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THIEF RIVER FALLS WATER QUALITY STUDY

Pennington SWCD & City of Thief River Falls

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City of Thief River Falls

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HoustonEngineering Inc.

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of Minnesota

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EXECUTIVE SUMMARY

Sediment and water quality issues within the Thief River and Red Lake River watersheds are local priorities for the Pennington Soil and Water Conservation District (SWCD) and the City of Thief River Falls (City). This water quality study quantifies the amount of sediment and pollutants entering Thief River and Red Lake River from surface runoff within the City, as well as from three identified sites experiencing major river bank erosion. Furthermore, the study targets locations for Best Management Practice (BMP) projects that are efficient at delivering measurable water quality benefits.

An existing conditions P8 water quality model was developed in order to quantify the pollutant loads generated by stormwater runoff from within the city. Additionally, because development is planned for the future, a second P8 model was used to evaluate how future development might affect downstream water quality. The P8 model simulates rainfall, pollutant loading, and runoff from the watershed and subsequently routes the runoff through existing water quality treatment features that simulate pollutant and particle removal. The pollutant loads currently entering Thief River and Red Lake River, including Total Suspended Solids (TSS), Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Total Hydrocarbons (HC), are summarized in **Table 1**.

The results of the P8 modeling effort and the erosion estimates have been used to target optimal locations and types of conservation projects and practices within the urban boundary of Thief River Falls. Targeting efforts focused on cost effective locations for BMP construction, which incorporates the concentration of and amount of pollutants that would be treated at BMP locations. Also, the City and SWCD provided local insight regarding on-the-ground conditions to the targeted BMP locations, resulting in 12 proposed BMP locations for further analysis, which are described in **Table 5**. With the assistance of MPCA guidelines, a BMP type was selected for each location, and the proposed BMPs were modeled in P8 to estimate the amount that City pollutant loads were reduced. Construction and maintenance costs of the proposed BMPs were estimated and annualized over a 30-year period.

A field assessment was also carried out to identify and document any evidence found in the field indicating potential sources of E.coli or inorganic nitrogen in the Chiefs Coulee watershed, followed by recommendations regarding the removal of sanitary flow from the surficial drainage system.

Three river banks were also identified as priorities for assessment. Field investigation measurements and the MN BWSR pollution reduction estimator spreadsheet was used to approximate the mass of sediment and TP loss at each site. Construction costs were estimated for stabilization practices and a sediment and TP cost effectiveness was calculated. Results can be found in **Table 10**.

Both the surface water BMPs and streambank stabilization projects were ranked with the goal of providing the City information on which to base their decisions on which projects to pursue and in which sequence. **Table 11** provides a summary which prioritizes the proposed BMPs by TSS and TP reductions and cost effectiveness, which will also be valuable information when competing for grant dollars in pursuit of project implementation. It was found that the streambank stabilization practices are highly effective in reducing the sediment loading to downstream locations with turbidity impairments, as are BMP’s 4 and 5. However, in selecting projects for implementation, other factors such as timing of capital or development projects, as well landowner interest should also be considered. For example, **Table 11** shows that BMPs 9 and 12 are not the highest ranked BMPs according to pollutant reduction and cost, but they would still be very worthy projects and may warrant consideration as being high priorities due to the fact that the land authority is the City, which will highly facilitate their implementation. Furthermore, future development or capital improvement projects will likely provide opportunities for BMP 4, BMP 5, and BMP 8 implementation. The BMPs could serve as a collaboration possibility to meet water quality requirements of the projects, and provide additional treatment for a greater benefit to the resource.

The results of this study show that a majority of the City's stormwater runoff enters Thief River and Red Lake River untreated, and that eroding river banks are contributing large amounts of sediment and TP to the rivers. However, substantial water quality benefits can be realized through cost-effective stormwater BMPs and river bank stabilization practices. This study has targeted, identified, and prioritized surface water treatment projects based on technical feasibility, potential water quality benefit, and cost effectiveness, which will be valuable information when competing for grant dollars in pursuit of project implementation. It is recommended that the City and SWCD consider applying for grants or other funding sources through the Minnesota Board of Water and Soil Resources (BWSR).

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List of Acronyms and Abbreviations

BMP	Best Management Practice
BWSR	Minnesota Board of Water and Soil Resources
CAD	Computer-Aided Drawing
cfs	cubic feet per second
CIP	Capital Improvement Project
CMP	Corrugated Metal Pipe
CN	Curve Number
DCIA	Directly Connected Impervious Area
DEM	Digital Elevation Map
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
H&H	Hydrologic and Hydraulic
HC	Total Hydrocarbons
HEI	Houston Engineering, Inc.
LiDAR	Light Detection and Ranging
MLCCS	Minnesota Land Cover Classification System
MnDNR	Minnesota Department of Natural Resources
NAVD	North American Vertical Datum
NED	National Elevation Dataset
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
QC	Quality Control
RCP	Reinforced Concrete Pipe
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UMN	University of Minnesota
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
VERTCON	Vertical Conversion

1 INTRODUCTION

1.1 BACKGROUND

Sediment and water quality issues within the Thief River and Red Lake River watersheds are local priorities for the Pennington Soil and Water Conservation District (SWCD) and the City of Thief River Falls (City). Large-scale efforts are underway in both the Red Lake River Watershed and Thief River Watershed to identify and target opportunities for projects and practices on rural landscapes that result in measurable water quality benefits throughout the watershed. However, municipalities lack the necessary detailed information to prioritize and target practices in an urban setting.

An Accelerated Implementation Grant (AIG) was awarded through the Board of Water and Soil Resource's (BWSR) Clean Water Fund in 2016 for a study which includes the development of a P8 water quality model for the city of Thief River Falls to target locations for projects and practices that are efficient at delivering measurable water quality benefits. The resulting data and information will be used for education and outreach with residents of Thief River Falls, as well as be used as a tool for accelerating the implementation of conservation projects and practices within the City.

Additionally, because urban development is still occurring in Thief River Falls, and more is planned for the future, the P8 model has been used to evaluate how future development might affect downstream water quality to aid in development decisions and to enable water quality managers to plan for conservation practices to offset any impacts that may result. This report also summarizes field investigations of potential sources of E. Coli within the city and measurements of three actively eroding river bank locations.

The results of the P8 modeling effort and the erosion estimates have been used to target optimal locations and types of conservation projects and practices within the urban boundary of Thief River Falls, as well as estimate their costs and potential water quality benefits.

The results of this study provide a means to target practices that provide measurable water quality benefits, and help to ensure that local or state funding is being invested in the right practice in the right place. The recommendations for projects and practices provided in this report, including estimates of their cost-effectiveness and their measurable water quality benefits, will enable project managers to accelerate the implementation of on-the-ground projects.

1.2 STUDY AREA

The 17.1 square mile (10,947 acres) study area shown in **Figure 1** contains the entire City of Thief River Falls (5.1 square miles) and its tributary drainage area. The majority of the city is developed, with a series of storm sewer pipes which collect and convey stormwater downstream, generally in the direction toward the Thief River and the Red Lake River, which have their confluence within the city. The Red Lake River flows into the City from the east and after converging with the Thief River from the north, it flows southwest through a dam and exits the City to the south.

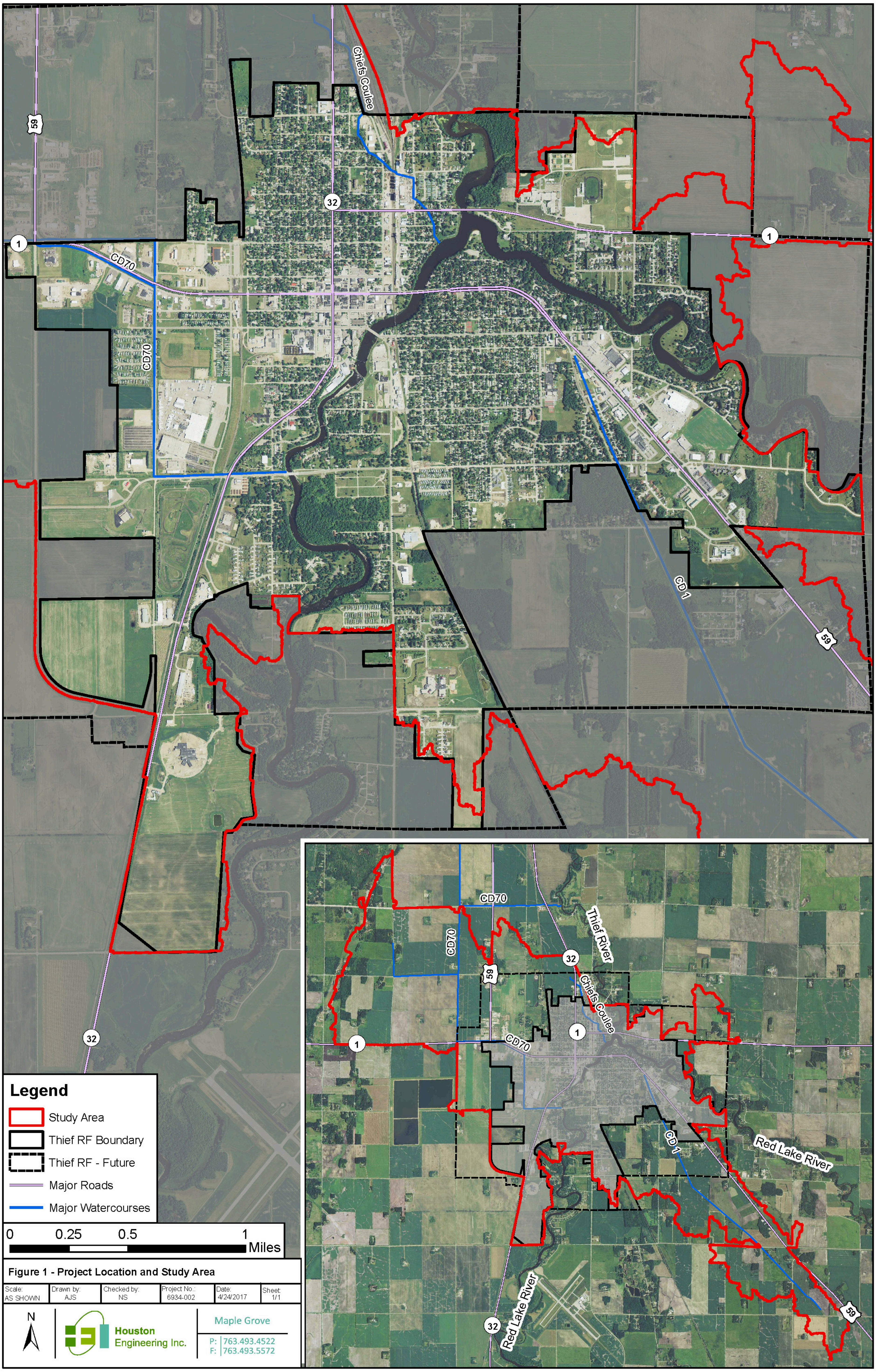
The land-use consists of a mix of land-uses which includes single-family residential areas, commercial and industrial areas, a railway corridor, a college, scattered greenspaces, a high-density city center, and surrounding agricultural land.

The SWCD and the City initiated this detailed water quality assessment of the area within the existing and future City Boundary as well as the contributing runoff to the City from the surrounding rural areas.

The primary land use of the area contributing flow to the city is agriculture. There are three notable water conveyance systems which flow into the city boundary. First, County Ditch 70 (CD70) collects runoff from a total of 4,600 acres (including 3,640 acres outside the city boundary), starting northwest of the city and continuing through the west side of the City, discharging to the Red Lake River at Greenwood St W. The northern portion of CD70 was excluded from the study area as it flows to the east, and not into the City. Second, RLWD[1] Ditch 14 (also called CD1) drains 2,590 acres of the study area (including 2,200 acres outside of the City), collecting runoff from southeast of the City before entering the Red Lake River within the eastern side of the City. A mechanical flow split was identified along the ditch which can divert flows to the west, away from the city during large rain events. During normal operating conditions, Ditch 14 contributes flow to the city, so it was assumed for the purposes of this study, that all flow through Ditch 14 flows into Thief River Falls. Finally, Chiefs Coulee watershed is 485 acres (including 260 acres outside of the City), and it flows from the north through open channel and storm sewer before entering the Red Lake River just south of the Thief River confluence. A recent construction project diverted the northern portion of Chief Coulee's watershed to the north, and therefore out of the study area.

[1] Red Lake Watershed District

Figure 1: Project Location



1.3 Purpose of the Study

Planning is critical to effectively implement stormwater management practices across a watershed. A comprehensive watershed analysis can target sediment and nutrient source loading areas, as well as predict water quality load reductions from Best Management Practice (BMP) implementation based on technical water quality simulation and Geographic Information Systems (GIS) analysis. Demonstrating a measurable water quality benefit is a prerequisite when seeking additional funding for implementation. For this reason, the City of Thief River Falls plans to proactively implement water quality practices in a targeted manner. This will lead to water quality improvements that are fiscally efficient in urban landscapes and help reduce pollutants entering Thief River and Red Lake River. The Thief River is listed by the Minnesota Pollution Control Agency (MPCA) as impaired for turbidity, and a Draft Thief River Watershed Total Maximum Daily Load (TMDL) study was released in July 2016. Downstream, the Red Lake River is also listed as impaired for turbidity, but currently no TMDL has been completed.

Total Suspended Solids (TSS), Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Total Hydrocarbons (HC) are known pollutants from surface water runoff to downstream water bodies and are commonly used as indicators for other pollutants. As part of this study, a water quality simulation model has been designed to fulfill the following goals:

- Quantify existing average annual TSS, TP, TKN, and HC yields from specific subwatersheds;
- Estimate existing BMP pollutant load and volume reductions;
- Quantify average annual TSS, TP, TKN, and HC delivered yields from the subwatersheds (subsequent to BMP implementation);
- Evaluate water quality impacts of development and redevelopment (applying future conditions land use);
- Evaluate select near channel erosion sites for TSS and TP contributions and evaluate management actions;
- Prioritize subwatersheds for surface water best management practices (BMPs); and
- Assess effectiveness of BMP implementation.

2 Surface Water Quality Assessment

2.1 Assessment Method

The P8 Urban Catchment Model[2] software program was utilized to model existing water quality in runoff from the study area. P8 simulates rainfall, pollutant loading, and runoff from the watershed and subsequently routes the runoff through water quality treatment features that simulate pollutant particle removal. Pollutant loading and runoff are modeled over defined areas called *subwatersheds* based on characteristics such as impervious area. Pollutant removals are modeled as features called *devices*, such as BMPs and natural treatment features that remove pollutants through particle settling, decay, and filtration/infiltration.

[2] Program for Predicting Polluting Particle Passage Through Pits, Puddles, and Ponds (P8)

Water quality computer simulation models can be a valuable tool for urban stormwater managers. These models can be used to simulate the pollutant loads generated from the landscape and identify the subwatersheds and catchments with the largest amount of nutrient and sediment load reaching critical resources. This project uses the P8 water quality model to identify and quantify potential sources of water quality pollution.

To create the P8 model, first, subwatersheds and their hydrologic inputs were created utilizing land-use, zoning, soils, impervious land cover, stormsewer, and LiDAR topography data. Next, the model network was created and any existing treatment features were input by identification through aerial photography and LiDAR topography. Further data was provided by the City and the SWCD for the inputs of existing BMPs and flow routing. Due to the size of the study area and limitations in the number of devices in P8, two P8 models were created to simulate water quality in the study area (divided into east and west) and the results subsequently combined.

Because a number of urban developments have begun within the City, and further development is expected in the future, the existing P8 model was enlarged to include the runoff from future annexed areas and was used to evaluate how future development might affect downstream water quality (see **Figure 1**). To be conservative, it was assumed that Thief River Falls may be subject to NPDES MS4 stormwater permits in the future as it expands into annexed areas. MS4 requires no net increase in volume, TSS, or TP. Therefore, future development areas were modeled as they currently exist, as it was assumed that any pollutant load increase caused by development will be mitigated.

There are 11 known constructed BMPs in the watershed that were included in the existing conditions models. An additional four natural treatment features were also modeled that included wetlands and ponds. Also modeled were an additional six sediment separators (see **Appendix B**).

All available monitoring data from the MPCA for Chief's Coulee, CD70, and Harz Park were reviewed for their potential to be used in calibration. However, in addition to the data being sparse, it only contains measured concentrations and no flow monitoring data which would allow for the estimation of loads and therefore could not be used for calibration. However, as a check for reasonability, a comparison of pollutant concentrations was made between the model results and the local monitoring data.

Because P8 is designed to simulate urban areas, and there are large portions of the study area which are agricultural, adjustments to the load accumulated during rainfall events were made to the agricultural subwatersheds to match literature values. The results were then checked against other literature values, as well as the MPCA Watershed Pollutant Load Monitoring Network (WPLMN) average values measured at river monitoring locations from 2007-2014.

