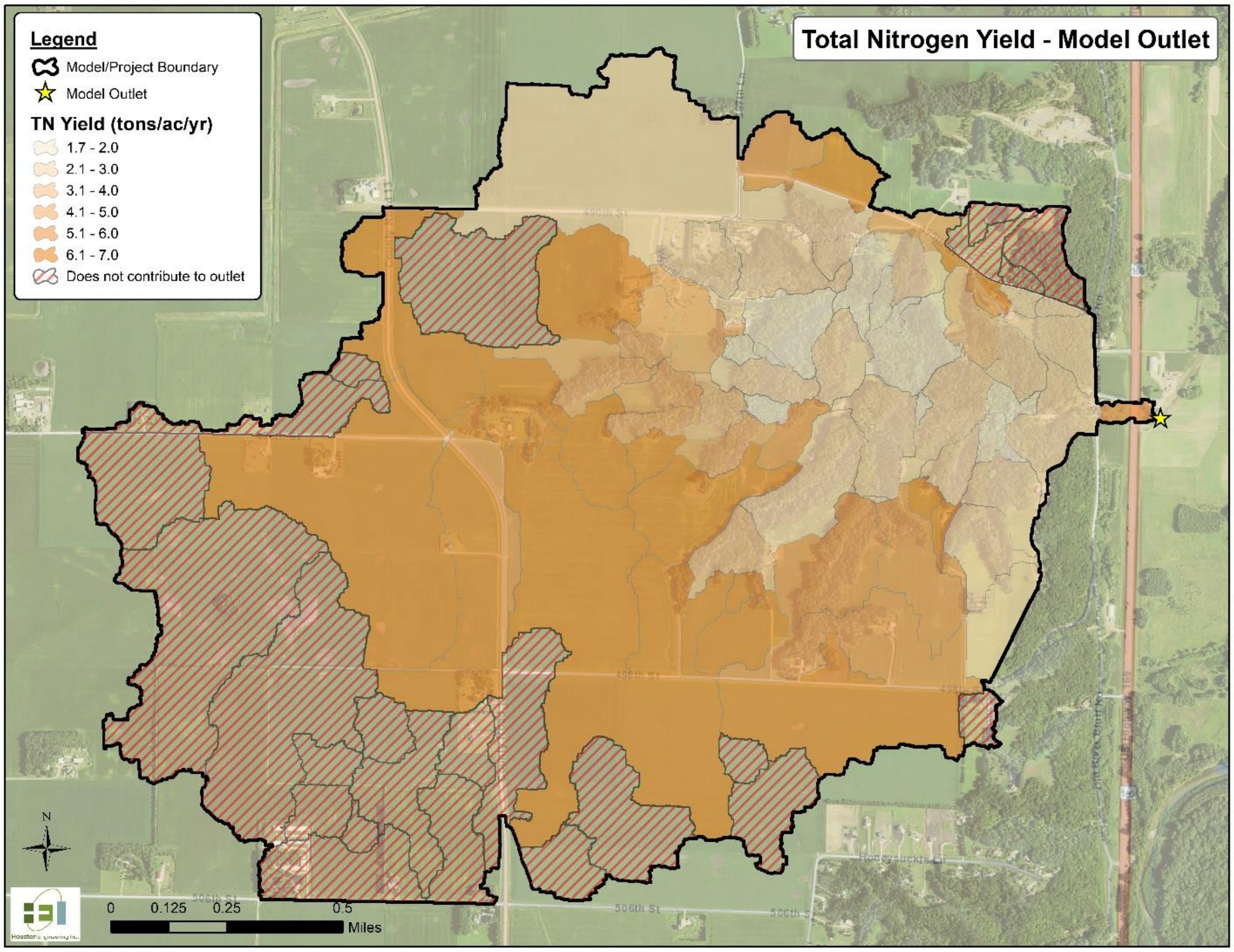
Sediment Yield - Catchment
Legend
Model/Project Boundary
Model Outlet
Sediment Yield (tons/ac/yr)
0.0 - 0.5
0.6 - 1.0
1.1 - 1.5
1.6 - 2.0
2.1 - 2.5
2.6 - 3.0
N
0
0.125
0.25
0.5
Miles


Sediment Yield - Model Outlet
Legend
Model/Project Boundary
Model Outlet
Sediment Yield (tons/ac/yr)
0.1 - 0.5
0.6 - 1.0
1.1 - 1.5
1.6 - 2.0
2.1 - 2.5
2.6 - 3.0
Does not contribute to outlet
0 0.125 0.25 0.5
Miles
N

