WENCK File #1305-0034
April 2020

Dakota County Rural SWMM Study




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Executive Summary

Dakota County contracted Wenck to create a 450-square mile, county-wide stormwater model to evaluate flooding and water quality in rural reaches of the County. Wenck collaborated with Dakota County, the Vermillion River Watershed Joint Powers Organization (VRWJPO) and the North Cannon River Watershed Management Organization (NCRWMO) to direct project efforts.

Wenck reviewed and catalogued existing data that consisted of Flood Insurance Study reports and models, river gauge data, survey data from several sources, an XP-SWMM model of the upper portions of the Vermillion River and numerous GIS files from a variety of sources. After reviewing existing data, Wenck identified data gaps and compiled a survey request list for County staff to collect.

Wenck converted the existing XP-SWMM model to PC-SWMM and added in watersheds and conduits to model the lower reaches of the Vermillion River. Wenck created a new PC-SWMM model of the North Cannon River. Areas added were based on a combination of survey, LiDAR and GIS data. Wenck calibrated newly added areas to river gauge information.

After building the models, Wenck ran storm simulations for several design storm events, created inundation maps and identified approximately fifty potential stormwater improvement project locations. Potential projects identified included wetland restoration projects, flood storage projects, water quality improvement projects, or some combination thereof. Wenck then calculated estimated pollutant loading and volumes of flooded water at each of the potential project locations to allow for ranking potential project sites by severity of flooding or pollutant loading.

After generating the initial project list, Wenck collaborated with project stakeholders to screen and rank the individual project to identify ten sites for further study. For the ten sites, Wenck created preliminary grading plans, cost estimates and evaluated potential pollutant reduction and flood improvement. The ten projects were reranked to provide a list of high priority projects for the County to pursue as funding is available.

Four projects are identified as the “best” potential projects, and two are identified as the “worst” potential projects. The remain four are “average” potential projects.

Wenck summarized project findings and recommendations in a series of memoranda and reports. Final deliverables included catalogued GIS data, electronic PC-SWMM models, and a final technical report documenting Wenck’s methodologies.

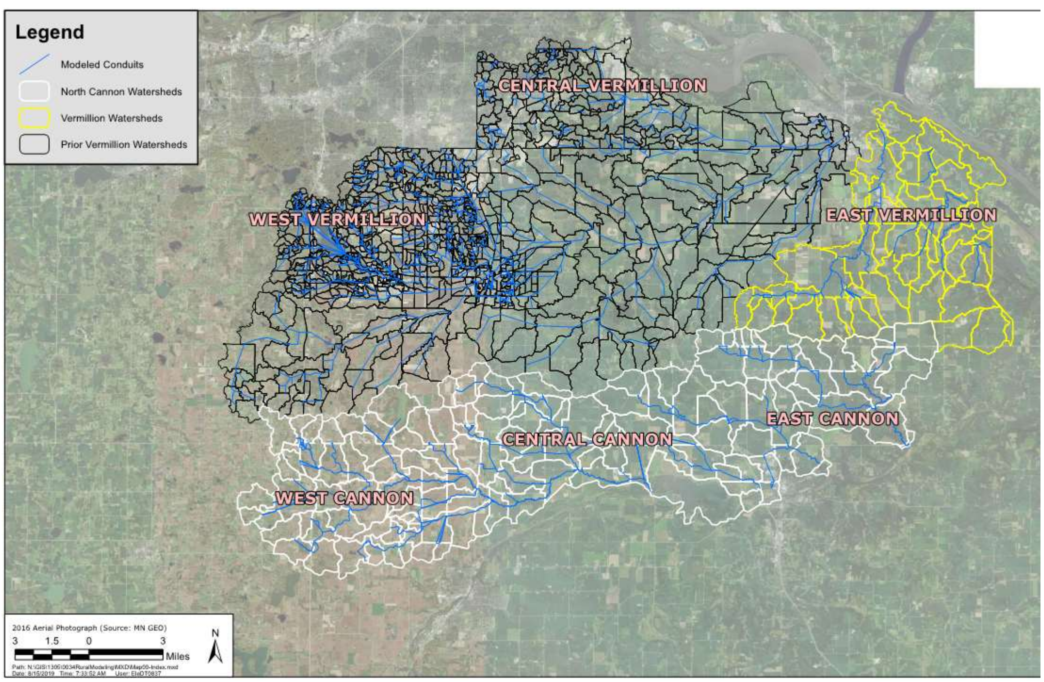
1.0 Introduction and Objectives

Dakota County hired Wenck to create a stormwater management model (SWMM) to study two large, primarily rural, watersheds within the county boundaries: the Vermillion River Watershed and the North Cannon River Watershed. The goal of the study is to identify flood and erosion prone areas and identify potential water quality improvement project locations (specifically wetland restoration and water retention projects) within both watersheds. This memorandum summarizes Wenck's modeling approach and provides a list of potential project locations based on model results.

1.1 BACKGROUND

Wenck collaborated with stakeholders from the County Environmental Department (County), the Vermillion River Watershed Joint Powers Organization (VRWJPO), the North Cannon River Watershed Management Organization (NCRWMO) and the Dakota County Soil and Water Conservation District (SWCD) to identify key project objectives. The first phase of the project involved identifying data gaps in the available water quality and drainage studies. The second phase of the project involved developing a new PC-SWMM model for the North Cannon watershed, converting the existing Vermillion River XP-SWMM model to PC-SWMM[1], and adding the Sand Coulee and Etter Creek watersheds to the Vermillion model. Figure 1-1 displays the project area.

Figure 1-1: Project Area



[1] Wenck and County staff together decided to utilize PC-SWMM software rather than XP-SWMM software due to licensing concerns, GIS integration, and ease of access via EPA-SWMM, a free-to-download SWMM program.

The third phase involved calibrating the models, analyzing preliminary results, and generating a list of potential flood and/or water quality improvement project locations. This memorandum summarizes Wenck's approach for the first three phases and provides a list of preliminary projects.

1.2 OBJECTIVES

This primary goal of this study is to identify and quantify flood and erosion prone areas within the rural parts of the County such that wetland restoration and water retention project locations may be identified. After such regions have been identified and quantified, they shall be ranked based on a variety of metrics that are determined as part of this Study. Based on Stakeholder input and the provided rankings, preliminary design will be provided for a select number of projects that includes cost estimates and water quality models.

1.2.1 Assess Flooding and Pollutant Loading

Anecdotally the County has a general sense for what rural areas in the County are flood prone. Many of these areas are used for agriculture, and therefore do not receive as high of level of attention or study as urban flood prone areas. This study will assist in identifying and quantifying rural areas that are subject to frequent flooding. As urban areas within the County continue to expand, stormwater volume passing through the County's creeks and rivers will continue to increase. An understanding of the County's floodplains and their management will increase in importance as the years progress.

By identifying flood prone areas and quantifying flood volume, the County will have a better understanding of flow through its rural areas, to direct future investment in flood protection projects. In addition to improving flood management throughout the County, future flood mitigation projects offer an opportunity to incorporate water quality improvement best management practices (BMPs) to help the County achieve total maximum daily load (TMDL) goals and generally improve water quality. By identifying pollutant loading to flood prone areas, future improvement projects may be compared against one another to identify which are the optimal use of County resources.

Finally, this project will assist in identifying areas where a flood prone area with high pollutant loading overlays an area that historically was wetland but has been filled or drained for purposes of agriculture. Such areas are locations for potential wetland restoration projects that may accomplish flood improvement and water quality improvement objectives, while investing in building the County's wetland mitigation bank that may be used to facilitate other County projects, or to offer for sale to developers to both ease future development and provide a source of funding for other County initiatives.

1.2.2 Identify Improvements

Several types of projects are considered within this study, ranging from stream bank restoration type projects, which are linear in nature, to a variety of discrete BMP projects, such as extended detention basins, wetland restorations or filtration basins. Based on collaboration with project stakeholders, wetland restoration projects are identified as the highest priority projects and are the primary type of project considered. Though this Study identifies a select number of potential projects, the PC-SWMM model may be used in the future to identify other project types that were not the focus of this Study.

1.2.3 Preliminary Design

This study includes preliminary design for ten projects that are considered high priority projects. The final deliverable will be project rankings, where Wenck compared each of the analyzed projects based on cost (including capital and maintenance cost), pollutant removal efficiency and floodplain impact. The list of ten projects may be used for annual budgeting purposes, grant applications, as a basis for preliminary conversations with landowners for purchasing land (or acquiring easements on land), or for other preliminary planning efforts.

1.2.4 Long Term

The long-term outcome of this Study is to provide the County with a planning tool that will direct future efforts for a variety of County programs. For example, the transportation group could use the model to identify undersized culverts below County roads and appropriately size new structures. As PC-SWMM is fully integrated with GIS, model output can easily be overlain with other shapefiles such as parcels, easements, regulated floodplain, wildlife conservation areas, DWSMAs, groundwater rehabilitation areas, soil type, land use, land cover, wetlands, and any other number of layers that may be affected by flooding or erosion.

2.0 Methodology

Wenck reviewed and catalogued existing data that consisted of Flood Insurance Study reports and models, river gauge data, survey data from several sources, an XP-SWMM model of the upper portions of the Vermillion River and numerous GIS files from a variety of sources. After reviewing existing data, Wenck identified data gaps and compiled a culvert survey request list for County staff to collect. Wenck generally matched modeling methodology from the existing Vermillion River model for calculating hydrologic and hydraulic input.

2.1 PREVIOUS STUDIES

A separate consultant developed the existing XP-SWMM model for the Vermillion River watershed. Wenck converted the XP-SWMM model to a PC-SWMM model and added the Sand Coulee and Etter Creek watersheds to the model using a combination of available culvert and cross section information from previous models, crossing and storm sewer data collected by Dakota County surveyors and cross sections developed from County LiDAR data. Delineated watersheds from local municipal storm water management plans were combined with topographically derived watersheds. The prior study primarily focused on urban areas, and how stormwater flows between the various communities within the Vermillion River watershed.