The P8 model was utilized to estimate watershed loadings from the subwatershed, subsequent removals from existing BMPs and natural treatment features, and the pollutant loads delivered ultimatly to Red Lake River on an annual average basis. The P8 model was also used to calculate the pollutant watershed loads based on anticipated future zoning of Thief River Falls, and finally to estimate the removals from proposed BMPs throughout the study area.

Further detail of the P8 model development is discussed in **Appendix A – Development of the Their River Falls P8 Water Quality Model**.

2.2 Summary of Existing Conditions Modeling

Sixty years of local historical precipitation and air temperature data (1953 to 2013) were simulated in the P8 model. Running the model for a long term simulation and averaging the results over that period allows for the calcuation of annual average loads and removals of TSS, TP, TKN, and HC. Averaged annual load delivered to the downstream resources in the existing conditions model can be used as a baseline by which proposed treatment devices can be measured against and, ultimatly, to realize the benefit to the downstream resources.

The annual average total amount of pollutants currently entering the Red Lake River from the study area (some areas first entering the Thief River) are reported in **Table 1**. Also reported are delivered loads from the future conditions study area, the existing conditions delivered load from within the city boundary, and the future conditions delivered load from within the city and future annexations. The existing city pollutant removals and delivered loads area also summarized in **Figure 2**.

Table 1: Summary of annual average delivered pollutant loads from the city and entire study area.

	TSS (tons/yr)	TP (lbs/yr)	TKN (lbs/yr)	HC (lbs/yr)
Total Study Area – Existing Conditions	418	3,464	16,775	N/A[3]
Total Study Area – Future Conditions	463	3,785	18,306	N/A[3]
Within City Boundary – Existing Conditions	177	1,245	5,744	9,012
Within City Boundary – Future Conditions	231	1,735	8,175	12,051

Table 2: Summary of annual average delivered pollutant loads from within the city boundary contributing to the Thief River and Red Lake River.

Delivered load from within the city boundary	TSS (tons/yr)	TP (lbs/yr)	TKN (lbs/yr)	HC (lbs/yr)
To Thief River – Existing Conditions	3	18	92	138
To Thief River – Future Conditions	12	95	460	619
To Red Lake River – Existing Conditions	174	1,227	5,652	8,874
To Red Lake River – Future Conditions	219	1,640	7,715	11,432

[3] Due to fact that this study does not provide dependable estimate of HC from the surrounding rural areas (as discussed in **Appendix A**), the resulting loading for the "total study area" are not provided in Table 1; rather, only the loading results from within the City boundary.

Figure 2: Annual average pollutant removals and delivered loads from within the existing city boundary

Existing Conditions loading was also geographically displayed across the subwatersheds in **Figure 3, Figure 4**, **Figure 5**, and **Figure 6**. The figures show the average annual TSS, TP, TKN, and HC yields delivered downstream under existing conditions. Delivered yield is the actual amount of pollutant that is contributed to the downstream resource, taking into account both the initial loading from the land and the removal provided by any downstream treatment devices. Delivered pollutant yields are shown based on an annual subwatershed basis (i.e. in lbs/ac/yr) and can be used to identify areas producing the greatest amount of polluants.

Additional data on TSS, TP, TKN, and HC pollutant loading and removals can be found in **Table 7** and **Table 8**, of **Appendix A**.

Figure 3: Existing average annual TSS delivered yield

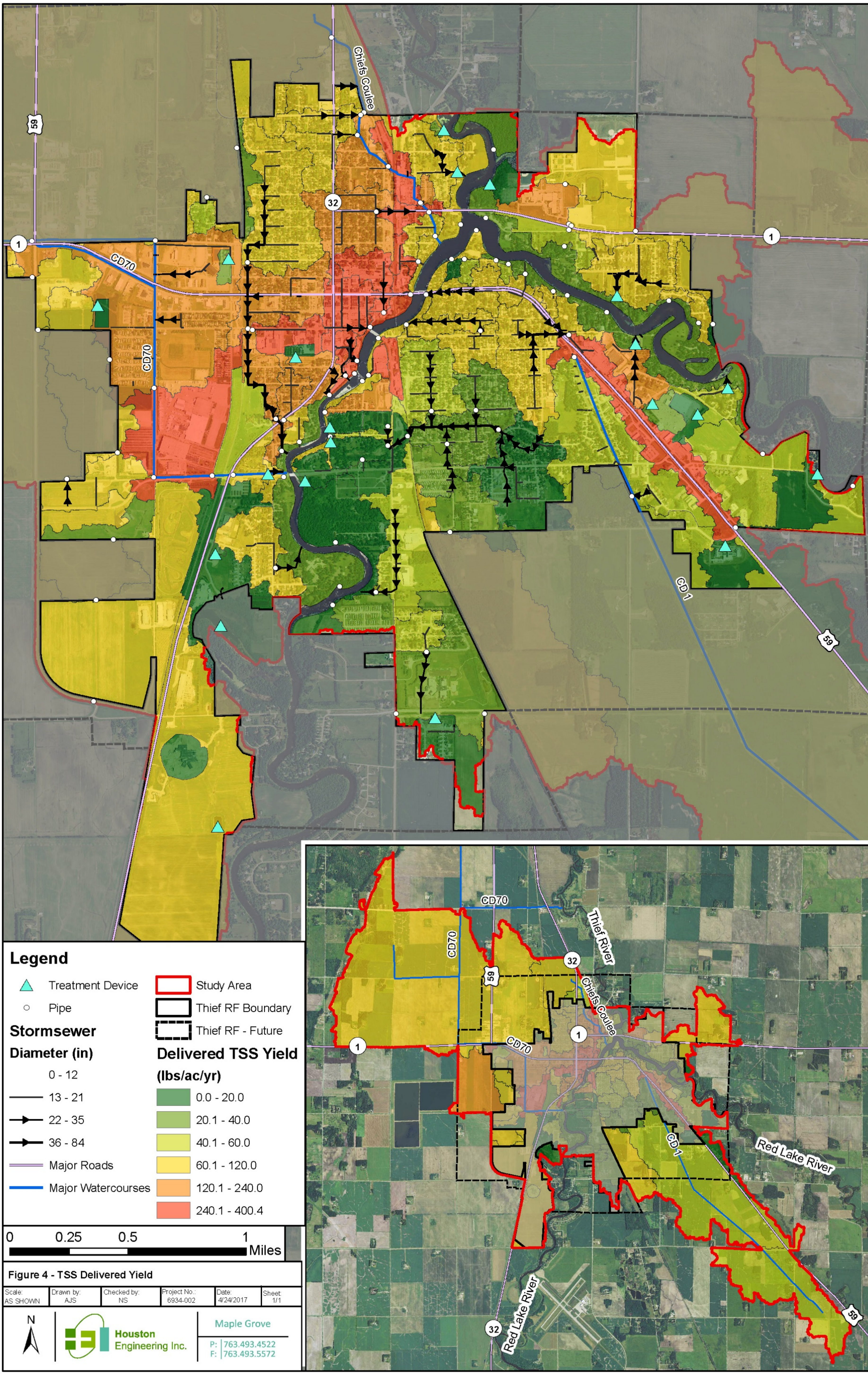


Figure 4: Existing average annual TP delivered yield

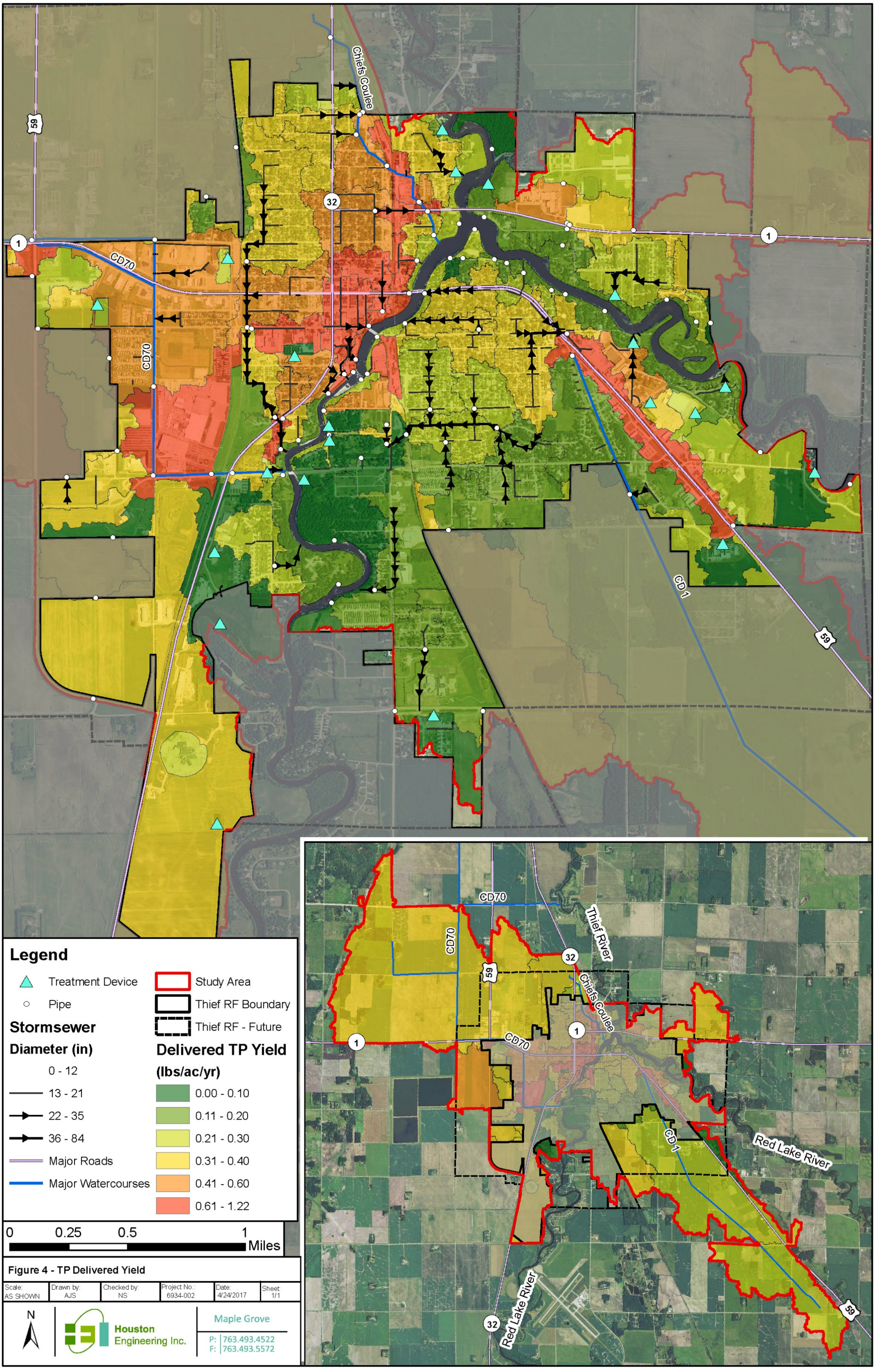


Figure 5: Existing average annual TKN delivered yield

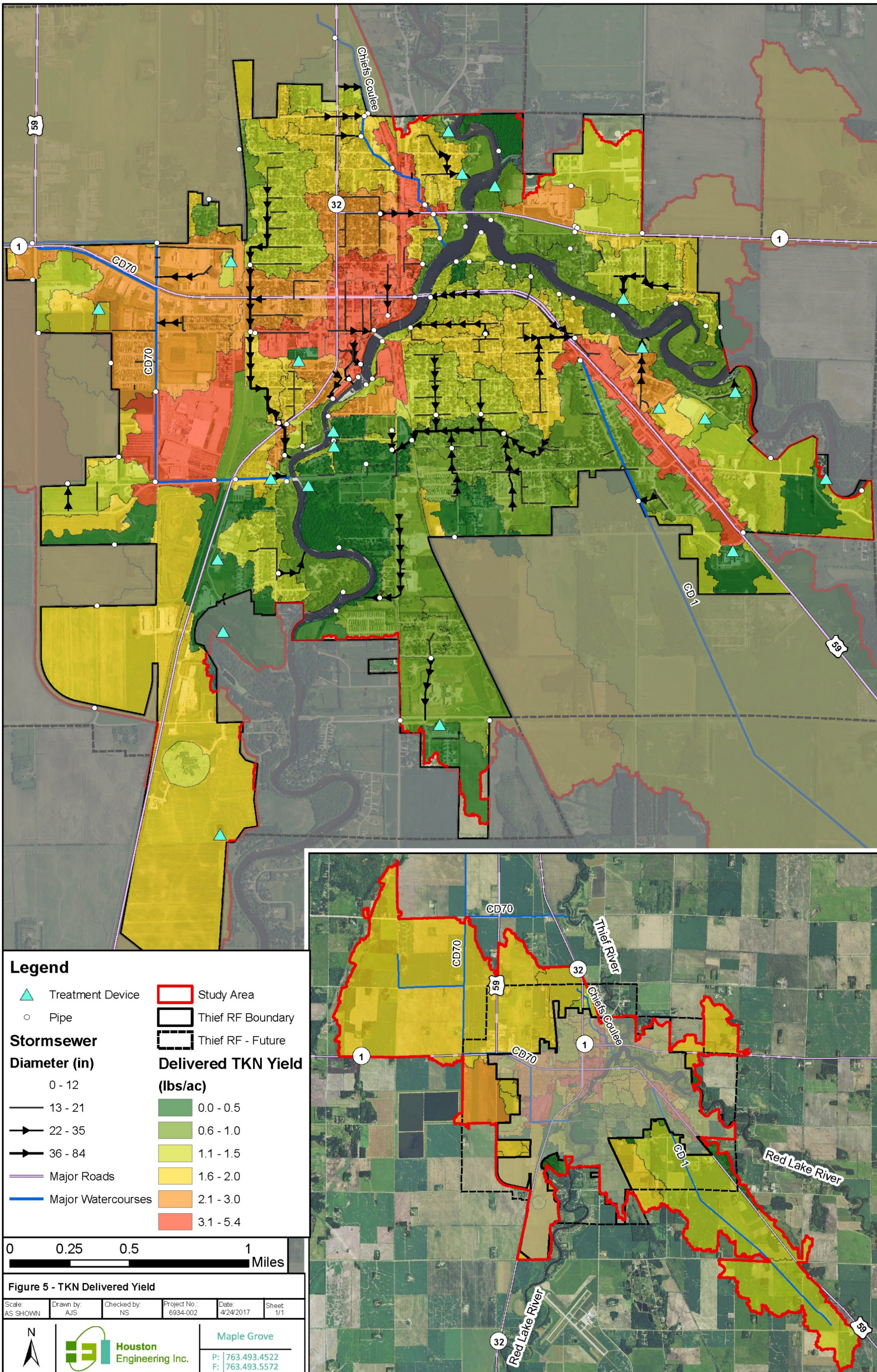
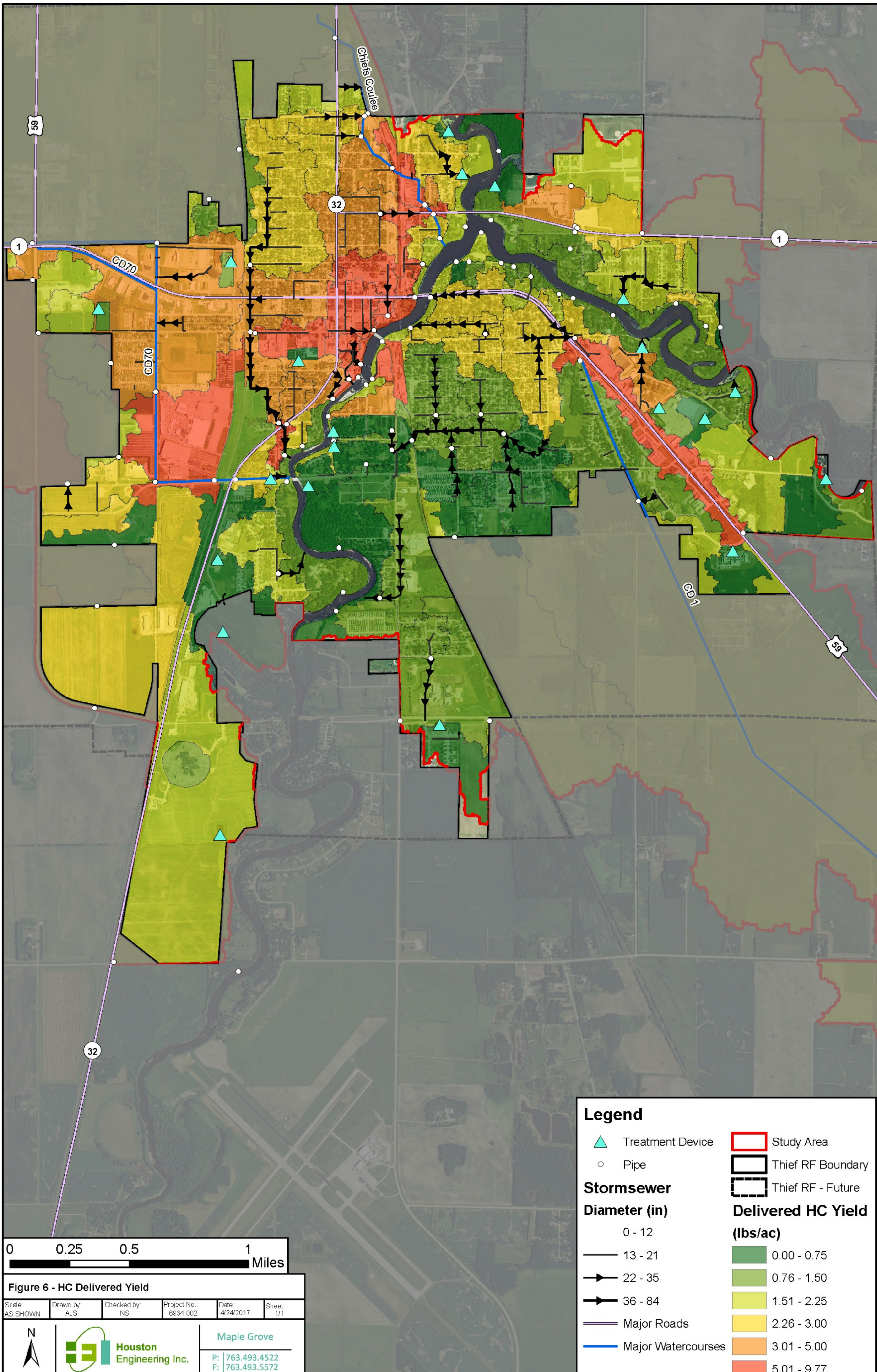


Figure 6: Existing average annual HC delivered yield



3 Surface Water Quality Improvement Plan

Results from the watershed water quality assessment show that there are a number of existing features providing treatment in the city, but only a small percentage of the existing pollutant load is being treated. To improve the quality of the runoff from the study area, additional stormwater BMPs could be implemented to capture and treat more runoff. This section presents the methods used to target and prioritize additional stormwater treatment practices within the City and evaluates those BMPs for water quality improvement benefit.