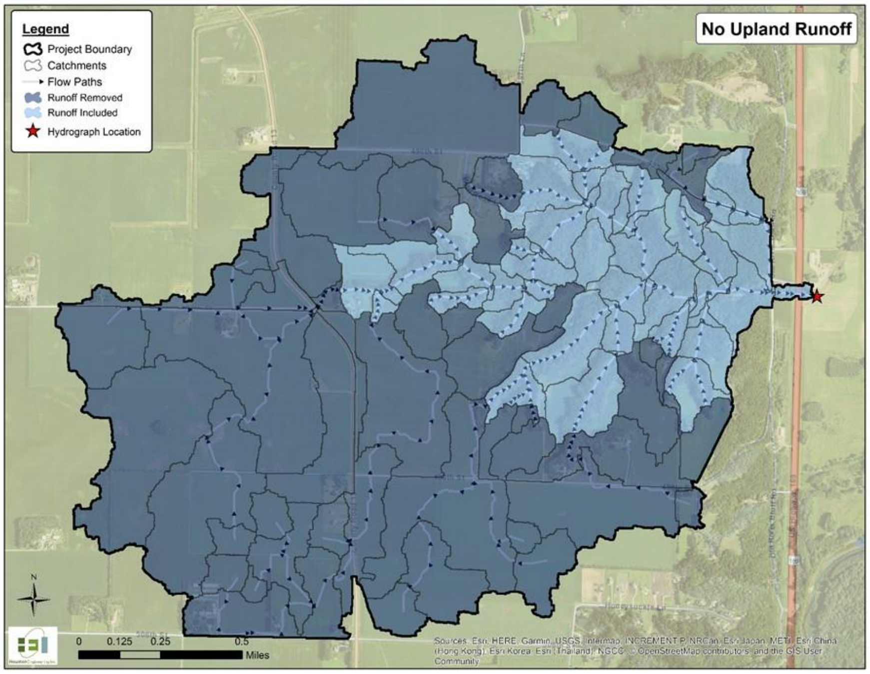

Total Phosphorus Yield - Catchment
Legend
Model/Project Boundary
Model Outlet
TP Yield (lbs/ac/yr)
0.1 - 0.2
0.3 - 0.4
0.5 - 0.6
0.7 - 0.8
0.9 - 1.0
N
0
0.125
0.25
0.5
Miles


Legend
Model/Project Boundary
Model Outlet
TP Yield (tons/ac/yr)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Does not contribute to outlet
Total Phosphorus Yield - Model Outlet
N
0
0.125
0.25
0.5
Miles

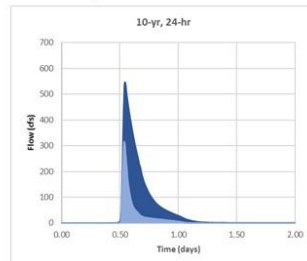

Total Nitrogen Yield - Catchment
Legend
Model/Project Boundary
Model Outlet
TN Yield (lbs/ac/yr)
1.7 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
N
0
0.125
0.25
0.5
Miles
506th St

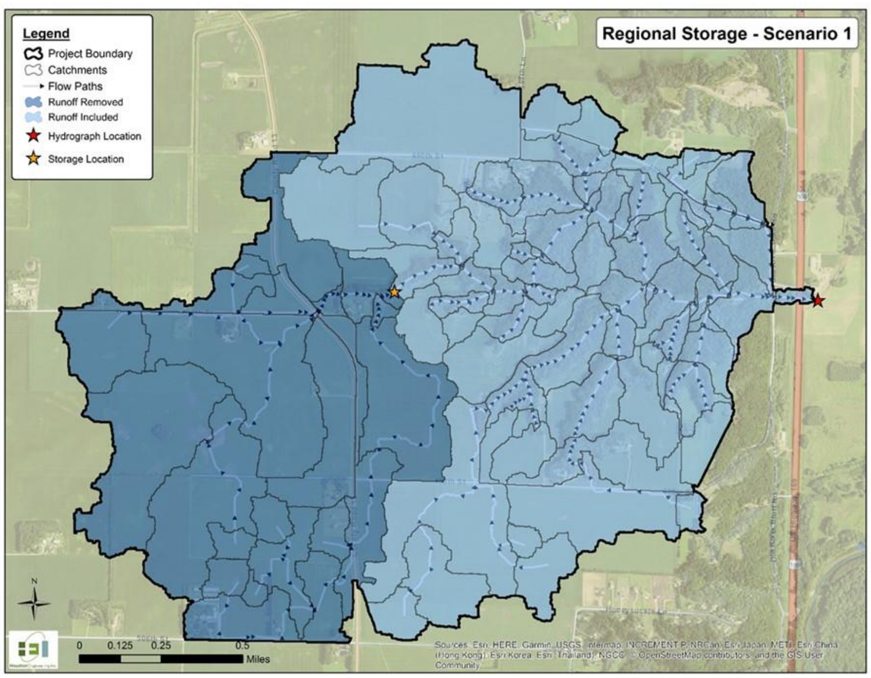

Total Nitrogen Yield - Model Outlet
Legend
Model/Project Boundary
Model Outlet
TN Yield (tons/ac/yr)
1.7 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
Does not contribute to outlet
N
0 0.125 0.25 0.5
Miles