2.2 XP-SWMM TO PC-SWMM CONVERSION

Wenck converted the existing XP-SWMM model to PC-SWMM using XP-SWMM's ability to save-as an EPA-SWMM file, and PC-SWMM's ability to import an EPA-SWMM file. After the files were imported, Wenck performed spot checks throughout the imported model to check whether data imported accurately. After Wenck reviewed the data, the existing XP-SWMM model and PC-SWMM model were concurrently run, and results compared to verify PC-SWMM model output was in line with XP-SWMM output.

2.3 HYDROLOGY

To match the XP- model, Wenck used the SWMM hydrology method and the Horton method of estimating infiltration to model watershed hydrology. The EPA developed the SWMM method for advanced watershed modeling; SWMM hydrology functions well for single event or long-term modeling. The SWMM method uses the following parameters to estimate runoff: subwatershed width, percent impervious, slope, impervious depression storage, pervious depression storage, impervious Manning's coefficient, pervious Manning's coefficient and percent of impervious with zero detention. Additionally, Wenck used the Horton method to estimate infiltration rates over permeable area. The Horton method considers maximum and minimum infiltration rates, a decay constant, drying time and maximum infiltration volume.

Initial input values for various hydrology parameters was largely a GIS exercise; Wenck calculated input values based on County-provided and publicly available GIS information. Table 2-1 summarizes hydrologic input information.

Table 2-1: Hydrology Input Parameter Summary

Parameter	Description	Calculated From
Area	Watershed area	Watersheds delineated in GIS based on LiDAR.
Width	Area divided by longest flow path.	Watersheds delineated in GIS based on LiDAR. Longest flow path calculated based on an assumed ratio of length to width.
Percent Impervious	Percent of impervious area within watershed.	Calculated based on land cover, land use, and assumed percent impervious table from prior study report. See Table 2-2 for additional information
Impervious Depression Storage	Depth of initial abstraction over impervious area.	Assumed to be a constant 0.06 to match methodology from prior study.
Impervious Manning's Coefficient	Manning's n for overland flow over impervious area.	Assumed to be a constant 0.014 to match methodology from prior study. See Table 2-3 for additional information.
Pervious Depression Storage	Depth of initial abstraction over pervious area.	Calculated based on land cover, land use, and assumed percent impervious table from prior study report. See Table 2-3 for additional information.
Pervious Manning's Coefficient	Manning's n for overland flow over pervious area.	Calculated based on land cover, land use, and assumed percent impervious table from prior study report.
Zero Detention	Percent of impervious area with no depression storage.	Assumed to be a constant 0.0 to match methodology from prior study.
Maximum Infiltration Rate	Maximum infiltration rate.	Calculated based on SSURGO soil types and infiltration rates published in prior study report. See Table 2-4 for additional information.
Minimum Infiltration Rate	Minimum infiltration rate.	Calculated based on SSURGO soil types and infiltration rates published in prior study report. See Table 2-4 for additional information.
Decay Constant	Exponential constant that determines rate at which infiltration rate decreases.	Calculated based on SSURGO soil types and decay constant published in prior study report. See Table 2-4 for additional information.
Drying Time	Time for fully saturated soil to dry completely.	Assumed to be a constant 8-days. This generally matches prior study input[2].
Maximum Infiltration Volume	Maximum volume soil is capable of infiltrating.	Calculated based on depth to water table and an assumed soil porosity.

[2] XP-SWMM and PC-SWMM have slightly different inputs for drying time. XP- assumes a regeneration rate that is a user-input fraction of the decay rate. PC- assumes a linear regeneration rate based on maximum drying time. The assumed drying time of 8-days approximately matches the assumed regeneration rate.

Table 2-2 summarizes modeled impervious percentage by Minnesota Land Cover Classification System (MLCCS) information. Wenck created a weighted average percent impervious based on MLCCS data and watershed boundaries. Water surfaces were modeled as 100-percent impervious. The previous XP Study used tables based on 2005 land cover developed by Applied Ecological Services (AES), which was based on the MLCCS for the western portion of the Vermilion River and the 2005 Metropolitan Council land use classifications. Wenck's analysis for percent impervious is based on more precise values and updated information.

Table 2-2: Impervious Percent by Land Cover Classification

Land Cover Classification	Impervious Percent (%)
11-25% Impervious	18
26-50% Impervious	38
5-10% Impervious	7.5
51-75% Impervious	63
76-100% Impervious	90
Developed, High Intensity	90
Developed, Low Intensity	34.5
Developed, Medium Intensity	64.5
Developed, Open Space	10
Agricultural Land, Cultivated Crops, Deciduous Forest, Hay/Pasture, Herbaceuous, Maintained Tall Grass, Mixed Forest, Short Grasses, Shrubland, Tall Grasses, Tree Plantation, Forest, Dry Tall Grasses,	0
Emergent Herbaceuous Wetlands, Open Water, Wetland Emergent Vegetation, Wetland Forest, Wetland Open Water, Woody Wetlands, Wetland Shrubs, Mud Flat	100

Table 2-3 summarizes pervious Manning's n values and depression storage by MLCCS land use information.

Table 2-3: Pervious Roughness Coefficient and Pervious Depression Storage by Land Use Classification

Land Use Classification	Manning N Pervious	Depression Storage
Farmstead	0.26	0.167
Agricultural	0.21	0.197
Undeveloped	0.28	0.178
Major Highway	0.22	0.194
Industrial and Utility	0.24	0.171
Wetlands	0.12	0.08
Open Water	0.12	0.08
Extractive	0.14	0.135
Golf Course	0.24	0.153
Institutional	0.25	0.169
Major Railway	0.01	0.01
Manufactured Housing Parks	0.24	0.159
Mixed Use Industrial	0.23	0.161

Land Use Classification	Manning N Pervious	Depression Storage
Mixed Use Residential	0.3	0.183
Multifamily	0.26	0.166
Office	0.23	0.171
Park, Recreational, or Preserve	0.28	0.177
Retail and Other Commercial	0.17	0.173
Seasonal/Vacation	0.24	0.15
Single Family Attached	0.25	0.171
Single Family Detached	0.27	0.169

Table 2-4 summarizes modeled infiltration parameters by soil type. Soil type was modeled based on SSURGO soils information.

Table 2-4: Horton Infiltration Parameters

Hydrologic Soil Group	Maximum Infiltration Rate, F_0 (in/hr)	Minimum Infiltration Rate, F_c (in/hr)	Decay Constant, k (1/sec)
A	5.0	0.38	0.00115
B	3.0	0.23	0.00115
C	2.0	0.10	0.00115
D	1.0	0.03	0.00115
A/D	1.0	0.03	0.00115
B/D	1.0	0.03	0.00115
C/D	1.0	0.03	0.00115

2.4 HYDRAULICS

Wenck input hydraulic parameters based on a combination of county survey information and LiDAR. Culverts and bridges throughout the project area are modeled based on survey information. Surveyed channel cross-sections represent open channels where available; LiDAR information was used for open channels where cross-section information was not available. Wenck used HEC-GeoRAS software to generate cross-sections and import information into PC-SWMM.

Table 2-5: Hydraulic Input Parameter Summary

Parameter	Description	Calculated From
Culverts	Conveyance links that are pipes beneath roads.	County survey information (preferably) or information was copied from existing models. Culverts assumed to be zero percent plugged.
Bridges	Bridge crossings where creek or river passes beneath a larger road.	County survey information (preferably) or information was copied from existing models.
Open Channels	Conveyance links that represent stream, creek and river channels.	HEC-GeoRAS was used to process information. Where available, County surveyed cross-sections were used to model channel geometry. When County survey was unavailable, cross-sections in existing models were used. Where existing cross-sections were unavailable, County LiDAR was used.

2.5 CALIBRATION

Wenck followed two procedures to calibrate the newly modeled areas. Where river gauge information was available, Wenck iteratively modeled a month-long simulation using actual precipitation data. A month-long simulation period was selected such that there would be some level of baseflow running through the system and such that the underlying soils were not assumed to be perfectly dry.

Where river gauge information was not available, Wenck calculated a runoff coefficient in inches of runoff per acre over a similar-in-size, already modeled and calibrated, rural watershed. Wenck then calibrated the newly modeled area such that the new area's runoff coefficient matched the existing area's runoff coefficient within reason.

For both calibration methods, adjusting the subwatershed width, and minimum and maximum infiltration rate parameters was the most effective. This generally matches the methodology followed to calibrate the prior model. Adjusting subwatershed width affects the watershed's time of concentration, determining when the peak runoff flow occurs. Minimum and maximum infiltration rate parameters affect the total volume of water that runs off pervious areas. After preliminary calibration efforts, Wenck generated inundation maps for County review to ensure model output corresponded to historic knowledge of drainage through the County.

Wenck calibrated the runoff volume for the additional Vermillion subwatersheds to match the average runoff depth from the existing Vermillion subwatersheds. Wenck applied a global factor to adjust the maximum and minimum infiltration rates from Table 2-4 to match the 100-year runoff depths. Wenck reduced the maximum and minimum infiltration rates to match the 100-year runoff depths. The model was run for the 2- and 10-year events using this calibration as a spot check.

Wenck calibrated the North Cannon Model using stage data for Chub Creek at Dixie Avenue (CR 83). Wenck created a precipitation file that utilized data from rain gages at the Minneapolis-St. Paul Airport (MSP), St. Paul, Red Wing, and Northfield. The precipitation data from the four nearby gages was then converted into a single dataset using the inverse distance weighting method. Wenck adjusted the maximum and minimum infiltration rates to match the stage data from Chub Creek. Wenck reduced the maximum and minimum infiltration rates to match the stage data from Chub Creek.