3.1 Targeting

The identification process of potential BMP locations requires the targeting of locations where there is potential to achieve the greatest improvement in water quality and in the most cost-effective manner. Many factors were considered in this targeting process. The BMP targeting and identification process is qualitatively summarized by the following progression of questions:

- Which subwatersheds are priority (e.g. highest pollutant yields)?
- Where is the highest treatment potential?
  - Locations downstream of priority subwatersheds.
  - Locations with the greatest incoming load.
- Will the landowner be receptive?
- Is there space for a BMP?
- Can runoff be captured?
- Are there constraints on BMP placement and type?
  - Soils, utilities, water table, slope

A combination of factors was taken into account and used to select the top locations where a water quality treatment BMP will likely make a significant impact in reducing nutrient and sediment loads to the rivers. A BMP targeting heatmap was created, as shown in **Figure 7**. The heatmap was formed by a systematic evaluation of concepts through GIS techniques. These concepts include TP yield, TP load, and suitable BMP locations, and are described further in the following:

1. Resulting TP[4] yields (in lbs/ac/yr) from the P8 model identify subwatersheds that contribute the highest delivered TP yields, shown in **Figure 4.** TP yields prioritize locations that receive more polluted runoff. Locations along major flow paths (stormsewers and ditches) throughout the watershed were ranked according to their upstream TP yield.

2. To identify locations that receive a significant quantity of pollutant loads, the TP loads (lbs/yr) resulting from the P8 model were also spatially represented in GIS. Locations along major flow

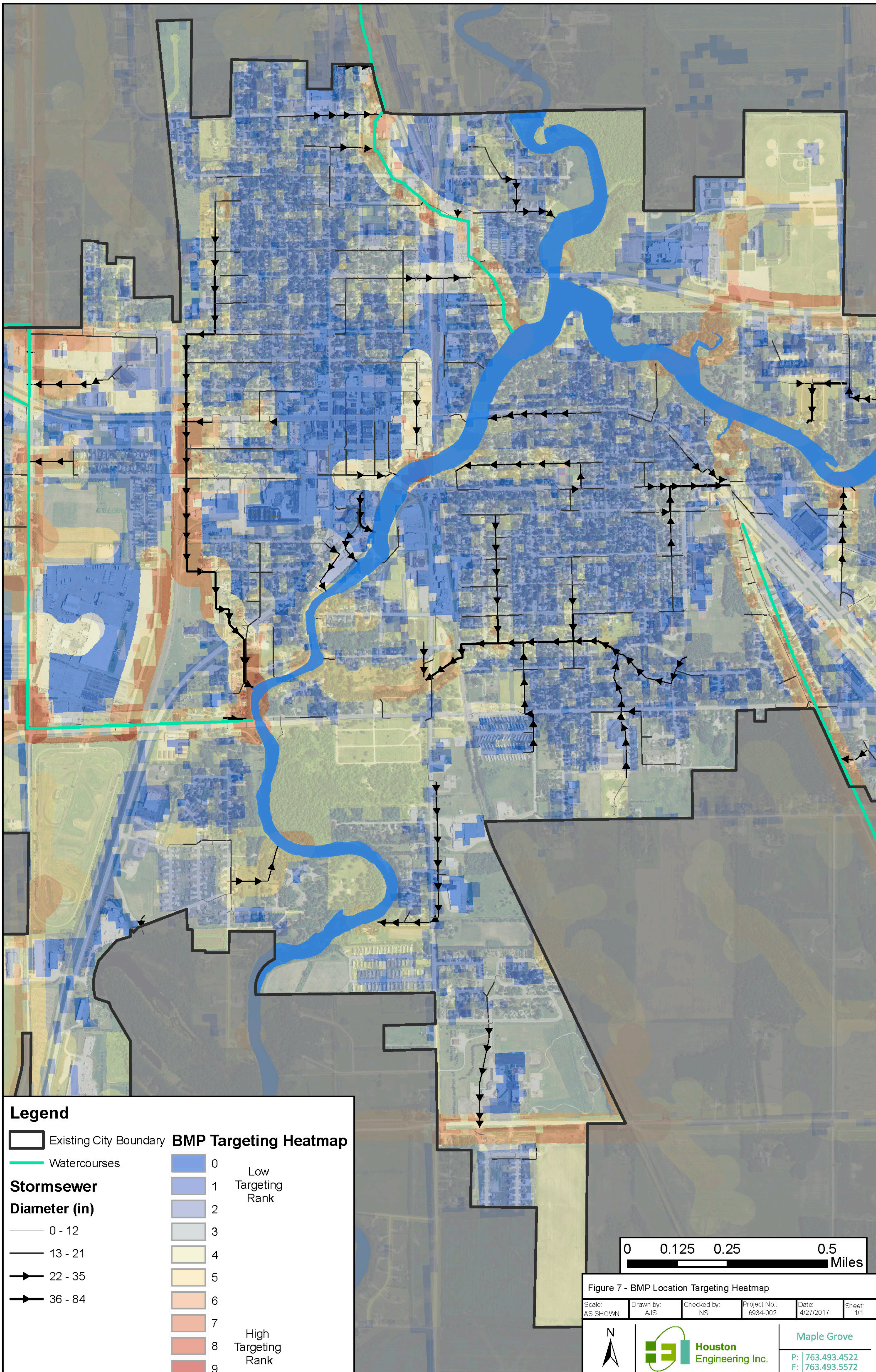
[4] Although total suspended solids and nitrogen are also assessed in this study, TP was selected as the primary indicator for pollutant loading from the primarily urban watershed. Literature shows urban areas produce relatively higher TP than agricultural areas – whereas for nitrogen, some urban areas may produce less than agricultural areas. Also, the pattern of TP, TSS, and TKN yields from the urban watersheds are highly similar for all three of these constituents, i.e. the yields are usually high for the same subwatersheds. Research has also shown that BMP's designed to remove TP and also successful at removing hydrocarbons

paths (stormsewers and ditches) throughout the watershed were ranked according to their upstream TP load.

3. Areas which are suitable (feasible and cost effective) for locating a BMP were identified by:
    a. Locations which are within 200 feet of major flow paths (stormsewers and ditches);
    b. Locations which consist of significant greenspace; and
    c. Locations located within a publicly owned parcel.

The BMP targeting heatmap highlights locations (in yellow and red) which have highest potential for effective BMP's (shown in **Figure 7**). The map is not expected to produce specific locations for practices, but to act as a guide for further investigation. The BMP targeting heatmap and input layers were reviewed by hand to verify the feasibility and select BMP locations.

Figure 7: BMP Location Targeting Heatmap and Potential BMPs



3.2 Proposed BMPs

After BMP locations are identified, a type of BMP needs to be identified that would be physically viable in a particular location. The site and physical constraints listed in **Table 3** was adapted from the Minnesota Stormwater Manual, and those constraints were applied to selected BMP locations (shown in **Table 4**) determine the initial feasibility of potential BMP types.

Table 3: BMP Comparison Matrix

		Site and Physical Constraints				Performance		Cost and Community Acceptance		
	BMP Type	**Footprint Size***	**Drainage Area (acres)**	**Depth to Groundwater (feet)**	**Soils**	**TP Removal (Percent)**	**Peak Flow Reduction**	**Construction Cost**	**Ease of Long-term Maintenance**	**Community Acceptance**
Sedimentation	Stormwater Ponds	1-3%	10-25	0	NA	50	Yes	Low	Easy to Medium	Medium to High
	Stormwater Wetlands	2-4%	25-200	0	NA	40	Yes	Medium	Medium	Medium to High
	Hydrodynamic	Varies	Varies	NA	NA	Varies	No	High	Medium	High
Filtration	Sand Filter	0-10%	0.5-5	0-3 feet	NA	50	No	Medium	Difficult	High
	Iron Enhanced Sand Filter			0-3 feet	NA	80	No	High	Difficult	High
	Bioretention	7-10%	0.5-2	≥3 feet	NA	44	No	Medium	Medium	High
Infiltration	Trench	0-10%	5-10	≥3 feet	>0.2 in/hour	90	No	High	Difficult	High
	Basin	1-10%	0-10	≥3 feet	>0.2 in/hour	90	Yes	Medium	Medium	Low

* Percentage of drainage area

In terms of BMP performance, volume reduction (e.g. infiltration and reuse) is usually regarded as a preferred stormwater treatment option. However, through discussions with City and SWCD staff and a review of soil data, it is assumed that soils in the area are generally not conducive to infiltration, and therefore, no infiltration BMPs were recommended. Upon the design phase of BMPs, soil borings could be performed to definitively rule out using infiltration at a particular site. In addition to water reuse, an alternative to infiltration is filtration or biofiltration that passes runoff through a media filter such as sand before collecting the filtered water with perforated underdrains. A sand filter provides treatment of pollutants through filtration and adsorption, while the addition of iron filings to the sand (iron enhancement), provides an additional chemical sink specifically for the removal of phosphorus. Finally, sedimentation practices (e.g. stormwater ponds or wetlands) are often a good treatment option when landscape conditions limit the use of a broader range of practices. If a targeted location's physical characteristics are feasible for BMP construction, performance and cost factors were used to select the most suitable and effective BMP type.

Table 4: Selection Table for Potential BMP Types

BMP ID	BMP Location	← Generally more preferred					Generally less preferred →			
		Stormwater Re-Use	Infiltration Basin*	Infiltration Trench*	Bioretention	Constructed Wetland	Stormwater Pond	Filtration	Low Flow Filter	Underground
1	Sports Field	●	○				●			○
2	Hartz Wearhouse		○				●		●	○
3	Hartz Park								○	
4	Hwy 59 and 1st St						○		○	
5	Arctic Cat East		○			●	○		●	
6	Downtown			●						●
7	Sherwood Ave S		○				●		●	○
8	Fairgrounds						○		○	
9	Oxbow Wetland Retrofit					●	○		○	
10	NCTC 1 (college)		○	●	○			○		
11	NCTC 2 (college)	●				●	○		○	●
12	N Labree & 12th St E		○				●			○

● indicates the site location characteristics are preferred for the given BMP type.
○ indicates the site location characteristics are feasible for the given BMP type.
* As soil conditions allow. It is assumed that clay soils or a clay confining layer exists throughout the city, therefore no infiltration practices were proposed.

A total of 12 BMPs were identified as potential locations for future structural BMPs and are shown on **Table 5** and **Figure 8**. An initial list of 16 BMPs were preliminarily prioritized and presented to the SWCD and City staff who provided valuable local perspective as to the feasibility and preference of BMP locations, (e.g. major utilities, landowner reception, type of BMP, whether land-use on a particular site could be altered to support a BMP, etc.). The discussion with staff led to the selection of the 12 priority BMPs for further study through conceptual design, modeling, estimating cost, and analyzing cost-benefit.

3.2.1 Planning Level BMP Sizing

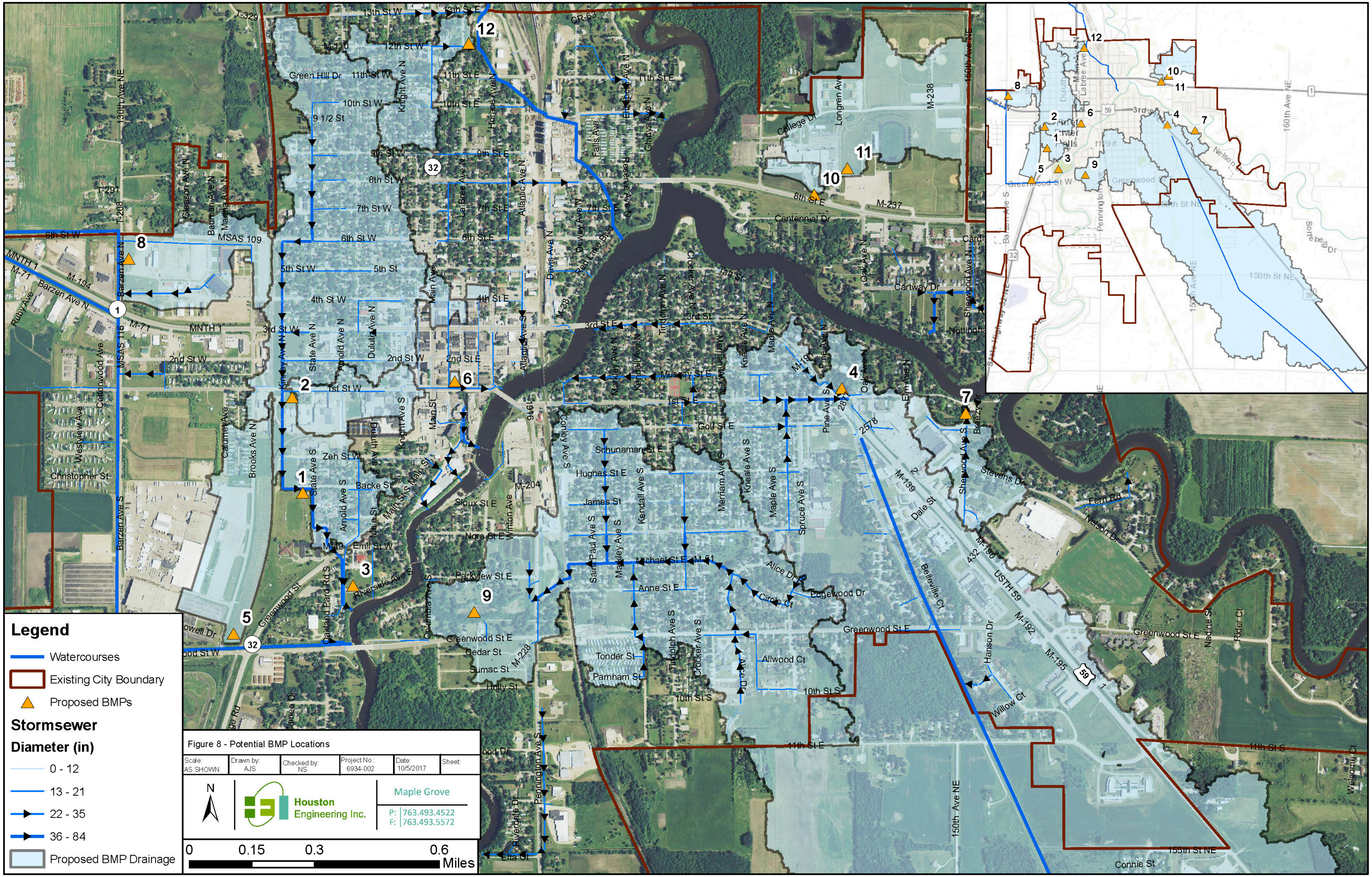
The criteria for the conceptual design of the 12 proposed BMPs followed guidelines from the Minnesota Stormwater Manual (MPCA, 2016). Filtration BMPs were sized to treat a volume of 1.1 inch of runoff over the contributing impervious surface. Wet detention ponds were sized to 1,800 cubic feet of dead storage per acre of tributary area and a live volume of 1 inch of runoff over the contributing impervious surface. Wetlands were also sized to 1,800 cubic feet of dead storage per acre of tributary area and, in addition, a live volume of 0.5 inches of runoff over the contributing impervious surface. These guidelines were not always met for BMPs with large contributing areas that were restricted in size due to site constraints.