B – INITIAL PROJECT SCENARIOS PPT

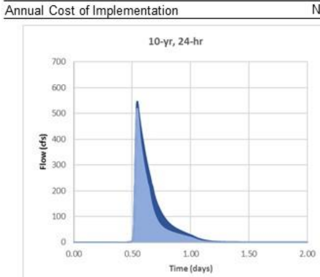


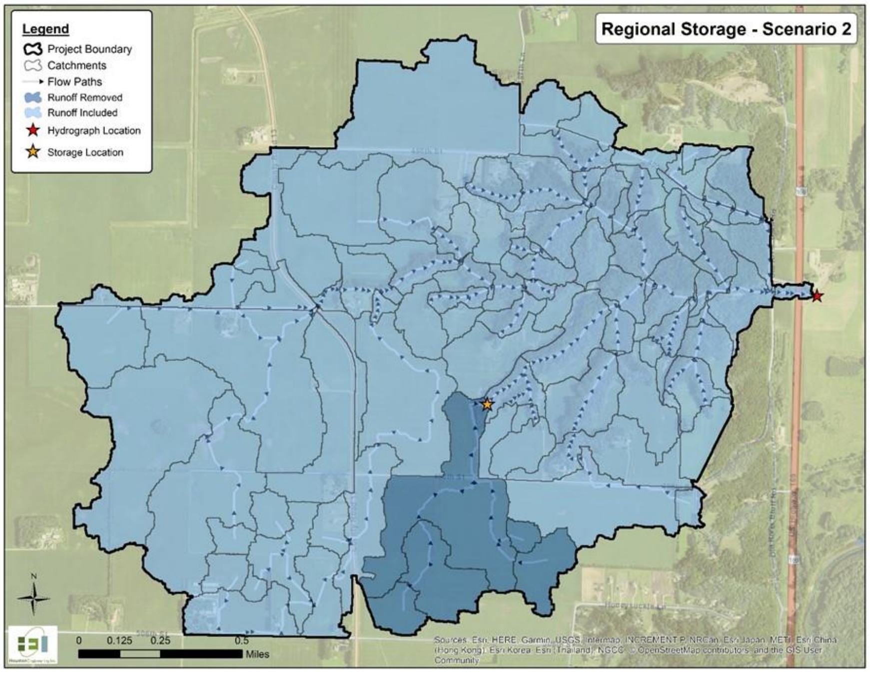
Scenario	
All upland runoff is stored and not allowed to enter the ravine system.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	315.9
Scenario Runoff Volume (ac-ft)	49.9
Peak Flow Reduction (%)	42%
Runoff Volume Reduction (%)	71%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	298
Scenario Annual Total Phosphorus Load (lbs)	77
Scenario Annual Total Nitrogen Load (lbs)	1,258
Annual Sediment Reduction (%)	76%
Annual Total Phosphorus Reduction (%)	78%
Annual Total Nitrogen Reduction (%)	78%
Cost	
Annual Cost of Implementation	N/A



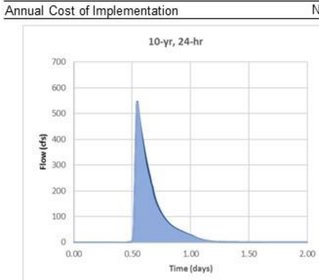


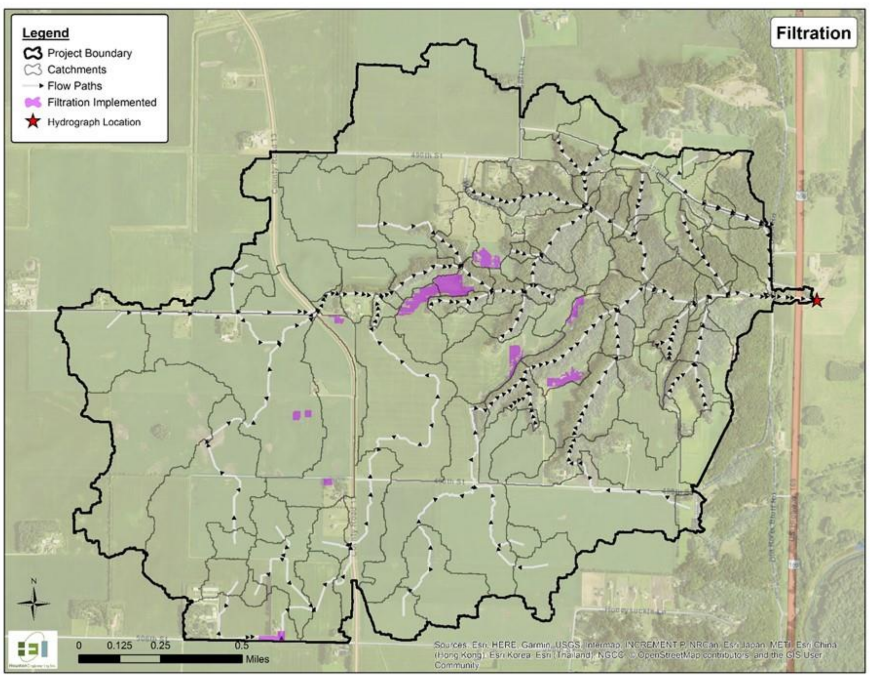
Scenario	
A regional storage pond is implemented to store upland runoff temporarily.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	519.0
Scenario Runoff Volume (ac-ft)	131.9
Peak Flow Reduction (%)	5%
Runoff Volume Reduction (%)	25%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	806
Scenario Annual Total Phosphorus Load (lbs)	234
Scenario Annual Total Nitrogen Load (lbs)	3,813
Annual Sediment Reduction (%)	35%
Annual Total Phosphorus Reduction (%)	32%
Annual Total Nitrogen Reduction (%)	34%
Cost	
Annual Cost of Implementation	N/A