3.0 Hydrologic and Hydraulic Results and Initial Screening

Wenck created a series of maps that display inundated areas, channel velocities, channel shear stress and overtopping roads based on model results. Wenck then identified 59 locations for potential water quality and flood improvement projects. The following maps are appended to this memorandum:

3.1 INDEX MAP (MAP 0)

Wenck divided the project area into six areas for viewing ease. This includes the West, Central and East Vermillion River, and the West, Central and East Cannon River areas. The index map identifies the boundaries for the six areas.

3.2 INUNDATION MAPS (MAPS 1-6)

Inundation maps identify areas that flood during the 100-year storm event based on modeled high-water levels (HWLs). Wenck created shapefiles for inundated area based on a combination of 100-year model output plus LiDAR information. The maps include the FEMA 100-year base flood as a background layer for reference and comparison.

3.3 CHANNEL EROSION MAPS (MAPS 7-12)

The channel erosion maps plot channels with high shear stress (greater than one psf[3]) and high velocities (greater than five fps[4]) such that erosion prone reaches may be identified. Velocity is a direct model output; shear stress is a calculated parameter. Prolonged shear stress greater than one psf will cause erosion, even in well vegetated channels. Prolonged velocities greater than five fps will also cause erosion in well vegetated channels.

3.4 PROJECT LOCATION MAPS (MAPS 13-18)

Wenck considered two broad types of potential projects: linear stream restoration-oriented projects and discrete wetland restoration or water retention-oriented projects.

3.4.1 Linear Stream Restoration Projects

Stream restoration projects are a BMP that entail regrading streambanks to shallower, less erosion prone slopes and reconnecting the surrounding fields to the floodplain. Streambank restoration projects would have moderate water quality improvement by eliminating a source of erosion and sediment. However, streambank restoration would have a less significant impact on flooding unless a significant amount of storage is excavated in conjunction with the streambank restoration, or flood-protection embankments are constructed.

Extended areas with high channel shear stress and high channel velocities are candidates for stream bank restoration projects. There are myriad reaches with hundreds to thousands of feet of channel that could be at risk for erosion due to elevated velocities and shear

[3] Pound per square foot.
[4] Foot per second.

stress. For sake of clarity, the map does not specifically identify potential stream bank location projects. Rather, reaches that could be selected for restoration projects are identified in the attached maps with red and yellow reaches.

3.4.2 Discrete Wetland Restoration and Water Retention Projects

The other type of project Wenck considered were discrete projects, such as wetland restoration, large scale infiltration basins, or large-scale flood storage projects. These projects would both improve water quality and improve flooding. Wenck created a point shapefile that visually represents potential BMP locations in the attached maps; BMP projects are presented in three subcategories:

- Flooding: locations where the model predicts significant flooding in the project location's watershed, but where hydric soils are not present. Potential projects could include large scale infiltration basins that would provide flood storage and improve water quality.
- Flooding and wetland restoration: projects with significant inundation and where hydric soils are present. Hydric soils are conducive to wetland hydrology, and are, in some cases, indicative of filled wetlands. Potential projects would restore wetlands, resulting in improved water quality and additional flood storage.
- Wetland restoration: projects that have hydric soils but do not show significant existing flooding based on model output.

Wenck identified 59, rural-based, potential BMP oriented project locations based on reviewing model output for flooding. Wenck initially reviewed inundation maps to identify preliminary BMP locations. This initial iteration was a qualitative analysis, in which Wenck visually compared modeled floodplains and overtopping roads with a structures shapefile and hydric soils shapefile. Locations with a relatively large area of flooding, overtopping roads, or (close to being) inundated structures were identified as potential stormwater improvement projects. Wenck considered rural areas within both the Vermillion River and North Cannon River Watersheds. Potential project locations outside of Dakota County were not considered in this analysis.

3.5 PROJECT RANKING

After identifying potential project locations, Wenck calculated the following parameters for the potential BMP-oriented projects:

- 100-year flooded area, within potential project's watershed.
- 100-year flooded volume, within potential project's watershed.
- Freeboard from 100-year high water level (HWL) to low opening[5] of structures[6].
- Freeboard from 100-year HWL to road overtopping[7].
- Total suspended solids (TSS) load to potential project location.
- Total phosphorus (TP) load to potential project location.

[5] Low opening determined based on structure shapefile and LiDAR.

[6] Wenck calculated freeboard between HWL and low opening for all buildings within the study area. Structures with negative freeboard are indicative of buildings that currently will flood during the 100-year event. Structures with less than one foot of freeboard are at an elevated risk of flooding. Wenck provided results of the structure freeboard analysis in a shapefile separate from the potential project shapefile.

[7] Road overtopping elevation based on County survey data where available and LiDAR where not available.

Flooded area and volume provide a method to evaluate which project locations experience the most significant flooding. Flooded area ranged from 0.3 to 1477 acres, depending on project location. Flooded volume ranged from 0.1 to 40,000 acre-feet depending on project location.

Freeboard between 100-year HWL and low opening of structures identifies which buildings currently flood or are at an elevated risk of flooding. Freeboard from 100-year HWL to road overtopping elevations identify locations where roads are or are close to overtopping.

Wenck calculated TSS and TP loading following the MPCA published TSS and TP loading rates based on the projects' upstream contributing area and land uses shown in Table 3-1 and Table 3-2[8]. TSS loading ranged from 2.8 to 275 ton/yr; TP loading ranged from 121 to 6061 lb/yr. In Wenck's opinion, any selected project location would have more than enough TSS and TP load to justify a water quality improvement-oriented project.

Table 3-1: Total Suspended Solids Loading Rates

Land Use	MPCA Recommended TSS Loading Rate (lb/ac/yr)
Residential	76
Mixed Residential	111
Commercial	221
Industrial	193
Freeway	560
Open Space (Agricultural)	70

Table 3-2: Total Phosphorus Loading Rates

Land Use	MPCA Recommended TP Loading Rate (lb/ac/yr)
Native Grass	0.10
Forest	0.13
Pasture	0.70
Corn or Soybean	2.20
Mixed Agriculture	0.70
Low Density Residential	1.10
High Density Residential	1.30
Commercial	2.00
Highways	3.10

Wenck created a series of charts to evaluate the 59 projects to determine if any obvious trends emerged. Wenck focused solely on hydrologic and pollutant loading.

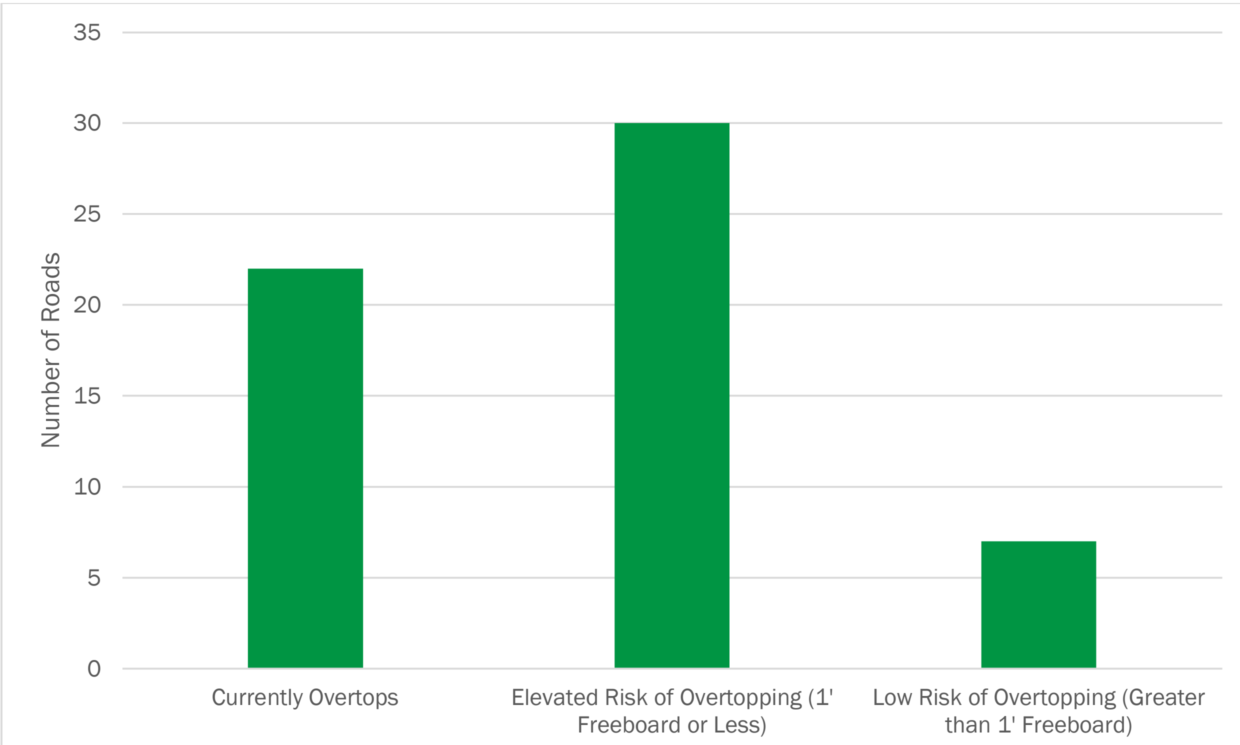
3.5.1 Overtopping Roads

Figure 3-1 divides projects into three categories, when considering adjacent roads: projects with roads that currently overtop, projects with roads that are at an elevated risk of overtopping (less than one foot of freeboard between HWL and road elevation), and projects with roads that are at a low risk of overtopping (greater than one foot of freeboard between HWL and road elevation. Most project locations identified are adjacent to roads that either

[8] With the exception of TSS Loading for open space. TSS loading for open space was modeled based on a 2014 Sauk River report that studied pollutant loading in a rural watershed based on collected water quality data (http://www.srwdmn.org/pdfs/project-reports/2014-MPCA-SRW-pollutant-source-assessment-eval-resource-management-secenarios.pdf)

currently overtop or are at an elevated risk of overtopping. Only seven projects are adjacent to roads that are at a low risk of overtopping, based on the one foot of freeboard criteria. Wenck recommends projects adjacent to currently overtopping roads or elevated risk roads be classified as higher priority projects than those projects adjacent to low risk roads.