Table 5: Identified Potential BMP types and descriptions

BMP ID	BMP Name	Drainage Area	BMP Type	Land Authority	Description
1	Sports Field	190.6	Underground Reuse for Irrigation	School	Divert a restricted amount of stormwater from the 54-inch stormsewer at Kinney Ave. S. into an underground storage tank. A water reuse system will provide storage capacity, filtration, and a pumping system to irrigate the practice field and/or field within track to the south.
2	Hartz Wearhouse	22.7	Pond	Private	Divert 21-inch stormsewer from 1st St. to a pond constructed in the vacant lot (which requires acquisition of private land). The pond will provide treatment of the upstream industrial stormwater through sedimentation and nutrient reduction.
3	Hartz Park	227.1	Underground Iron Enhanced Filtration	City	Divert low flows from 54 and 24-inch stormsewers near Riverside Ave. and Oakland Park Rd to open space in LB Hartz Park. A large underground tank built into the hillside will provide storage for a gravity driven iron enhanced sand filter. Runoff will percolate through the iron-sand media (underground) and be collected in drain tile before discharging to the river.
4	Hwy 59 and 1st St	1,676.0	Sedimentation Pond	Private	Options to collect runoff from ditch along Hwy 59, CD 1 and/or surrounding stormsewer to the lot on the northeast side of Hwy 59 and 1st St intersection (which requires acquisition of private land). The pond will not meet NURP sizing requirements, but will remove sediment from a large drainage area. The pond will require more frequent cleaning due to the large inflow of sediment.
5	Arctic Cat East	44.8	Constructed Wetland	Private	Redirect flow from NW ditch, across street to capture water from the large parking lots. Runoff will be treated by sedimentation and biological processes through pond areas and native wetland vegetation. The project could be combined with future development of this parcel.
6	Downtown	1.3	Urban Tree Trench	City	Runoff from the urban downtown area will be treated in tree trenches within the boulevard or sidewalk areas. The tree trench will be a linear underground area consisting of structural soil capable of sustaining tree growth. On the surface, the BMP could look similar to a line of trees planted along a street. There are many potential downtown locations that would be suitable, this study estimates 1,000 linear feet of tree trenches. BMPs could be implemented in conjunction with the downtown revitalization effort.
7	Sherwood Ave S	26.3	Iron Enhanced Filtration Basin	City	Capture 30-inch stormsewer which collects runoff from local streets. An iron-enhanced sand filter could be constructed in the vacant city ROW. Runoff will percolate through the surface iron-sand media and be collected in drain tile before discharging to the river.

BMP ID	BMP Name	Drainage Area	BMP Type	Land Authority	Description
8	Fairgrounds	39.8	Pond	County	Divert runoff from the 18 and 21-inch stormsewers from the north and south to a pond constructed by expanding the existing depression in the southeast corner of 6th St W and Barzen Ave, west of the Fairgrounds. The pond will provide treatment of the fairgrounds stormwater through sedimentation and nutrient reduction before discharging across Barzen Ave to CD 70.
9	Oxbow Wetland	276.7	Wetland Retrofit	City Easement	This existing wetland within an old oxbow currently collects runoff from a large residential area via a 54-inch and other stormsewers. Treatment in exist wetland will be increased by providing detention via a controlled outlet structure and reconstruct of portions of the wetland. Ponding areas and native wetland vegetation will also provide additional treatment. Restoration may require the disposal of lime-sludge within the site.
10	NCTC 1	10.8	Bioretention	College	The open space in front of the college provides an opportunity to capture runoff from the parking lots in two bioretention basins (aka raingardens). The BMPs would provide treatment by filtration of stormwater through soils under a garden landscape. If infiltration is not feasible, the filtered water will be collected through underground drain tile, and discharged to the ditch.
11	NCTC 2	71.0	Pond w/Reuse for Irrigation	College	Runoff will be captured through a constructed pond in the open space east of NCTC, collecting drainage from the existing ditch. The college stadium and many sports fields could be used as potential sites for irrigation water reuse. This provides treatment through two instruments: sedimentation in the pond and reducing stormwater volume through water reuse.
12	N Labree & 12th St E	29.3	Pond	City	A 24-inch stormsewer from a moderately sized residential drainage area will be collected into a pond located at a vacant city parcel. The pond will provide stormwater treatment through sedimentation and nutrient reduction before discharging into Chiefs Coulee.

Figure 8: Potential BMP Locations and their catchment areas



3.2.2 Construction and Maintenance Costs

A Preliminary Opinion of Probable Construction Costs (POPCC), engineering, administrative, and annual maintenance costs were estimated to determine total BMP implementation costs over a 30-year period as shown in **Table 6**. The estimates are approximate and should not be used for bidding or construction. They were developed without the benefit of a survey or geotechnical borings and are not intended to encompass all bid items. Also, the presence of bedrock, groundwater, significant utilities, access issues, or other unanticipated factors could inflate the cost higher than estimated. Therefore, a 25% contingency was added to each estimate, and the actual costs should be expected to vary. Engineering design and administrative costs were estimated at 30% of the POPCC.

Long-term maintenance of BMPs is critical to ensuring that they continue to perform as designed. BMPs proposed will require periodic sediment removal, inspection, mowing, and/or repair. To estimate the annual average cost for long term maintenance, methods from five sources (Chisago SWCD, 2011; EPA, 1999; Schueler, 1992; WCD, 2014; WERF, 2013) were applied and averaged over each BMP Type. Specific maintenance details are not included in this study, however, periodic major maintenance for BMP ID's 3, 4 and 7 shown in **Table 6** were estimated due to the high influx of pollutant loading at these BMPs. This maintenance includes iron supplementing for the iron enhanced sand filters and dredging of the BMP 4 sedimentation pond.

Table 6: Proposed BMP Annual Average Life-Cycle Cost Estimate

BMP ID	BMP Type	Construction Cost Est. (POPCC)	Engineering & Admin Cost Est.	Total Up-Front Cost Est.	Major O&M Annualized Cost Est.	Total Annual Maintenance Cost Est.	30-year Annualized Cost
1	UG Reuse	$ 186,000	$ 56,000	$242,000	-	$ 3,910	$ 10,600
2	Pond [A]	$ 126,800	$ 35,000	$161,800	-	$ 1,190	$ 6,200
3	Sand Filter	$ 408,000	$ 122,000	$530,000	$ 3,553 [D]	$ 9,650	$24,000
4	Pond [B]	$ 296,200	$ 64,000	$360,200	$ 4,813 [E]	$ 7,010	$16,600
5	Wetland	$ 193,000	$ 58,000	$251,000	-	$ 2,970	$10,300
6	Tree Trench	$ 305,000	$ 92,000	$397,000	-	$ 2,030	$14,600
7	Sand Filter	$ 130,000	$ 39,000	$169,000	$ 2,896 [F]	$ 4,850	$ 8,800
8	Pond	$ 138,000	$ 41,000	$179,000	-	$ 1,420	$ 6,900
9	Wetland [C]	$ 299,000	$ 90,000	$389,000	-	$ 4,600	$16,000
10	Bioretention	$ 65,000	$ 20,000	$ 85,000	-	$ 2,780	$ 4,600
11	Pond/Reuse	$ 181,000	$ 54,000	$235,000	-	$ 3,800	$ 10,300
12	Pond	$ 60,000	$ 18,000	$ 78,000	-	$ 620	$ 3,000

[A] Construction cost includes private land acquisition cost based on 2017 tax appraisal of $11,800.

[B] Construction cost includes private land acquisition cost based on 2017 tax appraisal of $83,200.

[C] Construction cost estimate does not include disposal costs of lime-sludge which exists from the effluent of a waste water treatment plan. Lime-sludge disposal cost was estimated without the benefit of soil borings or environmental testing, therefore quantity and cost may very drastically and may be in the range from $50,000 to $300,000 or more.

[D] Iron supplementing every three years, annualized.

[E] Pond dredging every ten years, annualized.

[F] Iron supplementing every seven years, annualized.

3.2.3 Water Quality Benefits

Pollutant load reduction estimates were developed for the 12 BMP scenarios. The proposed BMPs were modeled by modifying the existing P8 model. Proposed BMP benefits are shown in **Table 7** and **Table *8*** which are expressed in pollutant removals and removal value. Removal value is the cost to removel one pound (or ton for TSS) of pollutant for a given BMP, over that BMPs 30-year expected lifespan. The removal value is calcuated by dividing the annual pollutant removal by the 30-year annualized cost, which includes maintenance. Note that this is different than the cost effieceny values calculated in **Section 6.1.1**, which are based on capital costs.

The amount of pollutants removed by existing and proposed BMPs, and the remaining load delivered to the rivers is summarized in **Figure 9** and **Table 9**.

Table 7: Proposed BMP annual water quality benefit for TSS and TP

BMP ID	BMP Name	TSS Removal Efficiency	TSS Removal (tons/yr)	TSS Removal Value ($/ton)	TP Removal Efficiency	TP Removal (lbs/yr)	TP Removal Value ($/lb)
1	Sports Field UG Reuse	34%	2.3	$4,610	12%	5.7	$1,860
2	Hartz Wearhouse Pond	82%	2.4	$2,580	53%	9.4	$660
3	Hartz Park Filter	75%	4.2	$5,710	53%	24.9	$960
4	Hwy 59 Pond	35%	20.6	$810	11%	56.3	$290
5	Arctic Cat Wetland	93%	4.3	$2,400	65%	19.0	$540
6	Downtown Tree Trench	95%	0.4	$36,500	75%	2.0	$7,300
7	Sherwood Ave Filter	82%	1.8	$4,890	60%	9.7	$910
8	Fairgrounds Pond	86%	2.7	$2,560	54%	11.2	$620
9	Oxbow Wetland	96%	3.3 *	$4,850	65%	24.4 *	$660
10	NCTC 1 Biofiltration	95%	0.4	$11,500	72%	2.0	$2,300
11	NCTC 2 Pond w/Reuse	87%	3.3	$3,120	63%	15.2	$680
12	Labree & 12th St Pond	80%	1.2	$2,500	49%	4.8	$630
	Totals:		**47.0**			**185.0**	

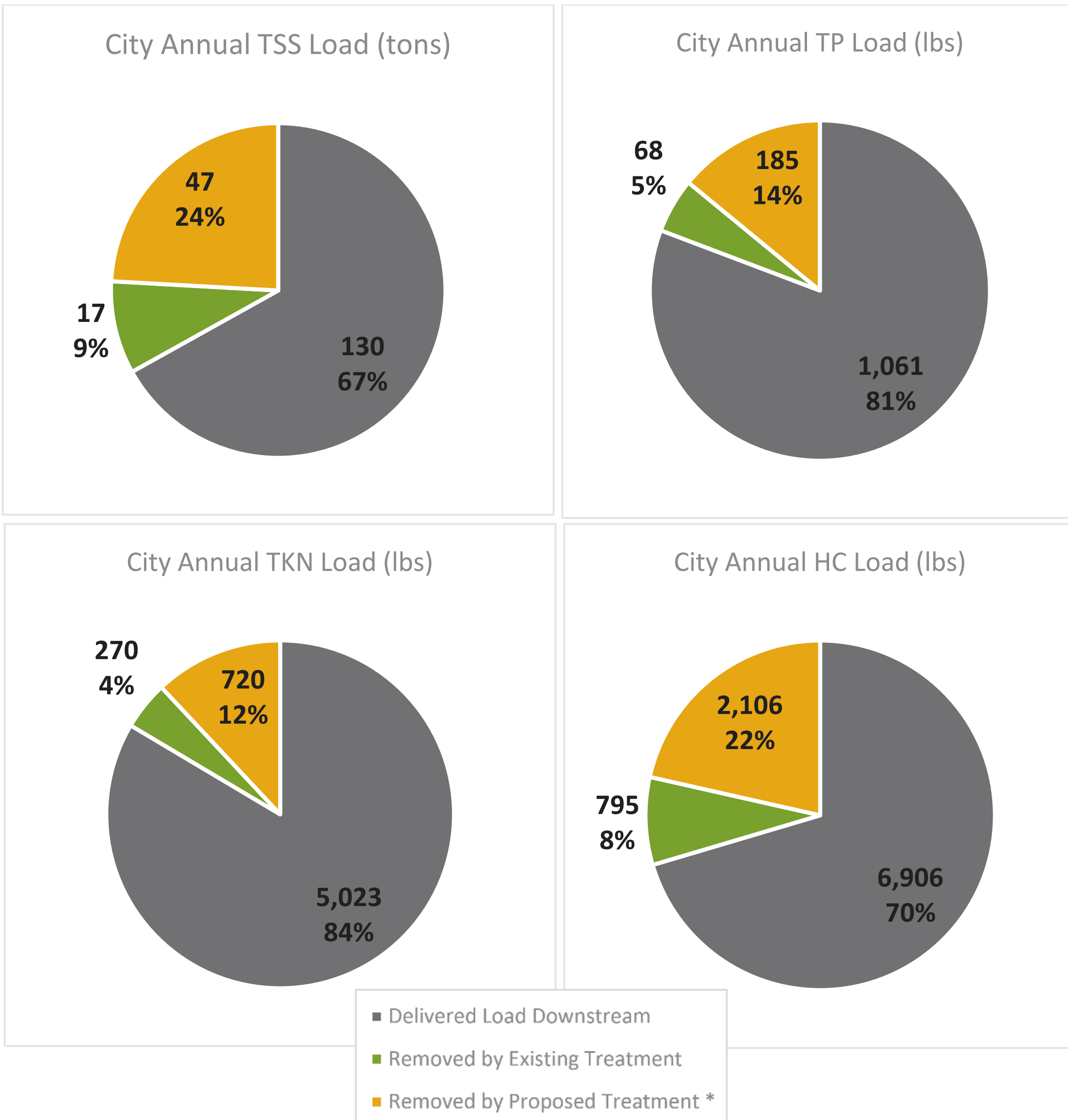
* Increase in removal from existing conditions (i.e. the removal in existing wetland was subtracted from the removals provided by the proposed reconstructed wetland)

Table 8: Proposed BMP annual water quality benefit for TKN and HC

BMP ID	BMP Name	TKN Removal Efficiency	TKN Removal (lbs/yr)	TKN Removal Value ($/lb)	HC Removal Efficiency	HC Removal (lbs/yr)	HC Removal Value ($/lb)
1	Sports Field UG Reuse	11%	24	$440	31%	106	$100
2	Hartz Wearhouse Pond	47%	37	$170	75%	106	$60
3	Hartz Park Filter	49%	107	$220	69%	202	$120
4	Hwy 59 Pond	8%	219	$80	28%	925	$20
5	Arctic Cat Wetland	57%	74	$140	85%	195	$50
6	Downtown Tree Trench	68%	8	$1,830	89%	19	$770
7	Sherwood Ave Filter	56%	42	$210	76%	87	$100
8	Fairgrounds Pond	47%	43	$160	77%	120	$60
9	Oxbow Wetland	56%	77 *	$210	86%	121 *	$130
10	NCTC 1 Biofiltration	65%	8	$580	88%	19	$240
11	NCTC 2 Pond w/Reuse	57%	62	$170	81%	151	$70
12	Labree & 12th St Pond	43%	19	$160	73%	56	$50
	Totals:		**720**			**2,106**	

* Increase in removal from existing conditions (i.e. the removal in existing wetland was subtracted from the removals provided by the proposed reconstructed wetland)

Figure 9: Annual average existing and proposed pollutant removals and delivered loads reaching the river from surface water within the existing city boundary



* Which consists removals from a portion of drainage area outside of the city for BMP 4.

Table 9: Annual average proposed pollutant removals and delivered loads reaching each river from surface water within the existing city boundary.