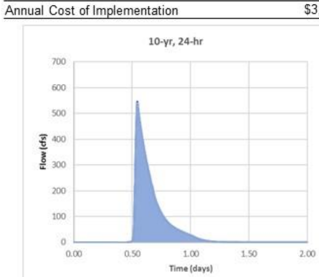


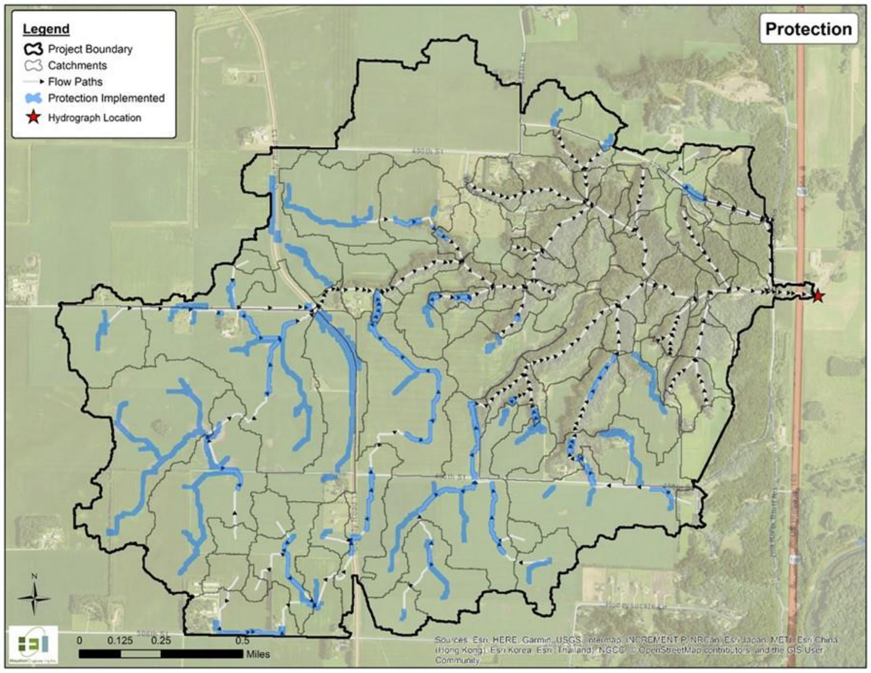
Scenario	
A regional storage pond is implemented to store upland runoff temporarily.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	543.3
Scenario Runoff Volume (ac-ft)	162.1
Peak Flow Reduction (%)	1%
Runoff Volume Reduction (%)	7%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,136
Scenario Annual Total Phosphorus Load (lbs)	314
Scenario Annual Total Nitrogen Load (lbs)	5,210
Annual Sediment Reduction (%)	8%
Annual Total Phosphorus Reduction (%)	9%
Annual Total Nitrogen Reduction (%)	10%
Cost	
Annual Cost of Implementation	N/A