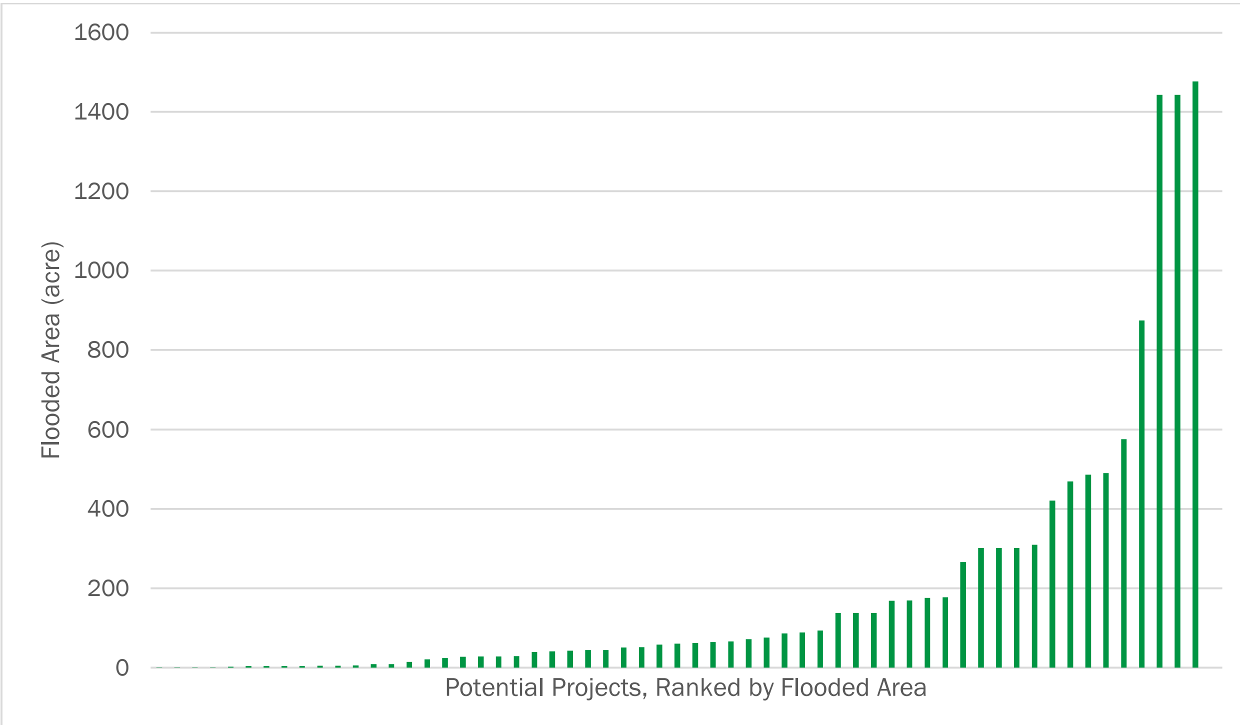
Figure 3-1: Roads that Currently Overtop or at an Elevated Risk of Overtopping



3.5.2 Flooded Area

Figure 3-2 is a bar chart that ranks projects by flooded area. There appears to be a relatively marked break in projects at 200 acres of flooded area. Once the flooded area exceeds 200 acres, flooded area increases more rapidly. Wenck recommends projects with greater than 200 acres of flooded area be classified as higher priority projects than projects with less than 200 acres of flooded area.

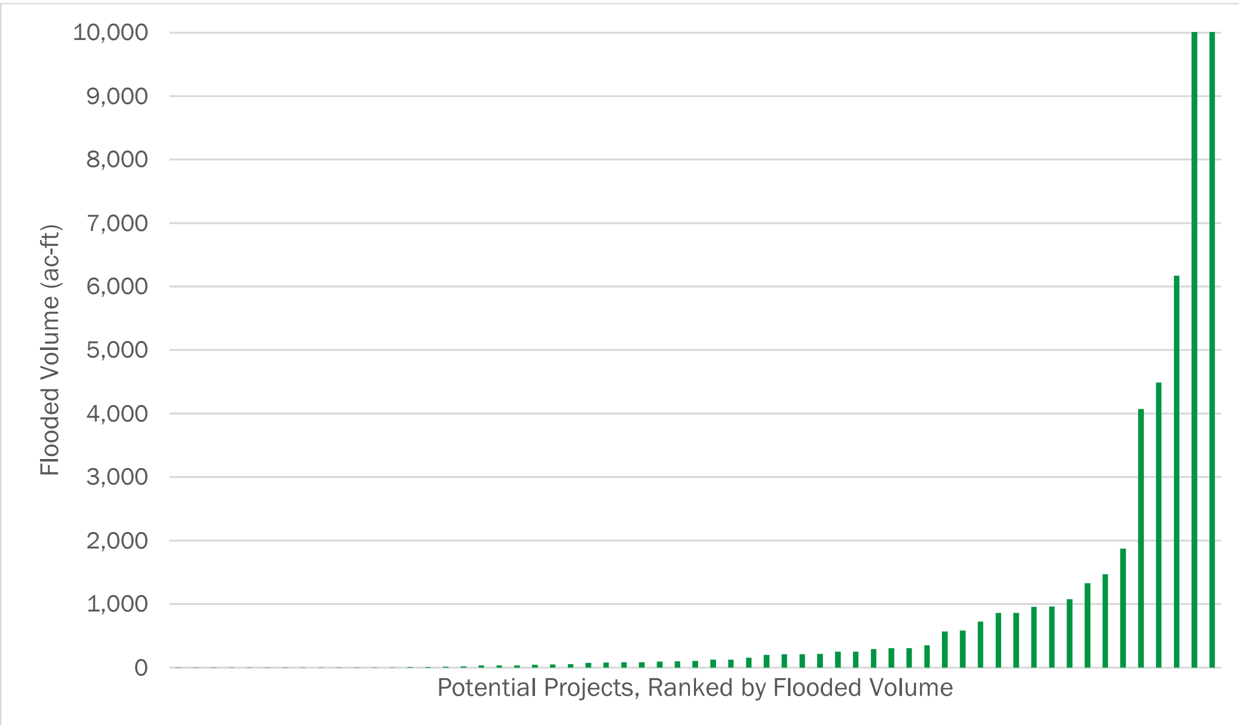
Figure 3-2: Projects Ranked by Flooded Area



3.5.3 Flooded Volume

Figure 3-3 is a bar chart that ranks projects by flooded volume. Like flooded area, there appears to be a relatively marked break in projects at 1,000 acre-feet of flooded area. Once the flooded area exceeds 1,000 acre-feet, flooded volume increases more rapidly. Wenck recommends projects with greater than 1,000 acre-feet of flooded volume be classified as higher priority projects than projects with less than 1,000 acre-feet of flooded volume.

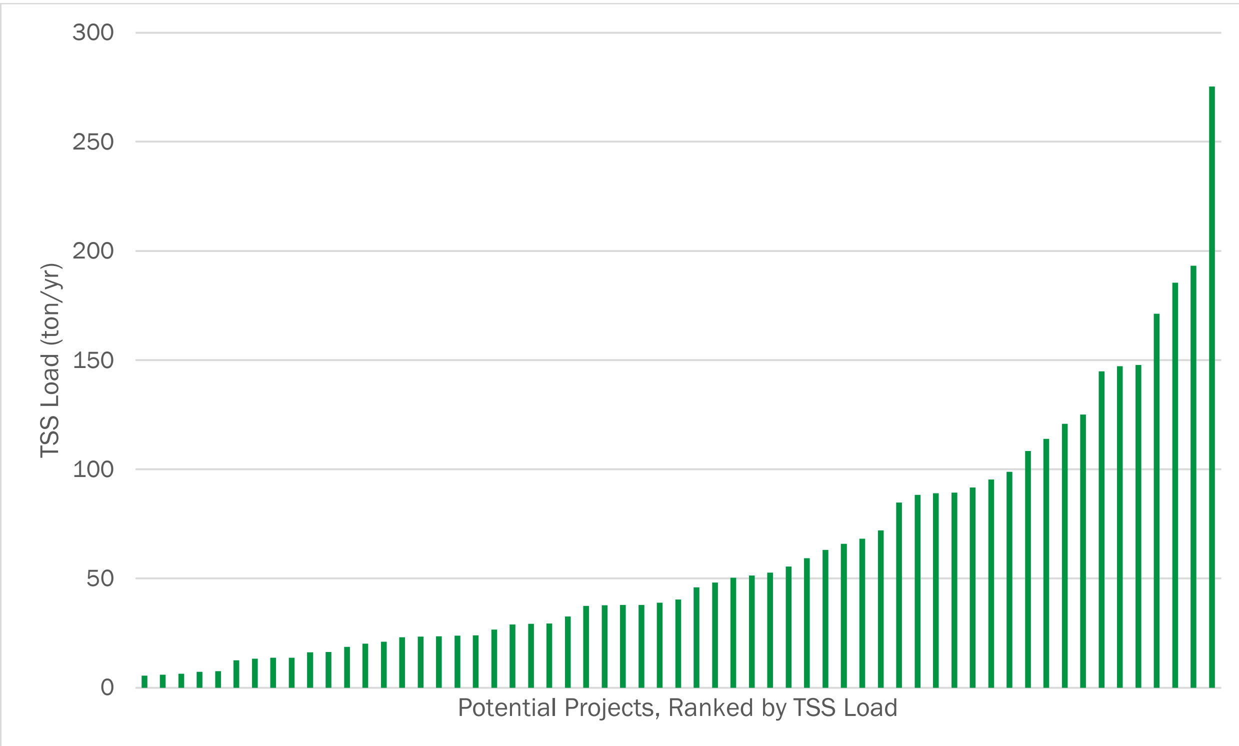
Figure 3-3: Projects Ranked by Flooded Volume



3.5.4 TSS Load

Figure 3-4 is a bar chart that ranks projects by TSS load. There appears to be a relatively marked break in projects at approximately 100 ton/yr of TSS load. Once TSS load exceeds 100 ton/yr, TSS load increases more rapidly. Wenck recommends projects with greater than 100 ton/yr of TSS load be classified as higher priority projects than projects with less than 100 ton/yr of TSS load.