	TSS (tons/yr)	TP (lbs/yr)	TKN (lbs/yr)	HC (lbs/yr)
To Thief River – Existing Conditions	3	18	92	138
To Thief River – Proposed Treatment	-	-	-	-
To Thief River – Proposed Delivered Load	3	18	92	138
To Red Lake River – Existing Conditions	177	1,245	5,744	9,012
To Red Lake River – Proposed Treatment	47	185	720	1,850
To Red Lake River – Proposed Delivered Load	130	1,060	5,024	7,162

4 ECOLI

The SWCD is currently completing a subsurface sewage treatment system inventory to identify sources of E.coli in Chief's Coulee. A field assessment was carried out led by the SWCD and the City to identify and document any evidence found in the field indicating potential sources of E.coli or inorganic nitrogen. Discharge from the storm sewer crossing Dewey Avenue North to the east had intense odor and visual signs of typical sanitary flow. Field investigation indicated that the observed sanitary discharge is entering the storm sewer on the area between Dewey and Atlantic Avenue, as the land parcel immediately upstream of the TRF Pallet site did not show signs of sanitary flow. The area between Dewey and Atlantic Avenue along Chief's Coulee should be considered a local priority for follow up management action to remove sanitary flow from the surficial drainage system.

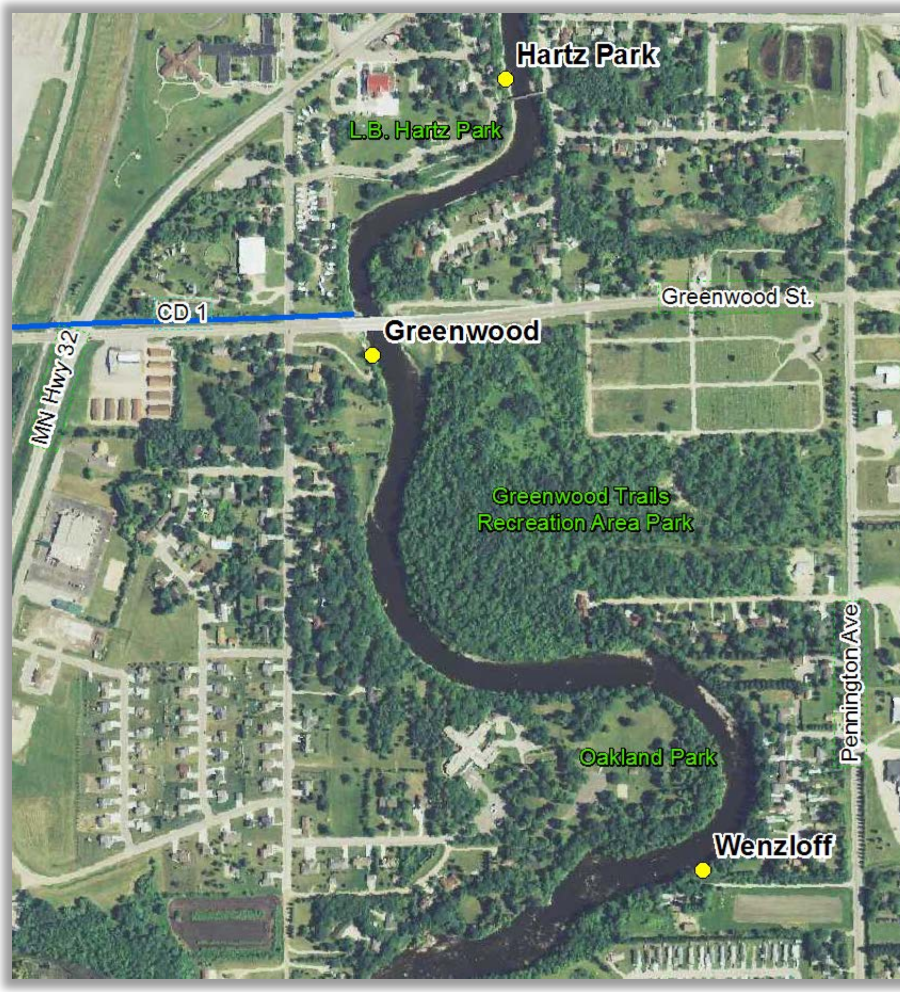
Figure 10: Discharge from storm sewer crossing Dewey Avenue North

5 NEAR CHANNEL EROSION ANALYSIS

Through this project, the city of Thief River Falls and Pennington SWCD identified three river banks that were priorities for field assessments to determine if management actions would provide a cost-effective means of reducing sediment and phosphorus contributions to the Red Lake River (**Figure 11**). For each site, field investigations were conducted to assess:

- Mass of sediment loss
- Mass of Total Phosphorus loss
- Practices that could be used to stabilize the sites
- Cost estimates for implementing stabilization practices

Figure 11: Channel Erosion Assessment Locations



The Wenzloff and Hartz Park sites were difficult to access for collecting all of the field measurements needed to assess the volume of erosion. For these two sites, field measurements were partially supplemented with information from Google Earth. The volume voided and soil types were estimated for each site and entered into the MN BWSR pollution reduction estimator spreadsheet for streams and ditches to estimate the mass of sediment and total phosphorus lost from the three sites. It was assumed that the stabilization efforts would reduce 100% of the sediment and total phosphorus loss from the sites.

Data collected during the site visits were used to estimate a stabilization cost and method for each of the three sites. The treatment value provided assumes a fixed construction cost divided by the estimated annual reduction of pollutant. The stabilization practices proposed do not include maintenance cost estimates. In other words, it was assumed that the practice would continue to function as designed after initial construction. However, it is recommended that a periodic check for signs of failure be performed. The summary results are shown in **Table 10**. Detailed practice implementation profiles have been provided for each of the three sites in **Appendix C.**

Table 10. Results of the near channel erosion analysis for three sites in the city of Thief River Falls.

Site	Sediment Reduction, tons/year	TP Reduction, lbs/year	Estimated Construction Cost	Sediment Cost Effectiveness, $/ton/year [5]	TP Cost Effectiveness, $/lb/year [5]
SS1 Wenzloff	83	70	$ 140,160	$1,699	$1,999
SS2 Hartz Park	165	140	$ 144,240	$874	$1,028
SS3 Greenwood	137	157	$ 121,410	$1,176	$1,026
Totals:	**385**	**367**	**$ 405,810**		

SS – Streambank Stabilization

6 RECOMMENDATIONS

6.1.1 BMP Prioritization

To assist with the decision on which projects should be first pursued and the subsequent sequence of implementation, both the surface water BMPs and streambank stabilization projects were ranked based on cost and benefit (see **Table 11**). The prioritization is based on equal weighting of the water quality benefit (reduction) and cost effectiveness (value) for TSS and TP. The cost effectiveness value was calculated by dividing the estimated capital cost of the projects (including engineering, administration, and construction costs) by the TSS or TP annual reductions.

[5] Cost effectiveness of streambank stabilization practices is the construction cost divided by the estimated annual pollutant mass reduction, and is not annualized over a time period.

Table 11. Ranking of BMP's.

Rank	BMP ID	Project Name	Land Authority	TSS Reduction (tons/yr)	TP Reduction (lbs/yr)	Capital Cost Est.	TSS Value ($/ton/yr)	TP Value ($/lbs/yr)	Rank Scale [C] (0-10)
1	SS2	Hartz Park	City	165.0	140.0	$ 144,240	$ 870	$ 1,030	9.7
2	SS3	Greenwood	City	137.0	157.0	$ 121,410	$ 890	$ 770	9.6
3	SS1	Wenzloff	City	83.0	70.0	$ 140,160	$ 1,690	$ 2,000	7.3
4	4	Hwy 59 Pond [A]	Private	20.6	56.3	$ 360,200	$ 17,520	$ 6,400	6.1
5	5	Arctic Cat Wetland	Private	4.3	19.0	$ 251,000	$ 57,980	$ 13,220	5.0
6	9	Oxbow Wetland [B]	City Easement	3.3	24.4	$ 389,000	$ 116,760	$ 15,960	4.9
7	11	NCTC 2 Pond w/Reuse	College	3.3	15.2	$ 235,000	$ 71,620	$ 15,480	4.9
8	3	Hartz Park Filter	City	4.2	24.9	$ 530,000	$ 125,120	$ 21,310	4.8
9	8	Fairgrounds Pond	County	2.7	11.2	$ 179,000	$ 67,240	$ 16,040	4.8
10	2	Hartz Wearhouse Pond [A]	Private	2.4	9.4	$ 161,800	$ 68,690	$ 17,170	4.8
11	12	Labree & 12th St Pond	City	1.2	4.8	$ 78,000	$ 63,230	$ 16,090	4.7
12	7	Sherwood Ave Filter	City	1.8	9.7	$ 169,000	$ 92,690	$ 17,380	4.7
13	1	Sports Field UG Reuse	School	2.3	5.7	$ 242,000	$ 104,890	$ 42,470	4.3
14	10	NCTC 1 Biofiltration	College	0.4	2.0	$ 85,000	$ 204,360	$ 42,400	3.9
15	6	Downtown Tree Trench	City	0.4	2.0	$ 397,000	$ 942,100	$197,040	0.0

[A] Includes the cost of required private land acquisition cost based on 2017 tax appraisal (see **Table *6***).

[B] Does not include the cost of lime-sludge disposal (see **Table *6***).

[C] Rank Scale is the equal rating of rank for four categories: TSS Reduction, TP Reduction, TSS Value, and TP Value. The values in each category were proportionally scaled to fit a range of 0 to 10 (0 being the least desirable) so that values could be averaged across all categories. For example, if a BMP had the highest value for each category, it would be assigned a 10 for each category and, thus, a Rank Scale of 10.

This study found that the streambank stabilization practices are expected to reduce a much larger amount of TP and sediment load entering the rivers then the surface water treatment BMPs, and therefore the streambank stabilization practices are considered a priority to reduce the sediment loading to downstream turbidity impairments. This does not negate the importance of surface water BMPs, many of which provide cost-effective reduction of TSS and TP, as well as capturing additional pollutants generated by urban impervious surface (TN, HC, and others not assessed in this study).

In prioritizing BMP implementation, factors outside of the technical and cost-benefit analysis can also play a large role. Often, land owner interest and the timing of capital improvement projects can dictate the priority and sequence of project implementation. For example, **Table 11** shows that BMPs 9 and 12 are not the highest ranked BMPs according to pollutant reduction and cost, but they would still be very worthy projects and may warrant consideration as being high priorities due to the fact that the land authority is the City, which will highly facilitate their implementation. Furthermore, future development or capital improvement projects will likely provide opportunities for BMP 4, BMP 5, and BMP 8 implementation. The BMPs could be implemented in conjunction with other public infrastructure projects to meet water quality requirements, as well as provide additional treatment for a greater benefit to the resource.

6.1.2 Other Considerations

In addition to the prioritized structural BMPs, non-structural BMPs could also be considered for implementation. Non-structural practices include street sweeping, limiting road deicing salt applications, and public education regarding stormwater issues such as lawn fertilizers and yard waste. Estimating load reductions for these non-structural BMPs is challenging, but they are consistently included in stormwater management plans because of their established effectiveness.

A field assessment was also carried out to identify and document any evidence found in the field indicating potential sources of E.coli or inorganic nitrogen in the Chiefs Coulee watershed. It is recommended that the site along Chief's Coulee between Dewey Avenue and Atlantic Avenue be considered a local priority for follow up management action to remove sanitary flow from the surficial drainage system

6.1.3 Conclusion

This study has measured existing pollutant loads, and targeted, identified, and prioritized surface water treatment projects within the city of Thief River Falls. Channel erosion was also assessed for sediment and phosphorus loading to the Red Lake River. Three river bank locations were evaluated to determine if streambank stabilization management actions would provide a cost-effective means of reducing sediment and phosphorus contributions to the Red Lake River. This analysis provided technical feasibility, potential water quality benefit, and treatment value for these projects, which will be valuable information when competing for grant dollars in pursuit of project implementation. The prioritization of the proposed projects based on cost and benefit is shown in **Table 11**. However, in selecting projects for implementation, other factors such as timing of capital or development projects, project scale, flood benefit, staff capacity, and landowner interest should also be considered.

It is recommended that grant funding such as the MN BWSR's Clean Water Fund Projects and Practices grant be pursued to assist with the design and construction of the highest ranking structural BMPs. Additionally, the Community Partners grant category, which requires a non-governmental partner (e.g. a college), is an option to implement the smaller scale BMPs (such as BMP 1, BMP 10, or BMP 11).

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Appendix A DEVELOPMENT OF THE THEIR RIVER FALLS P8 WATER QUALITY MODEL

Appendix A

Development of the Thief River Falls P8 Water Quality Model

TABLE OF CONTENTS

1.0 INTRODUCTION

Water quality modeling of the City of Thief River Falls and its contributing watershed (study area) was performed using the Program for Predicting Polluting Particle Passage through Pits, Puddles, & Ponds (P8) Urban Catchment Model software program. P8 is a model for predicting the generation and transport of stormwater runoff pollutants. Continuous water-balance and mass-balance calculations are performed on a user-defined system consisting of watersheds, devices, particle classes, and water quality components.

The following is described in this document:

- Methods used for the development of model hydrology, hydraulics, input parameters, and assumptions;
- Methods used in modifying the P8 model to account for agricultural runoff and the simulation of removals in sediment separators;
- Verification of the model against literature values and monitoring data; and
- Discussion of model results.

2.0 MODEL DEVELOPMENT

The water quality model of the study area was developed using P8, version 3.5. P8 simulates rainfall and runoff (i.e. hydrology) from the defined watersheds, accumulates dissolved and particulate pollutant loads from the watershed, and subsequently routes the runoff through water quality treatment devices that simulate pollutant particle settling, decay, and filtration/infiltration. Due to model capacity issues, the study area was modeled by two separate P8 models (P8 East and P8 West), and the results were then combined. The model development discussed in detail in the following subsections applies to both P8 models.

2.1 Hydrology

Model hydrology determines the volume of runoff generated by the watershed during a rainfall event, as well as the rate at which runoff is delivered to the treatment device network. Because P8 is a water quality model designed for long-term simulation of sediment and pollutant transport, it uses a simple hydrologic runoff method. The Thief River Falls P8 model's hydrologic input parameters were derived using the methods outlined in the following subsections.

2.1.1 P8 Subwatershed Delineation

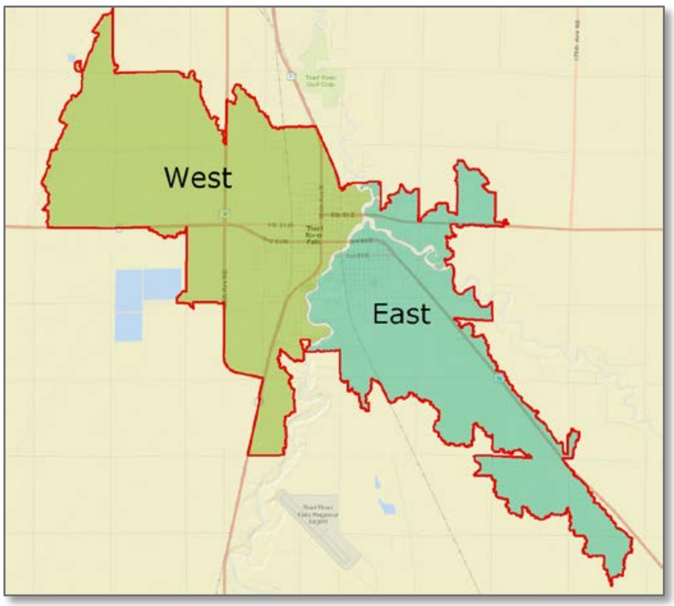
The P8 subwatershed boundaries for the model were delineated by combining GIS mapping of the existing stormwater infrastructure with bare-earth LiDAR topography. The locations of the P8 subwatershed pour points are based on existing stormsewer, ditches, treatment locations, topography, and the desired level of modeling detail so to best differentiate between areas of high and low loadings. The size and location of P8 subwatersheds was also influenced by the anticipated location of future development, future potential BMPs, the city boundary, and the need for spatial resolution and routing in model results. Additional effort was put into preserving the spatial resolution of the model to capture potentially higher loading from certain P8 subwatersheds.

During the delineation, additional drainage details available (plats, as-builts, and aerial images) were utilized to increase detail and accuracy. The P8 subwatershed boundaries were developed using automated methods within the ArcGIS software and the Spatial Analyst extension hydrology toolbar. This process involves defining pour points on the LiDAR data based on stormwater infrastructure, and automating the catchment delineation based on drainage to these pour points. In certain areas, where GIS data indicates private stormwater connections, rooftop drainage, or newly developed parcels that are not represented by LiDAR data, P8 subwatershed boundaries were delineated manually.