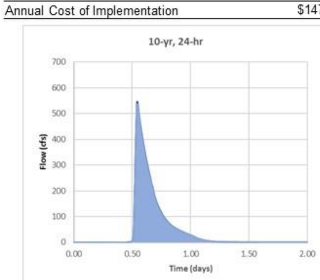


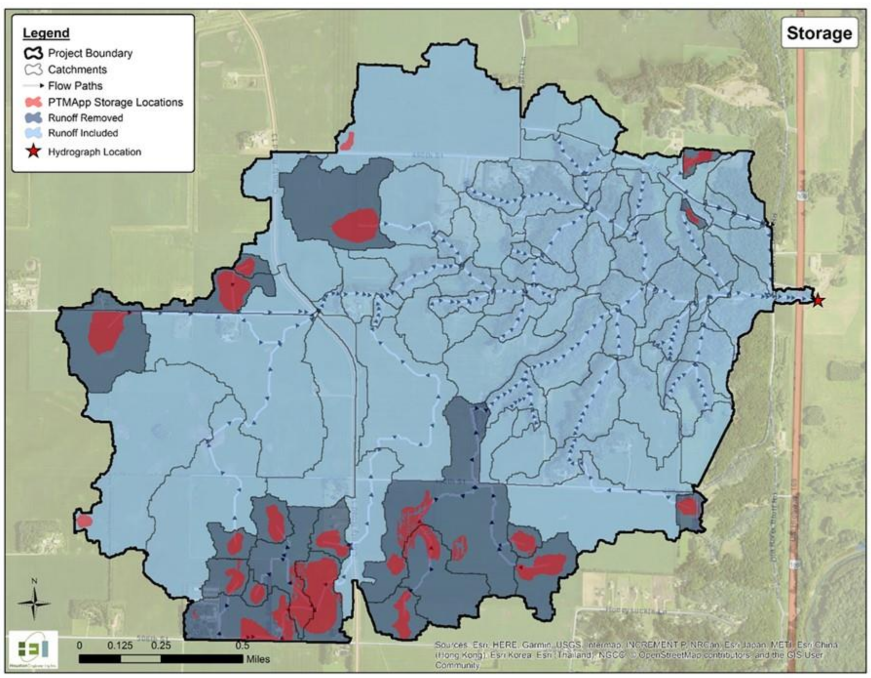
Scenario	
All filtration practices identified by PTMApp are implemented.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	542.2
Scenario Runoff Volume (ac-ft)	174.0
Peak Flow Reduction (%)	1%
Runoff Volume Reduction (%)	1%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,219
Scenario Annual Total Phosphorus Load (lbs)	345
Scenario Annual Total Nitrogen Load (lbs)	5,776
Annual Sediment Reduction (%)	1%
Annual Total Phosphorus Reduction (%)	0%
Annual Total Nitrogen Reduction (%)	0%
Cost	
Annual Cost of Implementation	$3,198



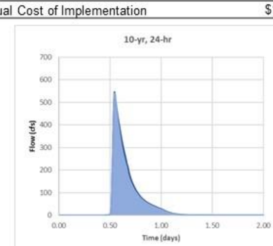


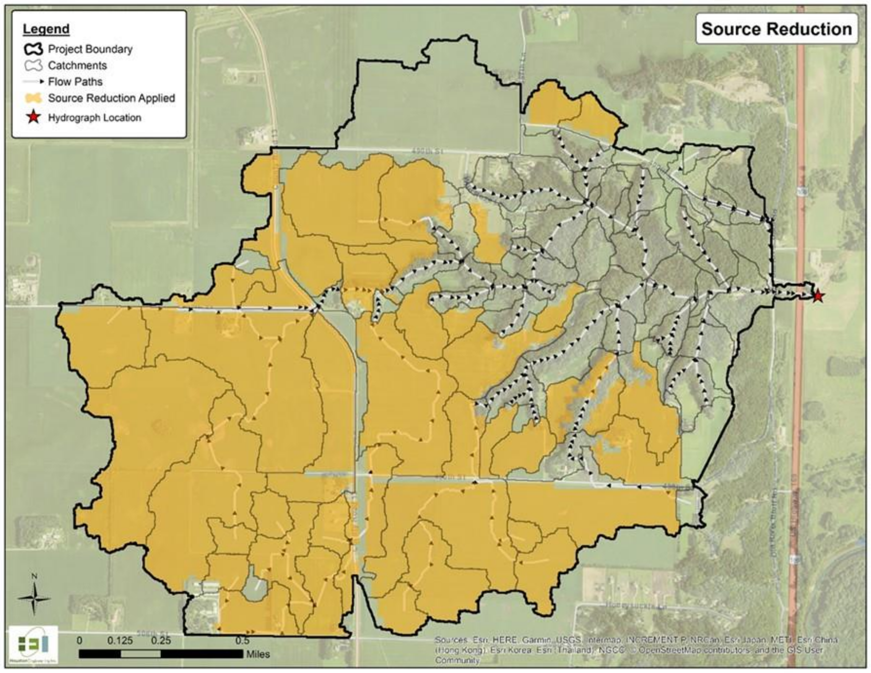
Scenario	
All protection practices identified by PTMApp are implemented.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	537.4
Scenario Runoff Volume (ac-ft)	170.2
Peak Flow Reduction (%)	2%
Runoff Volume Reduction (%)	3%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,158
Scenario Annual Total Phosphorus Load (lbs)	327
Scenario Annual Total Nitrogen Load (lbs)	5,454
Annual Sediment Reduction (%)	6%
Annual Total Phosphorus Reduction (%)	5%
Annual Total Nitrogen Reduction (%)	6%
Cost	
Annual Cost of Implementation	$147,999