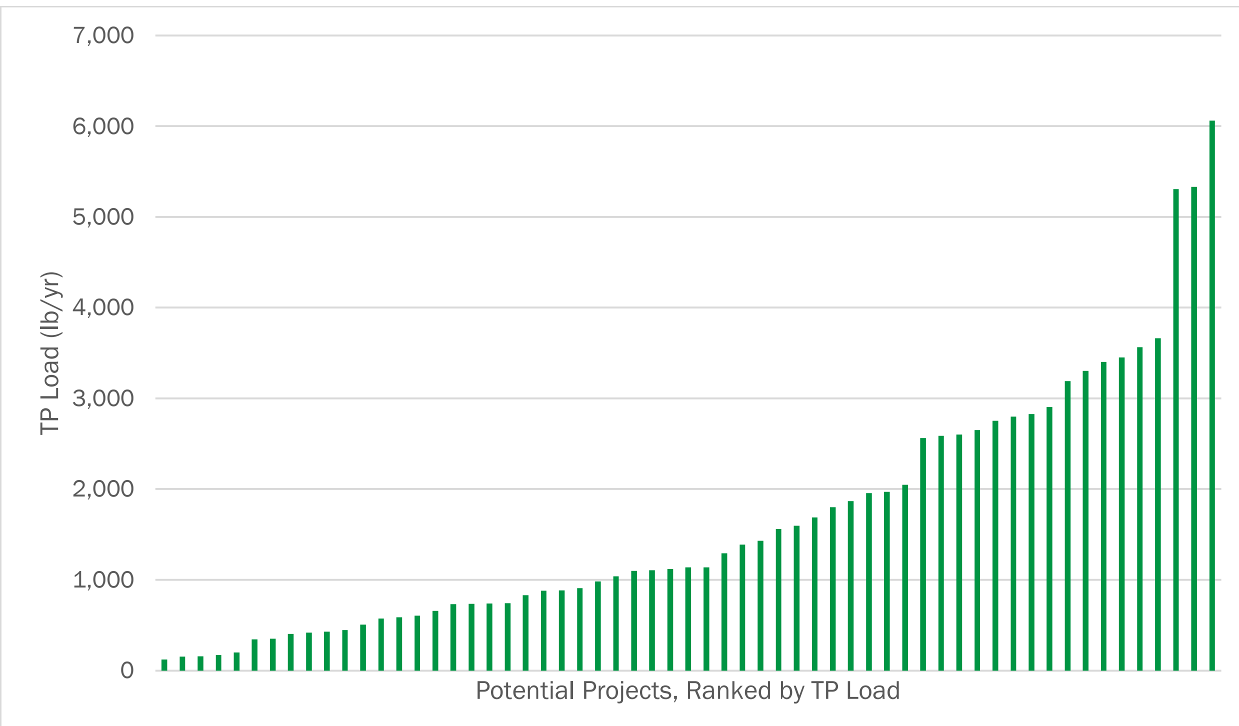
Figure 3-4: Projects Ranked by Total Suspended Sediment Load



3.5.5 TP Load

Figure 3-5 is a bar chart that ranks projects by TP load. Dissimilar to the charts above, there are no clean break points in the TP Loading chart; rather there generally is a linear increase in TP loading. There are several steps, where TP load increases and then resumes the linear trend. The steps appear to occur at approximately 2,500 lb/yr and 5,000 lb/yr. There also is a minor plateau around 1,100 lb/yr. Wenck theorizes this linear trend is due to a smaller difference between urban- and rural-areal loading rates for TP versus TSS. For example, MPCA research indicates corn or soybean fields generate TP at a rate equivalent to commercial areas, whereas TSS generated by corn or soybean fields (open space) is 15 percent of the TSS generated by commercial area. For purposes of this study, Wenck recommends projects with greater than 2,500 lb/yr of TP load be classified as higher priority projects than projects with less than 2,500 lb/yr of TP load.

Figure 3-5: Projects Ranked by Total Phosphorus Load



3.5.6 Composite Analysis

Table 3-3 provides a list of projects that meet or exceed the following threshold values. Wenck recommends the projects that exceed the most threshold values be considered for further analysis that factors in project cost, pollutant removal efficiency, flooding improvement, and other design considerations, such as land ownership, presence or lack thereof of easements, presence of hydric soils and potential funding sources.

- Adjacent to currently flooding or elevated risk of flooding roads.
- Greater than 200 acres of flooded area.
- Greater than 1,000 acre-feet of flooded volume.
- Greater than 100 ton/yr of TSS load.
- Greater than 2,500 lb/yr of TP load.

Table 3-3: Project Ranking Table

Project ID Number	Freeboard Threshold	Flooded Area Threshold	Flood Volume Threshold	TSS Load Threshold	TP Load Threshold	SUM
18	1	1	1	1	1	5
56	1	1	1	1	1	5
57	1	1	1	1	1	5
29	1	1	1	0	1	4
77	1	0	0	1	1	3
1	1	0	0	1	1	3
2	1	0	0	1	1	3
8	1	1	1	0	0	3
42	1	1	0	0	1	3
49	1	1	1	0	0	3
50	1	1	1	0	0	3
58	1	0	0	1	1	3
83	1	0	0	1	1	3
43	0	0	0	1	1	2
3	1	1	0	0	0	2
6	1	0	0	0	1	2
20	0	1	1	0	0	2
35	0	0	0	1	1	2
36	1	0	1	0	0	2
38	1	0	0	0	1	2
44	1	0	0	0	1	2
45	1	1	0	0	0	2
46	1	1	0	0	0	2
52	1	0	0	0	1	2
60	0	0	0	1	1	2
64	1	1	0	0	0	2
65	1	1	0	0	0	2
79	1	0	0	0	1	2
5	1	0	0	0	0	1
9	1	0	0	0	0	1
11	1	0	0	0	0	1
12	1	0	0	0	0	1
21	1	0	0	0	0	1
32	1	0	0	0	0	1
47	1	0	0	0	0	1
48	1	0	0	0	0	1
51	1	0	0	0	0	1
54	1	0	0	0	0	1
59	1	0	0	0	0	1
61	1	0	0	0	0	1
62	1	0	0	0	0	1
63	1	0	0	0	0	1
66	1	0	0	0	0	1

Project ID Number	Freeboard Threshold	Flooded Area Threshold	Flood Volume Threshold	TSS Load Threshold	TP Load Threshold	SUM
68	1	0	0	0	0	1
69	1	0	0	0	0	1
70	1	0	0	0	0	1
71	1	0	0	0	0	1
72	1	0	0	0	0	1
73	1	0	0	0	0	1
74	1	0	0	0	0	1
76	1	0	0	0	0	1
78	1	0	0	0	0	1
80	1	0	0	0	0	1
81	1	0	0	0	0	1
82	1	0	0	0	0	1
85	1	0	0	0	0	1
4	0	0	0	0	0	0
75	0	0	0	0	0	0
84	0	0	0	0	0	0

3.6 CROSS-COMPARISON WITH PRIOR COUNTY EVALUATION (MAPS 19-24)

After evaluating potential projects independent of prior County efforts, Wenck cross-referenced the SWMM-identified projects with a County provided shapefile of potential wetland restoration project locations, generated from prior County efforts. Collaboratively, Wenck and the County identified ten projects preliminary design based on flooded volume rank. Table 3-4 summarizes the ten identified projects. Maps 19-24 cross-reference County Project identification numbers and flood rank numbers.

Table 3-4: Project Ranking Table

Project ID Number[9]	County Project Number[10]	Flooded Volume Ranked	Comments
18	12	1	
20	11	2	
~~57~~	~~27~~	~~3~~	Project removed per County direction
50	7	4	
49	14	5	
8	3	6	
36	39	7	
56	40	8	
29	24	9	
42	13	10	
3	1	11	Tenth project added in to replace third ranked project

[9] Corresponds to Project ID Number listed in Table 3-3.

[10] Provided by County based on prior wetland restoration project investigation efforts.

4.0 Preliminary Design and Evaluation

Once ten projects were selected for further analysis, Wenck evaluated each site's existing topography and underlying hydric soils to identify berm alignments for the purpose of impounding water for wetland restoration projects. Wenck used County LiDAR to develop preliminary grading plans for each project, assuming earthen berms. Preliminary berm design assumptions are as follows:

- Ten-foot wide berm such that the berm could accommodate light maintenance equipment.
- Upgradient (wet) side of berm has a slope of 8:1, per Minnesota Board of Water & Soil Resources (BWSR) standards.
- Downgradient (dry) side of berm has a slope of 4:1, per BWSR standards.
- Set normal outlet at approximately two- to four-feet above the low contour or within one-foot of the hydric soil elevation.
- Top of berm elevation was set to provide 0.5-feet of freeboard between the top of berm and 100-year HWL.
- One-foot of freeboard is provided between the 100-year HWL and existing upstream infrastructure (roads, driveways, structures, etc., estimated based on LiDAR).