2.1.2 Description of the two P8 Models

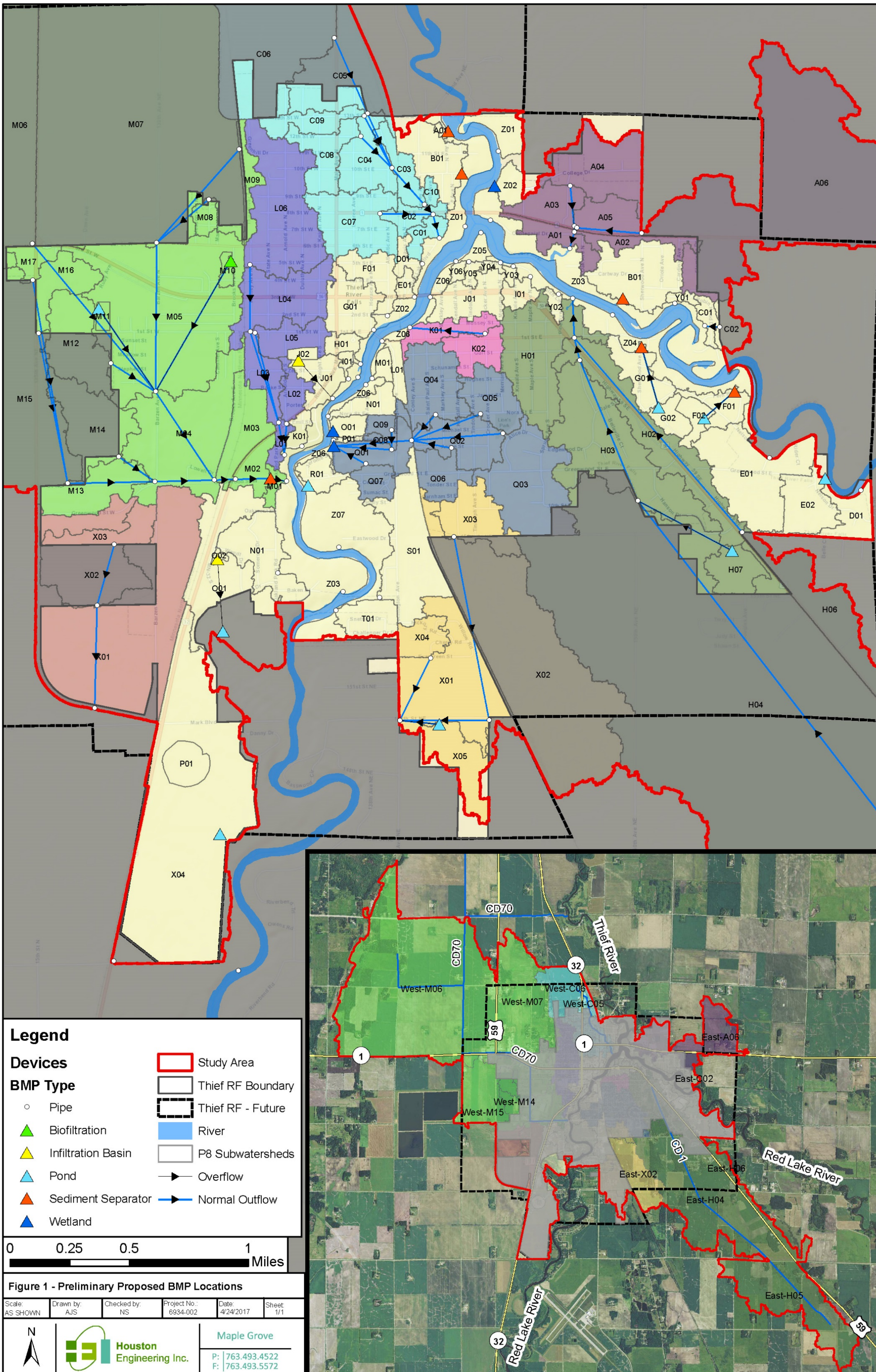
P8 version 3.5 (released 3/21/2015) allows for a maximum of 250 P8 subwatersheds to be simulated within a given model. The model is further restricted by a maximum of 75 devices at which calculations are performed. Therefore, the device locations determine the resolution of the model. To capture the desired level of detail and accuracy in the model, two separate P8 models were developed for the study area. A logical hydrologic boundary at which to split the study area was along the Thief River and continuing south along the Red Lake River. This created east and west areas for which two respective models were developed (**Figure 1**).

Figure 1: East and West P8 Model Boundaries



The final P8 subwatersheds used in the P8 model are shown in **Figure 2** and are colored according to major drainage basin. The study area contains a total of 117 P8 subwatersheds (62 in TRF East, and 55 in TRF West) and encompasses 10,947 acres or 17.1 square miles (4,552 acres in TRF East, and 6,395 acres in TRF West). P8 subwatershed labels were assigned based on, first, an East or West designation followed by a letter which corresponds to an outfall to the river, and lastly a unique identifying number, e.g. “East-A01”. Each subwatershed number corresponds to its runoff device number. **Figure 2** also shows the P8 devices in the models and the P8 network to depict the direction of the flow of runoff. **Section 3.3** describes the types of P8 devices in detail.

Figure 2: Thief River Falls P8 models network.



2.1.3 Runoff Modeling

Runoff from pervious areas and indirectly-connected impervious areas is modeled in P8 using the SCS Curve Number (CN) methodology (USDA, 1964) developed for the Generalized Watershed Loading Functions (GWLF) model (Haith et al., 1992). Runoff from impervious areas starts after the cumulative storm rainfall exceeds the specified depression storage, and thereafter the runoff rate equals the rainfall intensity. These methods require the calculation of watershed area, pervious CN, directly and indirectly connected impervious fractions, and depression storage. Unique hydrologic parameters were calculated for the P8 subwatersheds in the study area P8 models. Development of model inputs related to runoff modeling is discussed in the following subsections.

2.1.3.1 Land Use Data

Multiple runoff modeling parameters developed for the P8 model were calculated based on land use data. Existing and anticipated future zoning areas were provided by the city. The Thief River Falls land use zones were related to categories in the Minneapolis model guidance (Minneapolis, 2005)[1] to calculate directly connected impervious area (DCIA- see **Section 2.1.3.2**) fractions (the ratio of DCIA to total impervious area) and depression storage (as shown in **Table 1**). These two hydrologic parameters were calculated using area weighted averages of the zoning land use shapefile over the P8 subwatersheds, based on the values in the model guidance (Minneapolis, 2005).

Table 1: Met Council/City of Minneapolis model guidance land use hydrologic parameters used in P8 model.

Thief River Falls Zoning Land Use Code	Thief River Falls Zoning Land Use Category	Matched - City of Minneapolis model guidance Consolidated Land Use Categories	DCIA Multiplier	Impervious Depression Storage (in)
R1	Suburban Residential	Single Family Residential	0.6	0.02
R2	General Residential	Single Family Residential	0.6	0.02
R3	Multi-Family Residential	Multi-Family Residential	0.6	0.02
R4	High Density Residential	Multi-Family Residential	0.6	0.02
C1	Neighborhood Business	Mixed Urban	0.9	0.02
C2	General Business	Commercial/Industrial	1	0.094
C3	Central Business	Commercial/Industrial	1	0.094
C4	Downtown Fringe	Commercial/Industrial	1	0.094
I1	Light Industrial	Commercial/Industrial	1	0.094
I2	General Industrial	Commercial/Industrial	1	0.094
AG	Agricultural	none	0	0.02
PR	Parks & Recreation	Recreational	0	0.02

[1] The Minneapolis model guidance manual provides established basic criteria, standards, and data recommended for hydrologic calculations.

2.1.3.2 Impervious Area and Depression Storage

Directly Connected Impervious Area (DCIA) is defined as the portion of the total impervious area which is directly connected to stormwater infrastructure (i.e., flows to stormwater infrastructure without conveyance over pervious surfaces). DCIA for each P8 subwatershed was determined from land use DCIA fractions, described in Section 2.1.3.1. The Indirectly Connected Impervious Area (ICIA), is defined as the impervious area from which runoff must flow over pervious surface before flowing into stormwater infrastructure.

DCIA and ICIA are derived from the total impervious area. The University of Minnesota Remote Sensing and Geospatial Analysis Laboratory's impervious surface data was used to calculate area weighted averages over the P8 subwatersheds. The data was first updated by using the most recent aerial photography.

The depression storage assigned to a directly-connected impervious area determines the volume of rainfall abstracted by impervious surfaces before runoff occurs. The P8 default value for impervious depression storage of 0.8 inches was applied to all P8 subwatersheds.

2.1.3.3 Adjusted Pervious Curve Number

The Curve Number (CN) is an empirical parameter used to predict the potential for runoff from a surface. Typically, the CN applied to a watershed is determined by land use or surface type (e.g., lawn, residential, street or parking lot, etc.) and the infiltration potential of underlying soils. A pervious CN raster was developed by overlaying the 2011 National Land Cover Dataset (NLCD) and Hydrologic Soil Group designations from the Natural Resources Conservation Service's (NRCS) SSURGO database and applying pervious CN values from TR-55. The pervious curve number (pervious CN) entered into P8 was calculated as the area-weighted average of the pervious CN grid within each P8 subwatershed.

2.1.3.4 Precipitation and Temperature

In order to model a continuous simulation of watershed hydrology and pollutant transport, P8 reads hourly precipitation and daily average temperature data from a data file. Daily temperature and hourly precipitation data files used in the continuous 60-year P8 model simulation were developed (formatted) from data available from NOAA's Climate Data Online. Daily temperature data was available for Thief River Falls from 1949 to 1958 and 1973 to 2016. Daily temperature from Grand Forks was used for the gap period and supplemented with data from Fargo when records were missing (<3%).

Hourly precipitation data was only available at Thief River Falls from 2005 to 2016. Long term hourly precipitation data was available at Grand Forks from 1949 to 2013. Because of the limited time period available for Thief River Falls, the Grand Forks precipitation data was used for simulation in this study. For periods where no record was available at Grand Forks (13% of the time period), the data was supplemented with Fargo hourly precipitation. Precipitation and temperature files formatted for P8 and included in the project deliverables are summarized, below:

- **ThiefRF_temp.tem** – daily average temperature measured at Thief River Falls and supplemented with daily average temperature at Grand Forks and Fargo (1949-2014).
- **GrandForks_precip.pcp** – hourly precipitation measured at Grand Forks and supplemented with hourly precipitation at Fargo (1949-2013).
- **ThiefRF_precip.pcp** – hourly precipitation measured at Thief River Falls (2005-2016).

2.1.3.5 Runoff Coefficient and Gravel Areas

A significant amount (>80 acres) of compacted gravel lots used as a driving surface exists within the study area. Significant gravel areas identified in aerial photographs that were not designated as impervious in the University of Minnesota impervious dataset were tabulated, although gravel areas are usually highly compacted so that they generate pollutants more similar to impervious areas than pervious areas. To account for pollutant loading from these gravel areas and the limited perviousness of gravel lots, gravel areas were input into model as directly connected impervious areas with the runoff coefficient set to 0.85 to account for some abstraction of the gravel surface. For all other impervious surfaces, the default runoff coefficient of one was used.

2.1.3.6 Snowmelt, Evapotranspiration, and Runoff

Snowfall, the generation of snowpack, and snowmelt are modeled processes in P8. Depending on daily-average air temperature, precipitation events in P8 are modeled as either rainfall or snowfall. Over winter and spring months, snowfall accumulates across the watershed as snowpack. As daily-average air temperature begins to rise in the spring, accumulated snowpack is converted into snowmelt (i.e., runoff). All model parameters related to snowfall, snowpack, and snowmelt were left at default values.

The amount of runoff generated by a precipitation event is impacted by the antecedent moisture content (AMC) of the soil. P8 assumes either AMC2 (typical runoff potential) or AMC3 (highest runoff potential) depending on factors such as how much precipitation has been applied to the watershed over the last five days and whether or not the soil is frozen. Because AMC2 is the typical soil condition assumed by P8, pervious curve numbers applied throughout the watershed reflect AMC2 soil conditions. Default values were assumed for all parameters related to AMC calculation in P8.

2.2 Pollutant Loading

Sediment and associated pollutant loadings generated from pervious and impervious surfaces throughout the watershed are mobilized by runoff generated from precipitation events. The rate at which sediment particles accumulate throughout the watershed, as well the ability of particles to be removed by water quality BMPs via filtration and settling, is defined by particle characteristic assumptions. The pollutant load associated with particles is defined by water quality component assumptions applied in P8.

2.2.1 Particle Characteristics

Sediment characteristics (such as settling velocity, filtration efficiency, mass accumulation rate, etc.) can vary greatly based on the size of individual sediment particles. For this reason, P8 allows for up to five typical particle sizes (referred to as particle fractions) to be modeled. The P8 default particle file, NURP50, has been applied to the study area model to define particle characteristics of five particle fractions. The NURP50 particle file was developed from National Urban Runoff Program (NURP) studies (USEPA, 1986) and reflects the median (50th percentile) sediment characteristics of all monitored sites.

The only modification made to the default NURP50 particle file was that filtration efficiencies applied to each particle class were adjusted to allow for the simulation of biofiltration. The P8 default efficiency is 90% for P0 and 100% for particle fractions P10 through P80, in order to reflect the removal which would be expected through infiltration into the ground. However, to simulate pollutant removal via filtration (pollutants not removed and being conveyed downstream), the removal efficiencies were adjusted to reflect the typical phosphorus filtration efficiency of biofiltration systems reported in the Minnesota Pollution Control Agency's (MPCA) Minimal Impact Design Standards (MIDS) calculator. For the dissolved phosphorus fraction (particle fraction P0), the filtration efficiency was set to 20%. For the particulate fraction (particle fractions P10 through P80), the filtration efficiency was set to 80%.

2.2.2 Water Quality Component

The concentration of water quality pollutants (total suspended solids (TSS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), copper (CU), lead (PB), zinc (ZN), and Hydrocarbons (HC)) associated with each particle fraction is defined by water quality component assumptions applied in P8. For example, if the particle composition of TP associated with a particle class is 5,000 mg/kg, then the model assumes that 5,000 mg of TP is transported for every kilogram of that particle class transported. Because the pollutant particle composition associated with sediment can vary greatly depending on sediment size, P8 allows a unique pollutant particle composition (mg/kg) to be applied to each particle class. For the P8 model of this study area, the default water quality component parameters from the NURP50 particle file were assumed.

2.2.3 Agricultural Land

Because P8 is designed to simulate urban areas, and there are large portions of the study area which are agricultural, adjustments were made to the parameters used in the runoff and loading calculations for the agricultural subwatersheds to match literature values. It is noted that TSS, TP, and TKN pollutant loads in runoff from agricultural areas can vary greatly by region, crop type, soil, and farming practices. Because P8 is an urban model, it cannot account for these variables, however, for the goals and objectives of this study, it is reasonable to assume literature values for pollutant yields. P8 allows for the adjustment of the load accumulated in subwatersheds during rain events with a parameter called the Pervious Load Factor. The default value for the Pervious Load Factor is one. Adjusting this parameter effects all the pollutants, so it is important to consider all pollutants of concern. Modifying the Pervious Load Factor to a value of five for agricultural subwatersheds resulted in pollutant yields within an acceptable tolerance for TSS, TP, and TKN (see **Section 3.1**). The resulting TSS, TP, and TKN overall concentrations of the simulated runoff was also checked against monitoring data (see **Section 3.2**). HC is not generally associated with agricultural runoff, and therefore HC was not evaluated in the agricultural areas.

2.3 Water Quality Treatment Devices

In P8, surface runoff generated from watersheds, along with associated sediment and pollutants, is routed to water quality treatment devices (devices). P8 devices, such as ponds, infiltration basins, and pipes, determine how and where flow is hydraulically routed throughout the model. Additionally, sediment and pollutant removal via particle settling, decay, and filtration is calculated at those devices that provide treatment (i.e., ponds and infiltration basins; but not pipes).

Water quality treatment devices were identified by data provided by the city and through aerial photography. All defined storage and infiltration areas throughout the study area where water quality treatment is possible were included in the P8 model. A total of 119 devices were used in both models (east and west) in the existing conditions, 21 of which were used to simulate the water quality treatment within the study area (e.g. ponds, infiltration basins, or general devices). The use of two models allows for 150 devices (75+75) so the remaining available 31 P8 devices are preserved for future planning efforts and evaluation of BMPs.

A combination of LiDAR elevation as well as as-built or construction records were used to generate required inputs for treatment devices (bottom area, permanent pool area and volume, flood pool area and volume, and outlet dimensions). Where elevation data or construction records were not available, assumptions were made which are presented in the following subsections along with how each device type was identified and modeled.

2.3.1 Ponds

A total of 12 ponds were modeled throughout the study area. An additional 6 sediment separators were modeled as ponds (see **Section 2.3.5**). Ponds are storage areas with a defined normal outlet and overflow. The volume of water stored below the normal outlet of a pond is called the permanent pool (i.e. dead storage), and the volume retained above the normal outlet and up to the overflow elevation is the flood pool (i.e. live storage). Various pond outlet options can be utilized in P8 to simulate the discharge from the normal outlet. The assumptions made for ponds when no information is available are a dead storage depth of four feet and a live storage depth of two feet and a 12-inch orifice outlet.