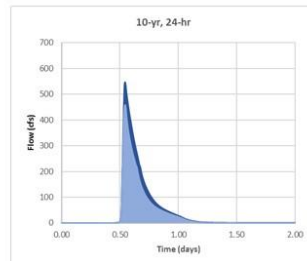


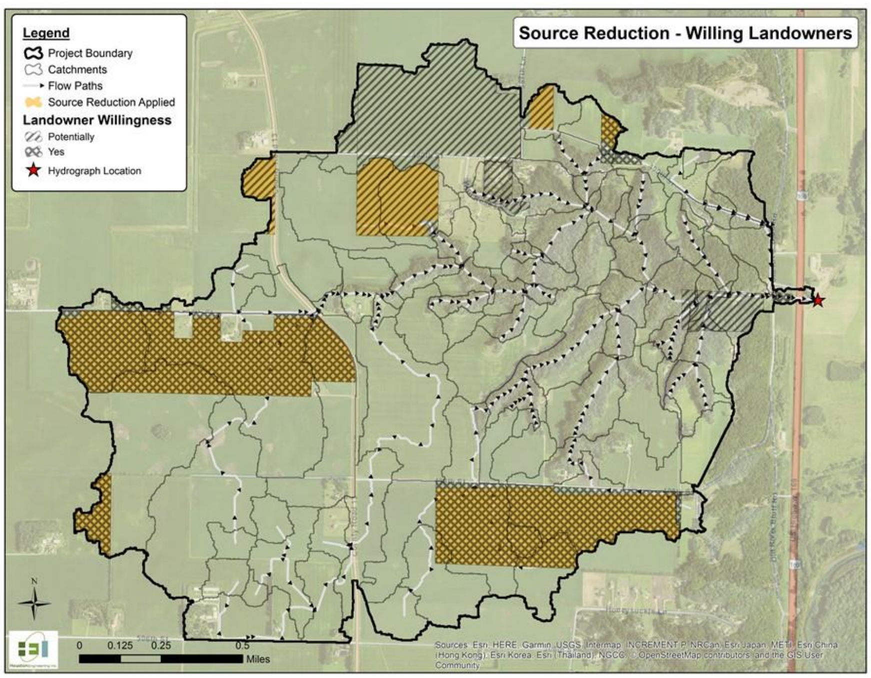
Scenario	
All storage practices identified by PTMApp are implemented. Any catchment that is suitable for storage that captures the majority of the catchment runoff, is removed from the XPSWMM model.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	541.4
Scenario Runoff Volume (ac-ft)	161.9
Peak Flow Reduction (%)	1%
Runoff Volume Reduction (%)	7%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,221
Scenario Annual Total Phosphorus Load (lbs)	342
Scenario Annual Total Nitrogen Load (lbs)	5,697
Annual Sediment Reduction (%)	1%
Annual Total Phosphorus Reduction (%)	1%
Annual Total Nitrogen Reduction (%)	1%
Cost	
Annual Cost of Implementation	$17,337



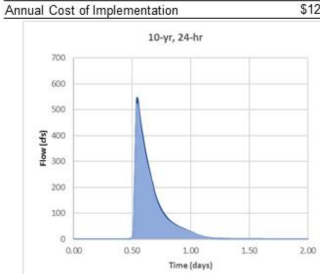


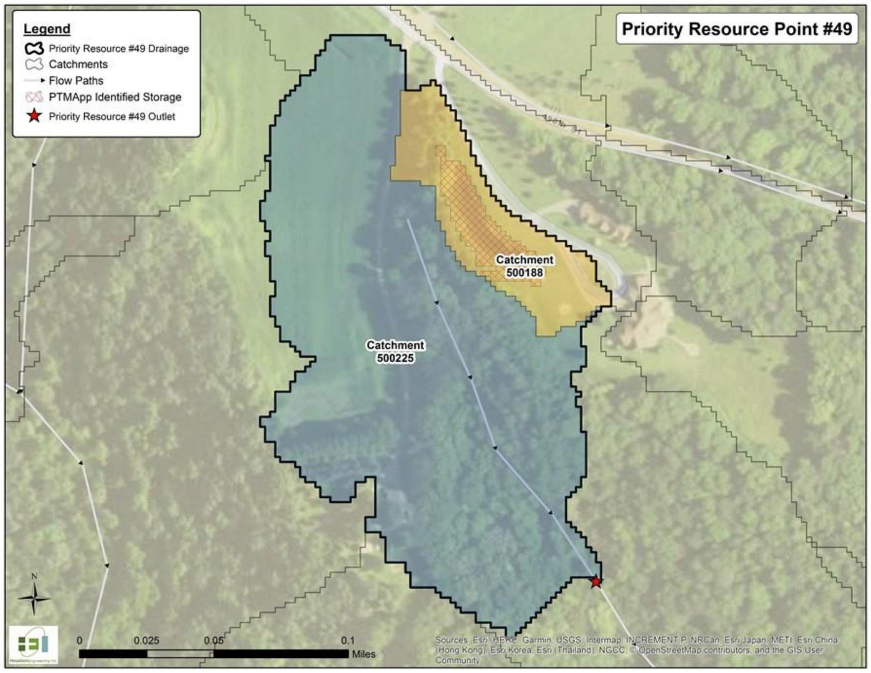
Scenario	
All source reduction practices identified in PTMApp are implemented.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	458.3
Scenario Runoff Volume (ac-ft)	137.7
Peak Flow Reduction (%)	16%
Runoff Volume Reduction (%)	21%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	845
Scenario Annual Total Phosphorus Load (lbs)	265
Scenario Annual Total Nitrogen Load (lbs)	5,137
Annual Sediment Reduction (%)	31%
Annual Total Phosphorus Reduction (%)	23%
Annual Total Nitrogen Reduction (%)	11%
Cost	
Annual Cost of Implementation	$38,065