Wenck updated the PC-SWMM model to incorporate the preliminary designs to determine the proposed HWL and to set the outlet and top of berm elevations. All preliminary designs were modeled in the same PC-SWMM model for purposes of file management, such that all proposed conditions are encapsulated in one consolidated proposed model.

Wenck evaluated water quality improvements using the software P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles, & Ponds). Wenck predicted pollutant loading and removal rate for each preliminary design. P8 model design assumptions are as follows:

- Pollutant removals for each design are independent of one another.
- Simulation period of ten years.
- Precipitation data from Minneapolis St. Paul (MSP) airport.
- Pervious area curve number of 74 (C soils).
- Indirectly connected to directly connected impervious area ratio is 50:50.

Preliminary plans that identify berm alignment, NWLs, HWLs and approximate land acquisition area are appended to this Report. For purposes of comparing and ranking the ten projects, Wenck quantified the total estimated life cycle cost, amount of TP removed, live storage volume provided, number of affected landowners and qualitatively identified project-specific design challenges for each potential wetland restoration.

4.1 COST ESTIMATING METHODOLOGY

Wenck determined cost estimates for each of the ten preliminary designs. Cost estimates factored in the following line items:

- Land Acquisition, assumed to be $7,500 per acre, based on current Dakota County farmland costs. This value will likely fluctuate depending on specific projects, specific landowners, and specific production value of the land to be inundated.

- Mobilization & demobilization.
- Traffic control.
- Temporary erosion & sediment control.
- Dewatering/temporary stormwater management.
- Plug & reroute drain tile. Regardless of project, it is expected that some level of draintile management will be required to ensure upstream landowners' farm fields are unaffected by the proposed impoundment. This value may vary significantly, depending on the magnitude of the project. A lump sum estimate of $50,000 is included and is based on wetland restoration projects Wenck has worked on in the past.
- Strip & salvage topsoil.
- Import berm material.
- Geotextile fabric.
- Riprap.
- Rodent protection rock. Per BWSR standards, means of rodent protection is necessary to prevent rodents from burrowing into the berm and creating seepage paths for the impounded water that create berm instabilities.
- Turf restoration.

Once a subtotal was calculated for the line items above, Wenck factored in engineering, land acquisition costs, permitting, and contingency costs. Engineering costs are estimated based on 20-percent of overall project costs. Exact project engineering fees may vary, depending on the scale and complexity of the project. It is anticipated that engineering fees will include some level of soils investigation, survey, design, a wetland specific planting plan in conformance BWSR standards and some level of construction administration.

Land acquisition is assumed to cost $7,500 per acre, based on current Dakota County farmland costs. This value will likely fluctuate depending on specific projects, specific landowners, and specific production value of the land to be permanently inundated. For purposes of this study, Wenck assumes the County will need to purchase or acquire easements over any land that will be permanently or temporarily flooded by these projects. Wenck determined land acquisition area based on a 20-foot buffer around the 100-yr HWL predicted from PCSWMM. The exact land acquisition areas and costs will be a function of final berm and outlet structure design, grading plan and landowner negotiations.

At time of this report's publication, $7,500 per acre of farmland is on the average, to above average cost for typical farmland. Farmland adjacent to creeks or overtop former wetlands may not have the production value as a typical acre of farmland and may be available for a lower cost per acre. Additionally, for purposes of this report, it is assumed that Dakota County will have to pay this fee of $7,500 per acre over the entire, proposed inundated area. This likely skews to the high side of anticipated land acquisition costs. However, as with construction costs, land prices will likely increase on a year to year basis and should be re-evaluated during future project specific design or outreach efforts.

Permitting and legal fees were estimated at 10-percent of the overall project costs. This item is intended to include time and resources to complete Department of Natural Resources (DNR), BWSR or other Agency required permits, and to account for some amount of legal fees. Finally, a 20-percent contingency was added in to reflect uncertainty at this preliminary stage of design.

4.2 PRELIMINARY PROJECT RANKINGS

Presented below are tables and figures ranking project alternatives based on several different parameters: total estimated project cost; total pounds of TP removed; effective TP removal cost; live storage volume; number of landowners; a subjective design challenges index; and a composite index that combines the six other rankings into an overall ranking.

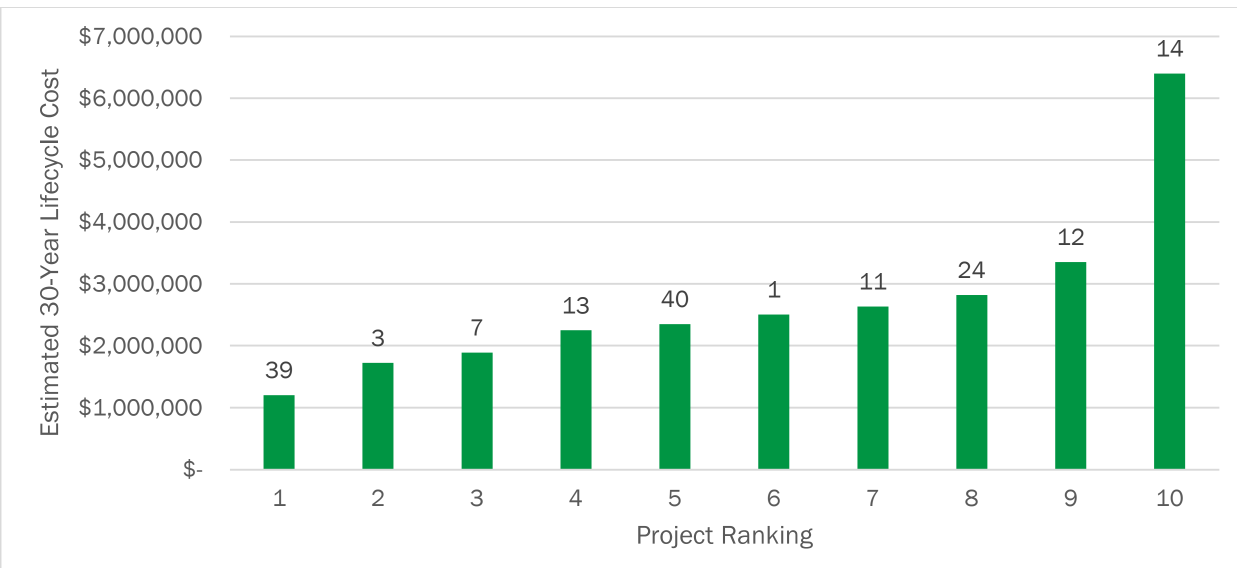
4.2.1 Ranking by Total 30-Year Life Cycle Cost

Ranking projects by total cost will allow the County to quickly discern whether a potential standalone project is feasible, based on total dollars available for a potential project. Table 4-1 and Figure 4-1 summarize projects, ranked by total 30-Year life cycle cost.

Table 4-1: Project Rankings by Estimated 30-Year Lifecycle Cost

Ranking	Figure	Project	Estimated 30-Year Lifecycle Cost
1	6	39	$1,201,707
2	5	3	$1,720,617
3	3	7	$1,890,090
4	9	13	$2,249,760
5	7	40	$2,349,567
6	10	1	$2,502,854
7	2	11	$2,635,367
8	8	24	$2,817,747
9	1	12	$3,354,127
10	4	14	$6,395,379

Figure 4-1: Project Rankings by Estimated 30-Year Lifecycle Cost



4.2.2 Ranking by Amount of TP Removed

Ranking projects by amount of TP removed will allow the County to quickly identify projects that remove the highest phosphorus load. Table 4-2 and

Figure 4-2 summarize projects, ranked by TP removed.

Table 4-2: Project Rankings by Amount of TP Removed

Ranking	Figure	Project	TP Removed (lb/yr)
1	5	3	1,404
2	10	1	1,076
3	1	12	1,028
4	4	14	716
5	2	11	668
6	9	13	574
7	3	7	424
8	7	40	409
9	6	39	161
10	8	24	139

Figure 4-2: Project Rankings by Amount of TP Removed

4.2.3 Ranking by Effective TP Removal Cost Over 30-Years

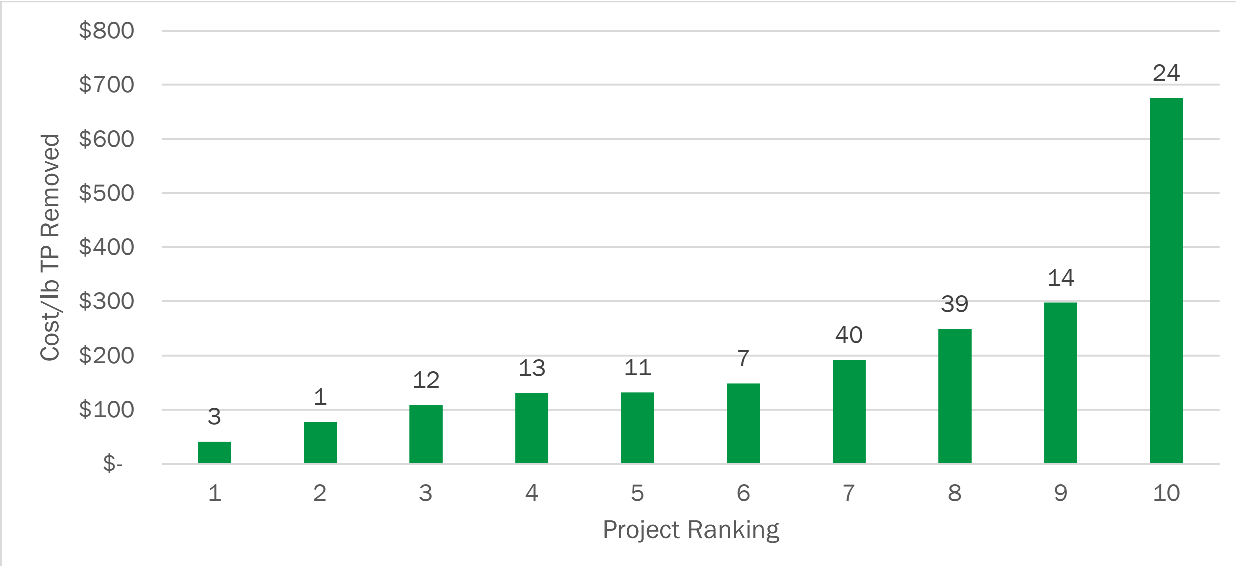
Ranking projects by effective TP removal costs will allow the County to quickly discern which potential project provides the greatest TP reduction per dollar. Amortizing removal costs over 30-years is common method of evaluating project TP removals, as infrastructure projects are commonly funded with bonds that are repaid over the course of several decades. Table 4-3 and Figure 4-3 summarize projects, ranked by TP reduction per dollar.