2.3.2 Infiltration Basins

Two BMP's were assumed to be constructed infiltrating BMPs, as they had no known constructed outlet or drain: the Altra Care and Lincoln High School BMPs. Storage volume, bottom elevation, and bottom area for these areas were assigned based on basin geometry from LiDAR or construction documents. An infiltration rate was assigned based on Hydrologic Soil Groups (HGS) from the SSURGO soils database and soils maps provided by the city. Overflow conveyance was simulated for the Lincoln High School BMP based on plan elevations, and based on LiDAR for the Altra Care BMP.

2.3.3 General Devices

General devices are the most versatile of the P8 device options, allowing the user to input area, infiltration, normal flow, and overflow at user-defined elevations. Due to this flexibility, general devices are ideal for modeling complex outlets. One General Device was used in the study area models to simulate the orifice and weir in the outlet of the pond at Greenwood St and Nelson Dr.

2.3.4 Pipes

Pipes are the most basic of the P8 device options, only providing routing and time of concentration (TC) inputs. In the case of the study area P8 model, pipes are used to act as placeholders for both future BMPs and timing throughout the watershed. Because P8 lists results by device, the use of pipes throughout the watershed also enhances the spatial resolution of the model results. Pipes were placed at strategic locations based on:

- Location of potential future BMPs based on nearby open space and public lands (schools, parks, etc.);
- Ability to capture runoff from within the city limits or tributary areas to the city limits.
- Drainage areas with similar land-use to preserve resolution; and
- Ability to attribute a TC.

P8 recommends that TC be used for large watersheds. Sensitivity analysis shows that TC does not affect the results in smaller watersheds. Therefore, TC were calculated in subwatersheds greater than 100 acres and were applied to their runoff pipe device. TCs for subwatersheds that received inflow from upstream areas were calculated along the flow path of the incoming runoff.

2.3.5 Sediment Separators

The City also provided information on sediment separators (also known as hydrodynamic devices). Because of the dynamic fluid hydraulics in these devices, P8 does not accurately simulate them. Therefore, Sizing Hydrodynamic Separators and Manholes (SHSAM) software program was used to estimate removal percentages of the six sediment separators. SHSAM predicts the amount of suspended sediments removed from stormwater runoff via a simple hydrologic model and a generic sediment removal response function. The program has been verified by laboratory testing in Saint Anthony Falls Laboratory (SAFL) at the University of Minnesota for an array of hydrodynamic separator and sump sizes.

The sediment separators were input as ponds into the existing P8 models, sized as small as possible to preserve continuity. The pond devices were calibrated to match percent TSS load reductions given by SHSAM for each of the six sediment separators. Appendix B provides further information the methods used to evaluate the sediment separators.

2.4 P8 Model Parameters and Continuity

The P8 model requires a variety of input parameters in addition to watershed, pollutant loading, and device data. These parameters define the length of simulation and job control conditions such as the calculation time step. The parameters selected for the P8 model are discussed in this section. P8 parameters not discussed in this section were left at the default settings as defined in P8 version 3.5.

- **Time steps per hour** – This parameter defines the number of calculations performed per model hour. Both models were set to run at 20 time steps per hour (3 minute time steps). This selection was based on three factors:
    1. In order to reduce model run time, it is desirable that the time steps per hour be minimized.
    2. The number of time steps required to eliminate hydraulic continuity errors (mass balance errors) greater than 2 percent. To achieve this objective, the time steps per hour was increased.
    3. In P8, the TC value in any device must be consistent with the model time step (i.e. the TC value must be in an increment that matches the model time step). Consequently, in order to increase the accuracy of the TC input, the model run time will increase. Therefore, since a value of 20 time steps per hour was found as a minimum for continuity reasons, the TC value must be in 0.05 hour increments (one hour divided by 20 time steps). This was a reasonable compromise between model run time and accuracy of the TC.
- **Warm up period** – A warm up period in the storm file was required because the model assumes that water in the dead storage of ponds contains no pollutants. Consequently, the first pass through the storm file results in lower pollutant loading than occurs after the warm up period. The warm up period used in the model was 4 years.

3.0 EXISTING MODEL RESULTS

The existing P8 models for the study area were run for a long term simulation of 60 years of historical precipitation and air temperature data. Running the model for a long term simulation and averaging the results over that period allows for the calcuation of annual average loads and removals of pollutants.

3.1 Assessment of Model Reasonability

As a check for reasonability, **Table 2** through **Table 5** compare annual average TSS, TP, TKN and HC yields or overall concentrations resulting from the P8 model to values reported in literature for urban high density, medium density, forest / low density, and agricultural (cropland) land use.

The majority of the P8 model results fall within, or are within, an expected tolerance of the reported literature values for each land use category. The Forest / Low Density P8 results are generally higher than the literature values. This is contributed to the fact that low density subwatersheds within the study areas likely consist of less forested areas than assumed in the literature values.

Further, the comparisons shown in the tables validate that the calibration of cropland subwatersheds (as discussed in **Section 2.2.3**) is reasonable not only for TP but also for TSS and TKN. It is known that TSS, TP and TKN can vary greatly even within cropland land use, but these results indicate that the model provides loads that are consistent with average values in this region of Minnesota. Conversely, the resultant HC load from cropland is assumed to be inflated, as explained in **Section 2.2.3**.

Table 2: Comparison of P8 Model Results for Total Suspended Solids to Literature Values

	Land Use			
	High Density	Medium Density	Forest / Low Density	Cropland
Source	**Average Annual TSS Yield (lbs/ac/yr)**			
Thief RF P8 Model	**331**	**159**	**54**	**69**
Pitt/NSQD, 2011 (Residential)	--	--	--	--
Burton, 2002 (Residential)	670	250	10	--
Horner, 1994 (Residential)	420	190	--	--
Reinelt, 1996	312	--	45	--
WPLMN Red Lake River [2]	--	--	--	79
WPLMN Thief River [2]	--	--	--	25

Table 3: Comparison of P8 Model Results for Total Phosphorus to Literature Values

	Land Use			
	High Density	Medium Density	Forest / Low Density	Cropland
Source	**Average TP Yield (lbs/ac/yr)**			
Thief RF P8 Model	**1.01**	**0.50**	**0.18**	**0.31**
Pitt/NSQD, 2011 (Residential)	--	--	--	--
Horner, 1994 (Residential)	1	0.5	--	--
LimnoTech, 2007 (Urban)	1.34	1.03/0.81*	0.07	0.34
Burton, 2002 (Residential)	1	0.3	0.04	--
Burton, 2002 (Forest)	--	--	0.07	--
WPLMN Red Lake River [2]	--	--	--	0.13
WPLMN Thief River [2]	--	--	--	0.09

* Medium urban density / low urban density

Table 4: Comparison of P8 Model Results for Total Kjeldahl Nitrogen to Literature Values

	Land Use			
	High Density	Medium Density	Forest / Low Density	Cropland
Source	**Average TKN Yield (lbs/ac/yr)**			
Thief RF P8 Model	**4.5**	**2.2**	**0.8**	**1.6**
Horner, 1994	4.2	2.5	0.3	--
WPLMN Red Lake River [2]	--	--	--	0.9
WPLMN Thief River [2]	--	--	--	1.3

[2] MPCA Watershed Pollutant Load Monitoring Network (WPLMN) average values measured at river monitoring locations from 2007-2014 assumed to represent cropland in this region of the state.

Table 5: Comparison of P8 Model Results for Hydrocarbons to Literature Values

	Land Use				
	High Density	Medium Density	Forest / Low Density	Cropland	Overall Concentration (mg/l)
Source	**Average Annual HC Yield (lbs/ac/yr)**				
Thief RF P8 Model	**8.1**	**3.9**	**1.4**	**1.9**	**3.2**
Shepp, 1996	--	--	--	--	0.7-6.6
Horner, 1994	--	--	--	--	< 5.0
Rabanal & Grizzard, 1995 (PAH, EMC)	--	--	--	--	3.5
Crunkilton, 1996 (Oil & Grease)	--	--	--	--	3.0

3.2 Comparison to Monitoring Data

There are three[3] MPCA monitoring locations in Thief River Falls, with limited data collected from 2008 to 2015. Due to the absence of flow data at the monitoring locations, the P8 models could not be calibrated to discrete pollutant loads. **Table 6** reports the averages of monitoring sample concentration of TP and TKN at Chiefs Coulee and CD70 compared to the annual average Event Mean Concentration (EMC) from the existing conditions P8 model. Due to the limited number of samples, the averages shown are for all the sample locations along the waterway. The P8 results fall within the mean and median for each pollutant and location except for TKN at CD70, where the P8 estimates higher TKN EMC. The vast majority of CD70 drains agricultural land, which was calibrated to literature values. As discussed in **Section 2.2.3**, the pervious load factor is coupled to each pollutant, and cannot be adjusted individually. Therefore, no changes were made to the model inputs, and the P8 results are considered reasonable for the purposes of this study.

Table 6: Concentrations (in mg/l) of TP and TKN monitoring data compared to existing conditions P8 model

	Local Monitoring Data			P8 Results
	No. of Samples	Mean	Median	Annual Average EMC
TP at Chiefs Coulee	18	0.7	0.5	0.5
TKN at Chiefs Coulee	18	2.7	1.8	2.4
TP at CD70	58	1.0	0.7	0.8
TKN at CD70	58	2.4	1.4	3.7

[3] Only two monitoring locations were assessed. The third location was at Hartz Park, but the monitoring location did not match the outfall location in the stormsewer data received. Due to this uncertainty, the small number of samples at that location, and the lack of TKN data reported, the location was not assessed.

3.3 Existing Model Loads and Removals

Average annual pollutant yields from the subwatersheds in the study area are reported in **Table 7**. Also reported in the table are the *delivered loads*. Delivered loads reflect the load from the subwatershed after considering pollutant removal at all downstream BMPs throughout the watershed. The intent is to present the loading that actually makes it into the receiving waterbody from that subwatershed. The subwatershed loads were divided by the subwatershed area to calculate the yields. Because delivered yield mapping indicates where yield is highest after considering the impact of existing water quality features, such mapping can be used to prioritize subwatersheds for future BMP implementation.

Table 8 summarized the annual averaged loads and removals from treatment devices within the existing model.

Table 7: Existing subwatershed annual average watershed generated load and delivered load to downstream resource

Subwatershed	Area (acres)	TSS Watershed Load (lbs/yr)	TSS Delivered Load (lbs/yr)	TP Watershed Load (lbs/yr)	TP Delivered Load (lbs/yr)	TKN Watershed Load (lbs/yr)	TKN Delivered Load (lbs/yr)	HC Watershed Load[4] (lbs/yr)	HC Delivered Load[4] (lbs/yr)
East-A01	20.4	1,045	1,045	3.6	3.6	16.6	16.6	26.5	26.5
East-A02	14.6	1,562	1,562	5.1	5.1	23.0	23.0	38.9	38.9
East-A03	25.7	4,835	4,835	15.4	15.4	68.9	68.9	119.3	119.3
East-A04	60.2	5,140	5,140	16.6	16.6	75.2	75.2	127.7	127.7
East-A05	24.9	2,481	2,481	8.0	8.0	35.9	35.9	61.5	61.5
East-A06	316.4	21,578	21,578	100.1	100.1	499.0	499.0	N/A	N/A
East-B01_SS	54.4	3,969	3,520	13.3	12.8	60.5	58.9	99.6	89.5
East-C01	8.2	681	681	2.2	2.2	10.2	10.2	17.0	17.0
East-C02	14.1	228	228	1.0	1.0	5.0	5.0	N/A	N/A
East-D01	22.6	1,091	1,091	5.4	5.4	27.1	27.1	N/A	N/A
East-E01	81.7	4,781	4,781	20.0	20.0	97.4	97.4	N/A	N/A
East-E02_GN	33.0	244	115	1.3	1.1	6.4	5.8	N/A	N/A
East-F01_SS	16.8	765	693	2.5	2.5	11.6	11.4	19.2	17.8
East-F02_WM	11.2	2,115	151	6.6	2.3	29.1	12.4	51.8	7.4
East-G01_SS	26.3	3,938	3,704	12.3	12.2	54.8	54.3	96.7	91.6
East-G02_WM	12.0	2,802	476	8.6	3.9	38.2	19.9	68.5	15.9
East-H01	80.8	9,586	9,586	30.5	30.5	137.0	137.0	236.8	236.8
East-H02	79.2	19,622	19,622	60.4	60.4	267.7	267.7	479.5	479.5
East-H03	119.4	6,293	6,293	20.8	20.8	94.3	94.3	157.3	157.3
East-H04	1285.8	74,932	74,932	358.0	358.0	1795.0	1795.0	N/A	N/A
East-H05	912.4	47,711	47,711	232.6	232.6	1171.1	1171.1	N/A	N/A
East-H06	86.4	801	801	4.0	4.0	20.0	20.0	23.4	23.4
East-H07_TCC	24.1	1,436	117	4.8	1.9	21.9	10.7	36.1	6.4
East-I01	9.4	785	785	2.5	2.5	11.4	11.4	19.5	19.5
East-J01	30.0	2,896	2,896	9.4	9.4	42.5	42.5	72.0	72.0
East-K01	19.3	2,076	2,076	6.7	6.7	30.0	30.0	51.4	51.4
East-K02	21.8	2,361	2,361	7.6	7.6	34.0	34.0	58.4	58.4
East-L01	8.7	3,106	3,106	9.5	9.5	42.2	42.2	75.8	75.8
East-M01	5.4	1,799	1,799	5.5	5.5	24.4	24.4	43.9	43.9
East-N01	14.4	2,134	2,134	6.7	6.7	30.0	30.0	52.5	52.5
East-O01_Wet	8.3	226	16	0.8	0.3	3.7	1.9	5.8	1.1
East-P01	1.4	80	80	0.3	0.3	1.2	1.2	2.0	2.0
East-Q01_Wet	27.0	1,008	384	3.6	2.6	16.6	12.6	25.8	11.4
East-Q02	39.3	3,408	1,297	11.0	7.9	49.6	37.7	84.6	37.3
East-Q03	81.7	4,073	1,550	13.6	9.8	62.2	47.3	102.3	45.1
East-Q04	47.2	5,357	2,039	17.4	12.5	78.6	59.8	133.2	58.8
East-Q05	31.6	3,055	1,163	9.8	7.1	44.0	33.4	75.6	33.3
East-Q06	23.3	1,519	578	4.9	3.6	22.4	17.0	37.8	16.7
East-Q07	14.1	227	87	0.9	0.6	4.1	3.1	6.0	2.6
East-Q08	6.2	826	314	2.6	1.9	11.7	8.9	20.4	9.0
East-Q09	6.4	323	123	1.1	0.8	4.9	3.7	8.1	3.6
East-R01_Green	12.9	468	89	1.6	0.8	7.3	4.3	11.8	3.3
East-S01	75.0	4,404	4,404	14.1	14.1	63.5	63.5	109.0	109.0
East-T01	22.6	837	837	2.9	2.9	13.2	13.2	21.2	21.2
East-X01	105.3	3,743	3,743	13.2	13.2	61.1	61.1	95.6	95.6
East-X02	259.4	18,996	18,996	87.1	87.1	432.7	432.7	N/A	N/A
East-X03	39.5	1,148	1,148	4.2	4.2	19.4	19.4	29.6	29.6
East-X04	19.4	921	921	3.1	3.1	13.9	13.9	23.1	23.1
East-X05_hwy8	37.6	761	133	3.0	1.7	14.4	9.4	20.3	6.1
East-Y01	3.4	347	347	1.1	1.1	5.1	5.1	8.7	8.7
East-Y02	4.3	372	372	1.2	1.2	5.4	5.4	9.2	9.2
East-Y03	2.4	121	121	0.4	0.4	1.8	1.8	3.0	3.0
East-Y04	2.2	185	185	0.6	0.6	2.7	2.7	4.6	4.6
East-Y05	4.0	232	232	0.8	0.8	3.5	3.5	5.8	5.8
East-Y06	2.9	55	55	0.2	0.2	1.1	1.1	1.5	1.5
East-Z01	18.4	406	406	1.7	1.7	8.3	8.3	11.1	11.1
East-Z02_Wet	10.6	1,317	58	4.2	1.4	19.0	8.0	32.6	4.3
East-Z03	63.5	2,419	2,419	9.0	9.0	42.3	42.3	63.0	63.0
East-Z04	44.8	1,722	1,722	6.0	6.0	27.5	27.5	43.8	43.8
East-Z05	5.5	466	466	1.5	1.5	6.8	6.8	11.5	11.5
East-Z06	19.0	1,524	1,524	5.0	5.0	23.0	23.0	38.2	38.2
East-Z07	73.2	1,295	1,295	5.6	5.6	27.5	27.5	35.7	35.7
West-A01_SS	1.4	51	34	0.2	0.2	0.8	0.8	1.3	0.9
West-B01_SS	36.8	4,203	3,867	13.6	13.3	61.4	60.0	104.4	96.8
West-C01	10.7	1,241	1,241	3.9	3.9	17.7	17.7	30.6	30.6
West-C02	12.9	3,562	3,562	11.0	11.0	49.0	49.0	87.2	87.2
West-C03	18.9	5,462	5,462	16.8	16.8	74.6	74.6	133.5	133.5
West-C04	35.4	5,000	5,000	15.8	15.8	70.5	70.5	123.1	123.1
West-C05	76.4	6,574	6,574	22.1	22.1	100.9	100.9	165.3	165.3
West-C06	221.7	14,427	14,427	67.5	67.5	336.8	336.8	N/A	N/A
West-C07	55.1	8,029	8,029	25.4	25.4	114.0	114.0	198.0	198.0

[4] Hydrocarbon loads were not evaluated in agricultural areas. A value of N/A will be shown for those subwatersheds deemed agricultural.