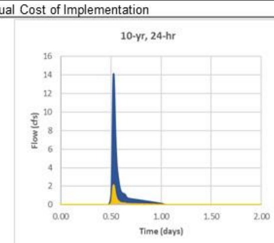


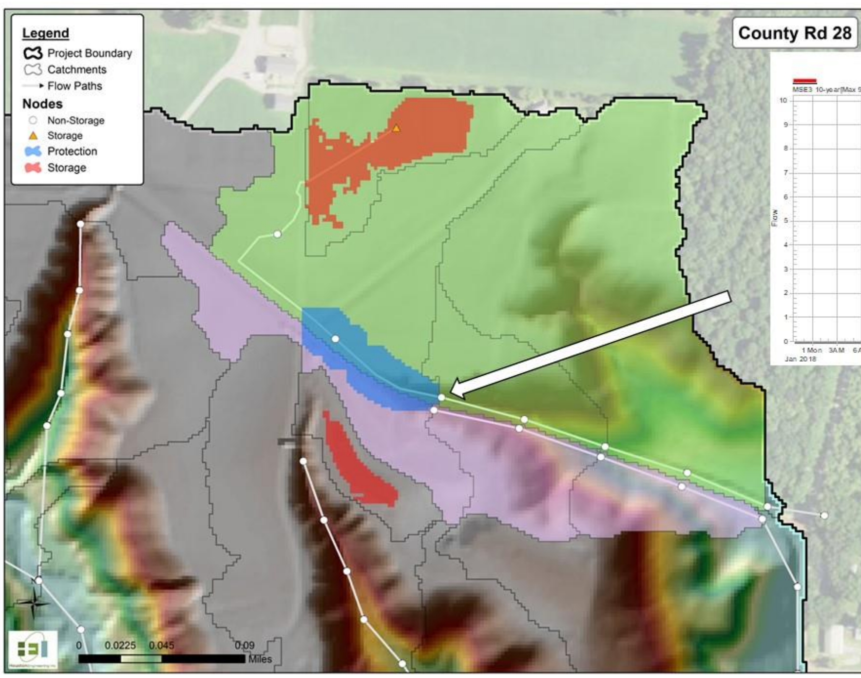
Scenario	
Source reduction practices identified in PTMApp are implemented only on parcels identified as "yes" or "potential" for landowner willingness.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	546.6
Existing Runoff Volume (ac-ft)	175.0
Scenario Peak Flow (cfs)	522.8
Scenario Runoff Volume (ac-ft)	163.0
Peak Flow Reduction (%)	4%
Runoff Volume Reduction (%)	7%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	1,233
Existing Annual Total Phosphorus Load (lbs)	345
Existing Annual Total Nitrogen Load (lbs)	5,776
Scenario Annual Sediment Load (tons)	1,113
Scenario Annual Total Phosphorus Load (lbs)	320
Scenario Annual Total Nitrogen Load (lbs)	5,574
Annual Sediment Reduction (%)	10%
Annual Total Phosphorus Reduction (%)	7%
Annual Total Nitrogen Reduction (%)	3%
Cost	
Annual Cost of Implementation	$12,043