Table 4-3: Project Rankings by Effective TP Removal Cost Over 30-Years

Ranking	Figure	Project	Effective TP Cost ($/lb)
1	5	3	$41
2	10	1	$78
3	1	12	$109

Ranking	Figure	Project	Effective TP Cost ($/lb)
4	9	13	$131
5	2	11	$132
6	3	7	$149
7	7	40	$191
8	6	39	$249
9	4	14	$298
10	8	24	$676

Figure 4-3: Project Rankings by Effective TP Removal Over 30-Years



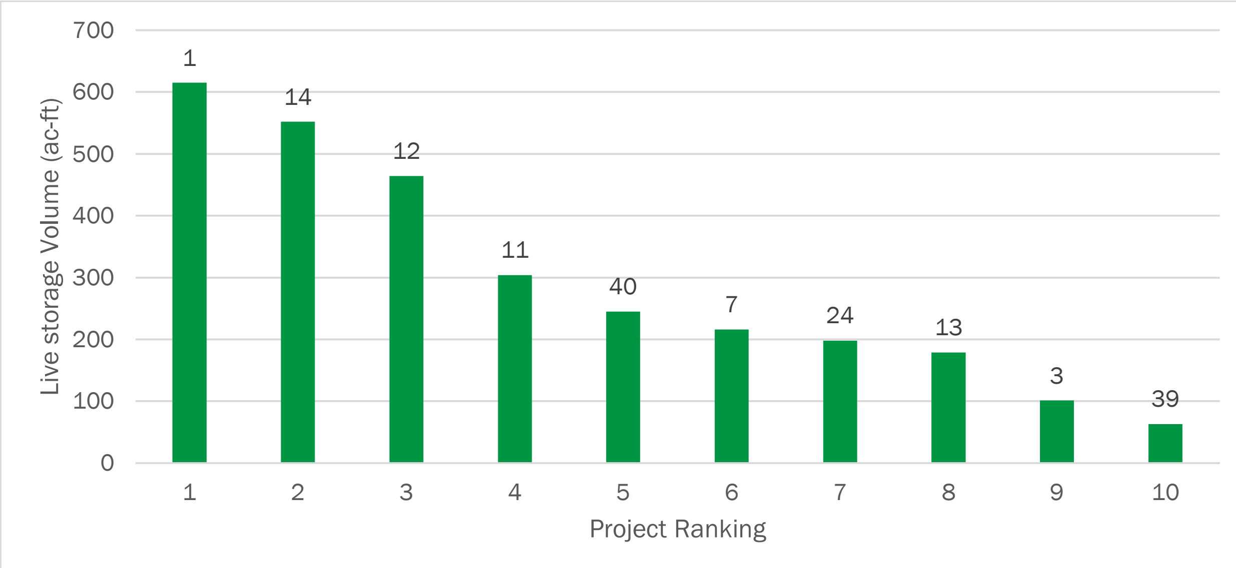
4.2.4 Ranking by Live Storage Volume

Ranking projects by amount of live storage volume will allow the County to quickly identify projects provide the highest level of flood protection. Additionally, live storage volume can serve as a proxy for total wetland area created as well, as the normal water levels for the projects considered are all roughly the same. Table 4-4 and Figure 4-4 summarize projects, ranked by live storage volume.

Table 4-4: Project Rankings by Live Storage Volume

Ranking	Figure	Project	Live Storage Volume (ac-ft)
1	10	1	615
2	4	14	552
3	1	12	464
4	2	11	304
5	7	40	245
6	3	7	216
7	8	24	198
8	9	13	179
9	5	3	101
10	6	39	63

Figure 4-4: Project Rankings by Live Storage Volume



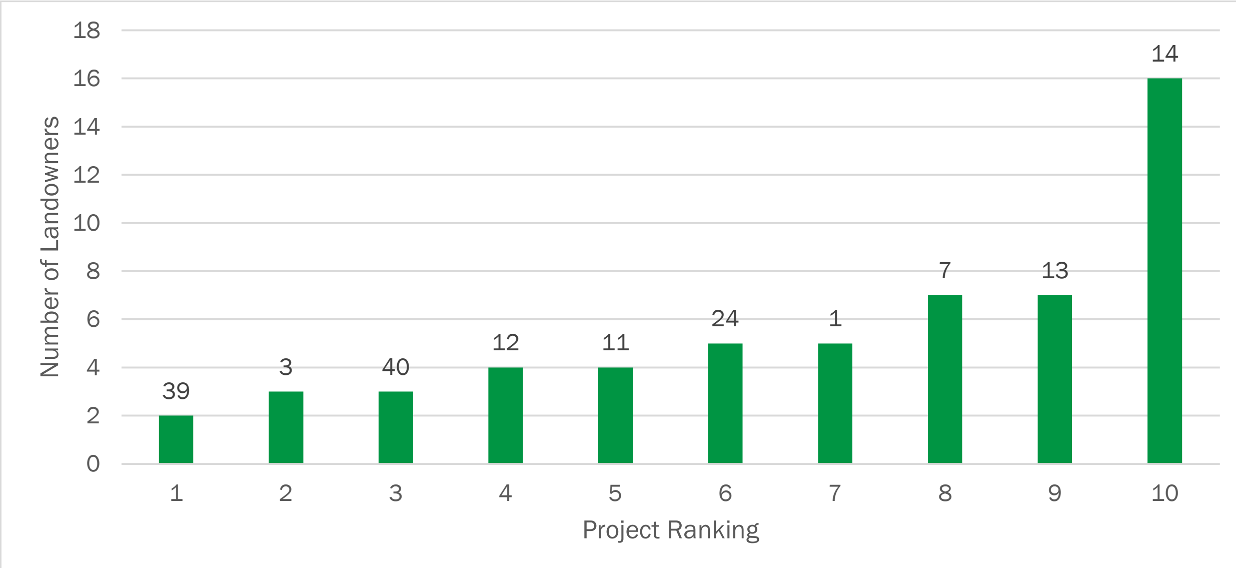
4.2.5 Ranking by Number of Landowners

Ranking projects by number of landowners will allow the County to quickly identify projects that have less landowners involved. It is assumed that fewer landowners involved in a project will result in a more efficient process, as there will be fewer individuals involved in the decision-making process. Table 4-5 and Figure 4-5 summarize projects, ranked by number of landowners.

Table 4-5: Project Rankings by Number of Landowners

Ranking	Figure	Project	Number of Landowners
1	6	39	2
2	5	3	3
3	7	40	3
4	1	12	4
5	2	11	4
6	8	24	5
7	10	1	5
8	3	7	7
9	9	13	7
10	4	14	16

Figure 4-5: Project Rankings by Number of Landowners



4.2.6 Ranking by Design Challenges Index

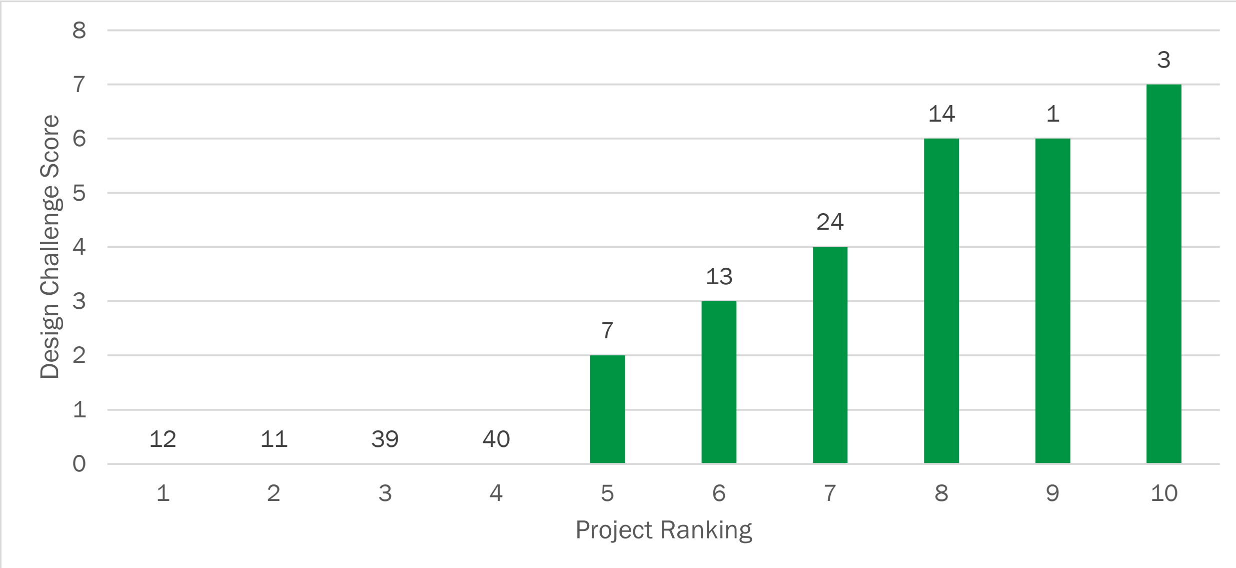
The "Design Challenges Index (DCI)" was created to reflect unique design challenges. One point was given to a project for every unique design challenge a project is anticipated to have; an optimal project would have a score of zero on the DCI. Example challenges that contributed to the DCI included multiple berm locations and hard to access project areas. The DCI's intent is to provide a general sense as to which projects will require additional time spent on upfront design, landowner involvement, and permitting.