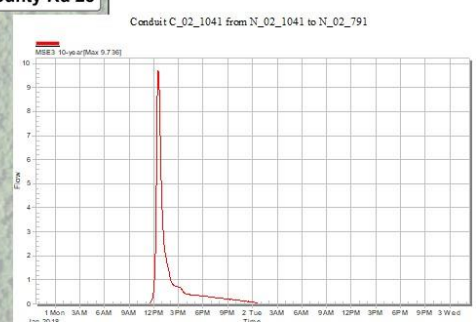


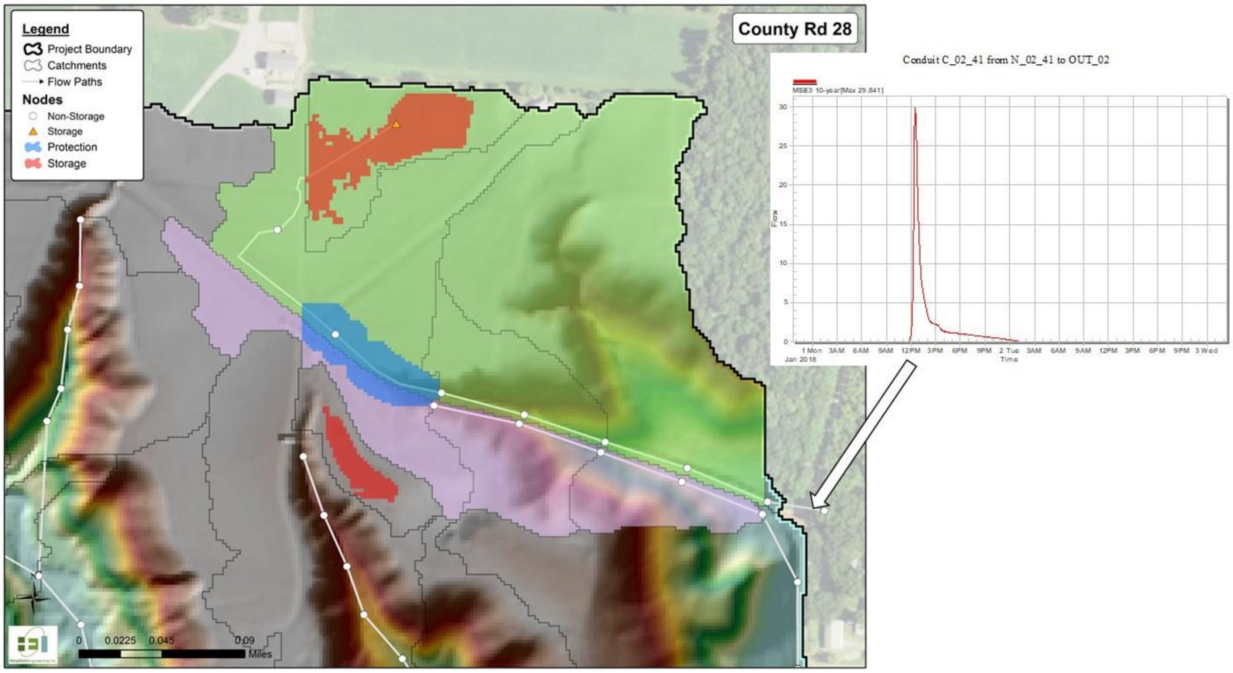


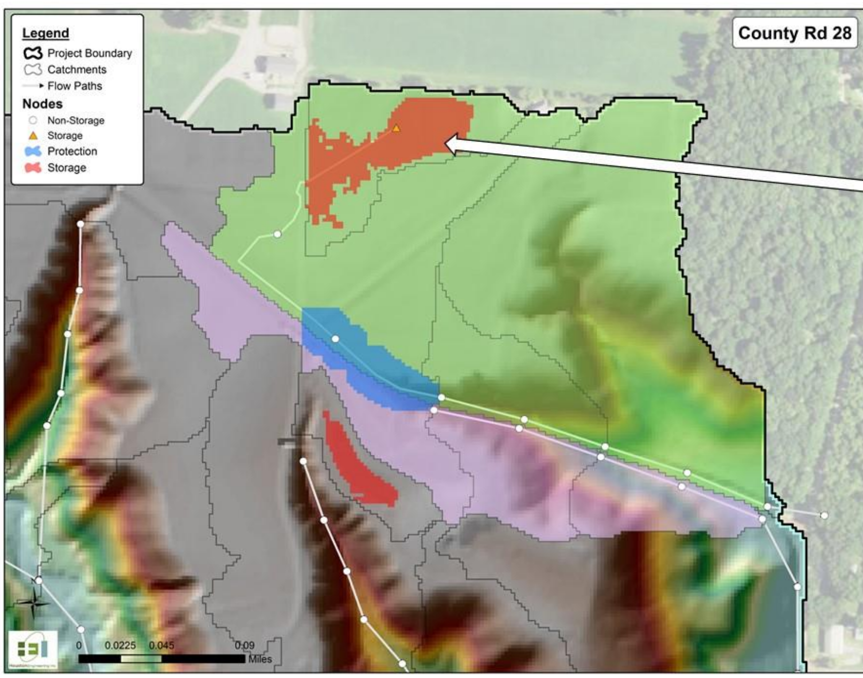
Scenario	
Analysis of a ravine where erosion is occurring.	
Hydrology/Hydraulics (Event-Based)	
Event	10-yr, 24-hr
Depth of Rainfall (in)	4.24
Existing Peak Flow (cfs)	14.1
Existing Runoff Volume (ac-ft)	1.6
500188 Peak Flow (cfs)	2.1
500188 Runoff Volume (ac-ft)	0.2
500188 Percent of Peak Flow (%)	15%
500188 Percent of Runoff Volume (%)	15%
500225 Peak Flow (cfs)	12.0
500225 Runoff Volume (ac-ft)	1.4
500225 Percent of Peak Flow (%)	85%
500225 Percent of Runoff Volume (%)	85%
Water Quality (Annual Average)	
Existing Annual Sediment Load (tons)	15
Existing Annual Total Phosphorus Load (lbs)	3
Existing Annual Total Nitrogen Load (lbs)	47
500188 Annual Sediment Load (tons)	3
500188 Annual Total Phosphorus Load (lbs)	1
500188 Annual Total Nitrogen Load (lbs)	10
500225 Annual Sediment Load (tons)	13
500225 Annual Total Phosphorus Load (lbs)	2
500225 Annual Total Nitrogen Load (lbs)	37
Cost	
Annual Cost of Implementation	N/A











No outflow on a 10-yr, 24-hr event.