Ranking projects by the DCI will allow the County to consider whether a potential project is feasible based on a rough estimate of how much time will be needed to design the project. Table 4-6 and Figure 4-6 summarize projects, ranked by the Design Challenges Index.

Table 4-6: Project Rankings by Design Challenges Index

Ranking	Figure	Project	Design Challenges Index	Design Challenge Notes
1	1	12	0	Easy access, single berm
1	2	11	0	Easy access, single berm
1	6	39	0	Easy access, single berm
1	7	40	0	Easy access, single berm
5	3	7	2	Two berms, moderate access difficulty
6	9	13	3	Three berms, moderate access difficulty
7	8	24	4	Four Berms, moderate access difficulty
8	4	14	6	Six Berms, large area
9	10	1	6	Five berms, difficult access
10	5	3	7	Seven berms, difficult access

Figure 4-6: Project Rankings by Design Challenge Index



4.2.7 Ranking by Composite Index

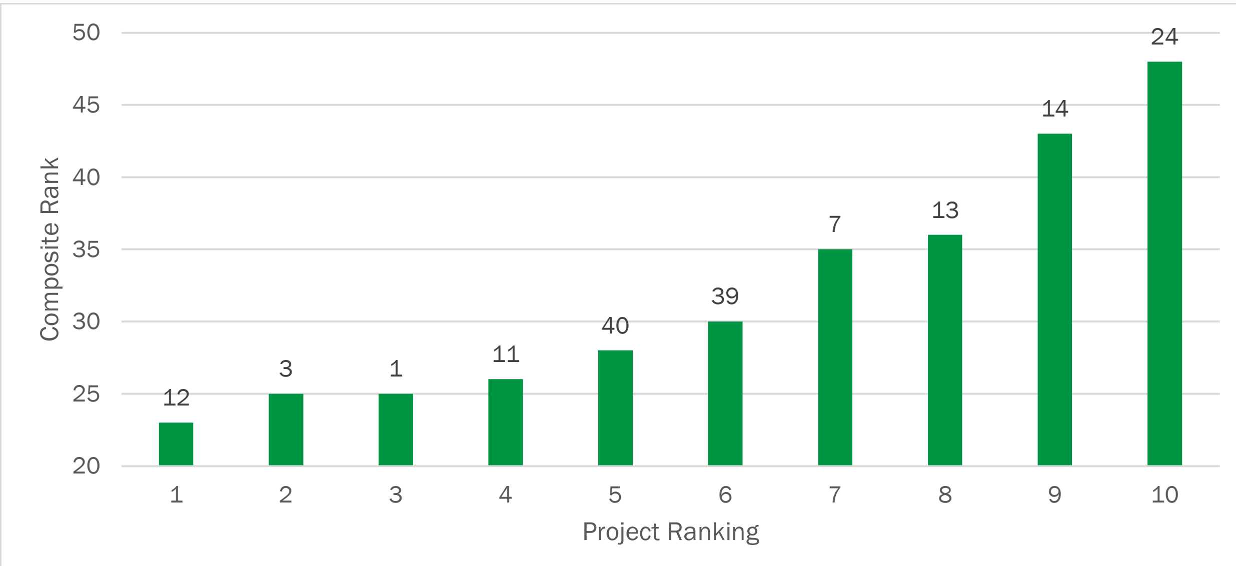
Finally, to combine the above six methods of project rankings, a composite index was created. The rank a project received in each method was summed to come up with an overall score. The theoretical perfect project would receive a composite score of six, representing being ranked first in all six above rankings. A lower Composite Index is preferable, and indicates a project ranks highly in several categories. Table 4-7 and Figure 4-7 summarize projects ranked by Composite Index.

Table 4-7: Project Rankings by Composite Index

Ranking	Reference Sheet C-10X	Project Number	Project Cost Rank	TP Removed Rank	Effective TP Removal Cost Rank	Live Storage Volume Rank	Number of Landowners Rank	Design Challenges Rank	Composite Index	General Classification
1	1	12	9	3	3	3	4	1	23	Best
2	5	3	2	1	1	9	2	10	25	Best
3	10	1	6	2	2	1	6	8	25	Best
4	2	11	7	5	5	4	4	1	26	Above Average
5	7	40	5	8	7	5	2	1	28	Above Average
6	6	39	1	9	8	10	1	1	30	Above Average
7	3	7	3	7	6	6	8	5	35	Below Average

Ranking	Reference Sheet C-10X	Project Number	Project Cost Rank	TP Removed Rank	Effective TP Removal Cost Rank	Live Storage Volume Rank	Number of Landowners Rank	Design Challenges Rank	Composite Index	General Classification
8	9	13	4	6	4	8	8	6	36	Below Average
9	4	14	10	4	9	2	10	8	43	Worst
10	8	24	8	10	10	7	6	7	48	Worst

Figure 4-7: Project Rankings by Composite Index



The Composite Index is a simple metric that combines several methods of ranking potential projects. All six individual ranking methods were weighted equally, which may not reflect reality. For example, site specific design challenges, such as an extensive permitting process to address wetland mitigation, combined with site access challenges, may combine to create a project that is infeasible, no matter how efficiently the theoretical project could remove TP. Nevertheless, the above rankings are presented to provide a baseline for further discussions and to provide a general sense of which projects will be more effective.

It should be noted that the intent of the "Composite Index" is not to definitively state that the higher of successively ranked projects are a "better" project than the next ranking (i.e. Project 12 ranked number one by the composite index method versus Project 3 ranked number two). However, general comparisons can be made like the projects ranked one through four on the Composite Index may be considered the "best" potential projects. Projects ranked nine and ten may be considered the "worst" potential projects. Projects ranked five through eight may be considered "average" potential projects, where projects ranked five and six are ranked ahead of the average Composite Index value of 32, and projects ranked seven and eight are ranked behind the average Composite Index value.

5.0 Conclusion

Wenck created County wide PC-SWMM models that analyze the Vermillion River and North Cannon River watersheds. This entailed converting an existing XP-SWMM model that was previously constructed to analyze inter-community flow in the urbanized portions of Dakota County. The focus of this study was on the rural, lesser developed areas of Dakota County, with the general objective of identifying potential wetland restoration, or other flood control and water quality control projects.

Wenck created the PC-SWMM models based on a combination of existing models, survey information, publicly available GIS information, and Stakeholder input. Wenck's approach aligned with prior efforts in terms of hydrologic, hydraulic and calibration methodologies and approaches. After constructing the models, Wenck modeled the 2-, 10- and 100-year 24-hour design storms, and the 100-year 10-day snowmelt event to evaluate flow throughout the County.

Wenck used model output to generate a series of Countywide inundation maps, channel erosion maps and potential project location maps where discrete BMPs could be constructed. The 59 identified BMPs were evaluated based on whether or not roads were overtopping, the total flooded area, total flooded volume, TSS and TP loading, and based on a combined, composite method. This composite ranking was compared to prior County efforts to identify ten, high value projects for preliminary design.

Wenck's preliminary design included preliminary grading plans, based on County LiDAR, cost estimates, updated PC-SWMM modeling of the "proposed" conditions, and water quality modeling to evaluate the pollutant removal potential of each of the preliminary designs. Based on the calculated metrics, the ten preliminarily designed projects were reranked based on life cycle cost, mass of TP removed, effective removal cost, a design challenges metric, and finally by a composite method, such that the ten high value projects may be ranked in order of highest value.

Based on the composite rankings, four projects (Projects 12, 3, 1 and 11) appear to have the best combination of costs, pollutant removals, flood protection and wetland banking credits, number of landowners, and other qualitative considerations. Two projects (Projects 14 and 24) appear to have the worst combination of parameters considered. The other four projects (Projects 40, 39, 7 and 13) are somewhere in the middle.

Based on the analysis herein, next steps include but may not be limited to selecting a specific project, identifying landowners to work with, acquiring land or easements, identifying funding sources, and proceeding to final design. Final design will include additional site survey, project specific modeling to design and optimize an outlet structure, plans, specifications, bidding assistance, and construction administration assistance.

Attachments

1. Map 0: Index Map
2. Map 1-6: Inundation Maps
3. Map 7-12: Channel Erosion Maps
4. Map 13-18: Project Ranking Maps
5. Map 19-24: Potential Project Maps
6. C-001 Title and Index Sheet
7. C-100 Project Location Map
8. C-101 Project 12 Preliminary Design
9. C-102 Project 11 Preliminary Design
10. C-103 Project 7 Preliminary Design
11. C-104 Project 14 Preliminary Design
12. C-105 Project 3 Preliminary Design
13. C-106 Project 39 Preliminary Design
14. C-107 Project 40 Preliminary Design
15. C-108 Project 24 Preliminary Design
16. C-109 Project 13 Preliminary Design
17. C-110 Project 1 Preliminary Design
18. C-801 Berm and Overflow Details
19. C-802 Overflow Details
20. Appendix A: Preliminary Design Cost Estimates

WENCK File #1305-0034
April 2020

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