Subwatershed	Area (acres)	TSS Watershed Load (lbs/yr)	TSS Delivered Load (lbs/yr)	TP Watershed Load (lbs/yr)	TP Delivered Load (lbs/yr)	TKN Watershed Load (lbs/yr)	TKN Delivered Load (lbs/yr)	HC Watershed Load[4] (lbs/yr)	HC Delivered Load[4] (lbs/yr)
West-C08	29.3	3,087	3,087	9.9	9.9	44.4	44.4	76.4	76.4
West-C09	20.3	2,358	2,358	7.5	7.5	33.7	33.7	58.2	58.2
West-C10	4.0	520	520	1.7	1.7	7.6	7.6	12.9	12.9
West-D01	7.3	2,189	2,189	6.7	6.7	29.9	29.9	53.5	53.5
West-E01	5.0	1,475	1,475	4.5	4.5	20.1	20.1	36.0	36.0
West-F01	22.9	7,051	7,051	21.7	21.7	96.3	96.3	172.3	172.3
West-G01	32.0	12,259	12,259	37.5	37.5	166.0	166.0	299.0	299.0
West-H01	7.7	3,089	3,089	9.4	9.4	41.8	41.8	75.3	75.3
West-I01	2.9	981	981	3.0	3.0	13.3	13.3	23.9	23.9
West-J01	19.7	3,280	3,280	10.4	10.4	46.9	46.9	81.0	81.0
West-J02_LHS	4.1	1,609	2	4.9	0.0	21.9	0.1	39.3	0.1
West-K01	7.2	696	696	2.3	2.3	10.3	10.3	17.3	17.3
West-L01	7.2	1,522	1,522	4.7	4.7	21.1	21.1	37.3	37.3
West-L02	14.1	1,816	1,816	5.9	5.9	26.4	26.4	45.0	45.0
West-L03	22.4	2,760	2,760	8.8	8.8	39.7	39.7	68.3	68.3
West-L04	57.4	9,250	9,250	29.3	29.3	131.1	131.1	228.0	228.0
West-L05	22.7	5,739	5,739	17.8	17.8	78.9	78.9	140.5	140.5
West-L06	96.5	9,409	9,409	30.5	30.5	138.1	138.1	234.0	234.0
West-M01	5.5	442	442	1.5	1.5	6.7	6.7	11.1	11.1
West-M02_SS	16.6	1,898	1,898	6.1	6.1	27.2	27.2	46.9	46.9
West-M03	35.6	1,900	1,900	6.6	6.6	30.4	30.4	48.3	48.3
West-M04	116.4	31,718	31,718	97.7	97.7	433.8	433.8	775.5	775.5
West-M05	227.8	34,903	34,903	110.0	110.0	492.2	492.2	859.5	859.5
West-M06	2897.0	196,231	196,231	906.6	906.6	4513.4	4513.4	N/A	N/A
West-M07	740.8	56,610	56,610	250.9	250.9	1237.7	1237.7	N/A	N/A
West-M08	8.5	400	400	1.4	1.4	6.4	6.4	10.2	10.2
West-M09	15.1	466	466	1.7	1.7	7.8	7.8	12.0	12.0
West-M10_REA	4.8	1,379	106	4.2	1.3	18.9	6.9	33.7	4.6
West-M11_Ruby	4.4	1,074	70	3.4	1.2	15.2	6.6	26.5	3.9
West-M12	52.9	4,213	4,213	18.6	18.6	91.8	91.8	N/A	N/A
West-M13	41.4	3,960	3,960	12.8	12.8	58.0	58.0	98.4	98.4
West-M14	55.5	4,353	4,353	19.6	19.6	96.9	96.9	N/A	N/A
West-M15	339.7	40,134	40,134	168.5	168.5	820.8	820.8	N/A	N/A
West-M16	28.0	2,493	2,493	8.1	8.1	36.4	36.4	61.9	61.9
West-M17	12.6	2,523	2,523	7.9	7.9	35.0	35.0	61.9	61.9
West-N01	45.7	3,649	3,649	11.8	11.8	53.3	53.3	90.6	90.6
West-O01_Oxbow	116.7	5,364	136	18.2	6.3	83.4	37.0	135.3	17.7
West-O02_Altra	1.8	114	0	0.4	0.0	1.6	0.0	2.8	0.0
West-P01_H	18.9	4,626	262	14.3	4.6	63.5	25.7	113.2	15.0
West-X01	258.5	23,492	23,492	98.6	98.6	479.9	479.9	N/A	N/A
West-X02	58.2	4,576	4,576	20.7	20.7	102.6	102.6	N/A	N/A
West-X03	23.9	600	600	2.3	2.3	11.1	11.1	15.9	15.9
West-X04	312.6	25,133	25,133	108.8	108.8	533.8	533.8	N/A	N/A
West-Z01	30.4	1,952	1,952	6.4	6.4	29.3	29.3	48.8	48.8
West-Z02	13.5	3,416	3,416	10.5	10.5	46.8	46.8	83.5	83.5
West-Z03	59.8	2,224	2,224	8.3	8.3	39.0	39.0	57.9	57.9

Table 8: Existing treatment devices annual average loading and removals

P8 Device Name	Drainage Area (ac)	TSS Load to BMP (lbs)	TSS % Removal	TSS Removal (lbs)	TP Load to BMP (lbs)	TP % Removal	TP Removal (lbs)	TKN Load to BMP (lbs)	TKN % Removal	TKN Removal (lbs)	HC Load to BMP (lbs)	HC % Removal	HC Removal (lbs)
East-B01_SS	54.4	3,967	11%	448	13.3	3%	0.4	60.5	3%	1.6	99.6	10%	10.1
East-F01_SS	28.0	929	9%	88	4.8	1%	0.1	24.1	1%	0.2	27.1	7%	2.0
East-F02_WM	11.2	2,115	92%	1,948	6.6	65%	4.3	29.1	57%	16.6	51.8	85%	43.8
East-G01_SS	38.3	4,444	6%	264	16.3	1%	0.2	74.9	1%	0.7	113.4	5%	5.9
East-G02_WM	12.0	2,802	82%	2,297	8.6	54%	4.6	38.2	47%	18.1	68.5	75%	51.7
East-H07_TCC	24.1	1,435	92%	1,318	4.8	60%	2.9	21.9	51%	11.2	36.1	82%	29.7
East-O01_Wet	8.3	226	93%	211	0.8	58%	0.5	3.7	48%	1.8	5.8	82%	4.7
East-Q01_Wet	276.7	19,771	62%	12,248	64.8	28%	18.0	294.0	24%	70.4	493.7	56%	275.9
East-R01_Green	12.9	470	81%	381	1.6	48%	0.8	7.3	41%	3.0	11.8	72%	8.5
East-X05_hwy8	37.6	768	83%	635	3.0	43%	1.3	14.4	35%	5.0	20.3	70%	14.1
East-Z02_Wet	10.6	1,316	96%	1,258	4.2	67%	2.8	19.0	58%	11.0	32.6	87%	28.3
East-E02_GN	33.0	242	53%	127	1.3	13%	0.2	6.4	10%	0.6	7.3	40%	2.9
West-A01_SS	1.4	51	33%	16	0.2	13%	0.0	0.8	11%	0.1	1.3	28%	0.4
West-B01_SS	36.8	4,200	8%	336	13.6	3%	0.3	61.4	2%	1.3	104.4	7%	7.6
West-J02_LHS	4.1	1,608	100%	1,606	4.9	100%	4.9	21.9	100%	21.8	39.3	100%	39.2
West-M10_REA	4.8	1,380	92%	1,274	4.3	70%	3.0	18.9	63%	11.9	33.7	86%	29.1
West-M11_Ruby	4.4	1,074	93%	1,004	3.4	65%	2.2	15.2	57%	8.6	26.5	85%	22.6
West-O01_Oxbow	118.4	5,357	97%	5,221	18.2	65%	11.9	83.4	56%	46.3	135.3	87%	117.6
West-O02_Altra	1.8	114	100%	114	0.4	100%	0.4	1.6	100%	1.6	2.8	100%	2.8
West-P01_H	18.9	4,625	94%	4,363	14.3	68%	9.7	63.5	60%	37.8	113.2	87%	98.2
Totals:				**35,156**			**68.4**			**269.8**			**795.2**

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Appendix B SEDIMENT SEPARATORS

Sediment Separator Analysis in Thief River Falls

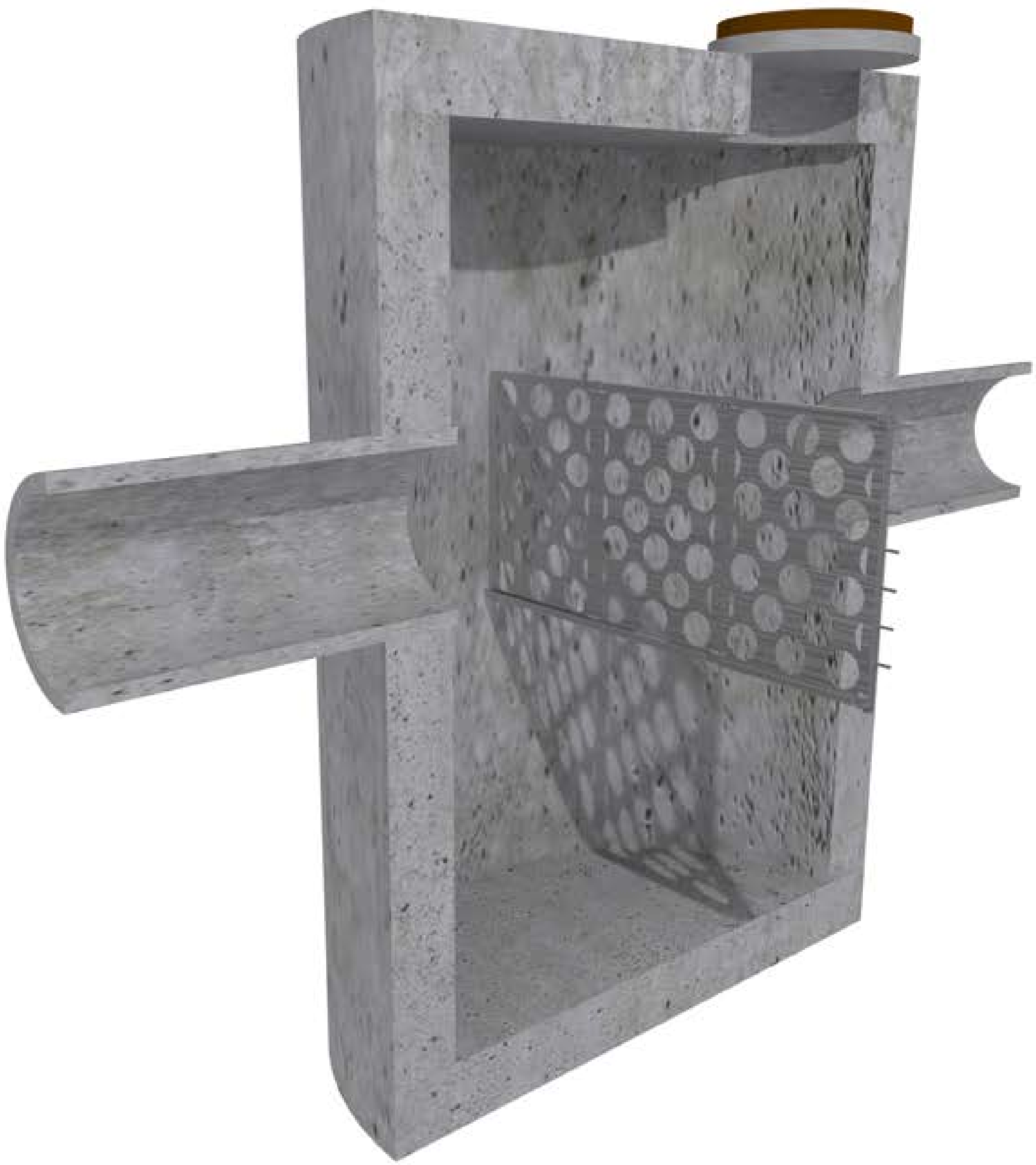
The City provided information on six sediment separators (also known as hydrodynamic devices). Because of the dynamic fluid hydraulics in these devices, P8 does not accurately simulate them. Therefore, the Sizing Hydrodynamic Separators and Manholes (SHSAM) software program was used to estimate removal percentages of the six sediment separators. The existing P8 model was subsequently calibrated to match percent load reductions given by SHSAM. SHSAM predicts the amount of suspended sediments removed from stormwater runoff via a simple hydrologic model and a generic sediment removal response function. The program has been verified by laboratory testing in Saint Anthony Falls Laboratory (SAFL) at the University of Minnesota for an array of hydrodynamic separator and sump sizes.

The results from the sediment separators show that many are overtaxed due to large contributing drainage areas. Larger drainage areas produce higher flows which will reduce the removal efficiency of a sediment separator. The sediment separator on Elizabeth Ave (West-A01_SS) treats 1.4 acres of runoff and removes an estimated 32% of the TSS load it receives. On the other hand, all of the remaining sediment separators have drainage areas greater than 28 acres, and removed 0% - 11% of the TSS load.

The results indicate that sediment separators are more effective with smaller drainage areas, as expected. This is confirmed by data provided by one manufacture's design guide (SAFL Baffle), which is included in part in the excerpt from SAFL Baffle Design Guide (included below), and can be used to more efficiently place sediment separators in future planning efforts.

Upstream Technologies
RevolutionaryBaffle.com | 651.633.6921
550 County Road D West, Suite 3
New Brighton, MN 55112

SAFL BAFFLE DESIGN GUIDE



SAFL Baffle DESIGN GUIDE

This guide can be used to design a SAFL Baffle and a sump structure for stormwater sediment removal. It will introduce you to some essential terminology, applications where the SAFL Baffle is useful, and design process. If this guide is not clear, please give our engineering team a call at 651.633.6921.

Contents

Essential Terminology:

SAFL Baffle:

- a perforated, stainless steel baffle
- bolts vertically into a sump structure for improved sediment capture

Sump structures:

- circular or rectangular structures
- one or more inlet pipes
- one outlet pipe
- depth below the outlet pipe (sump)

Applications:

The SAFL Baffle is a great choice for stormwater sediment removal in several situations:

- **Retrofits**: You are looking to improve the performance of your existing storm sewer infrastructure and have an existing sump structure that meets the criteria laid out in this guide.
- **Pretreatment**: You want to reduce maintenance of downstream BMPs like detention ponds, infiltration systems, and underground vaults.
- **Primary Treatment**: There is no room for other BMPs, or your project is low on funds, but you want to do something about stormwater sediment.

Sediment Removal Charts

Use these six charts to estimate the removal of a SAFL Baffle and sump structure for conceptual designs. Final designs should not use these charts, but instead, utilize the SHSAM Instructions section of this design guide.

Here are the assumptions used to generate these charts with SHSAM:

Area (acres):	1, 3, 7, 15
Impervious (%):	90
Hydraulic Length (ft):	381, 660, 1008, 1476
Average Slope (%):	1.5
CN (pervious):	90
Weather Station Precipitation:	Local, 15 minute
Water Temperature:	Local, average daily
Washout Included?:	Yes
Bypass?:	No
Sediment Distribution:	Janna-Omid

Janna-Omid Particle Size Distribution:

Particle Size (microns)	Percent Finer	Specific Gravity
1000	100	2.65
500	95	2.65
250	90	2.65
170	65	2.65
100	35	2.65
50	15	2.65
8	2	2.65
2	1	2.65

SHSAM estimated SAFL Baffle sediment removal for sample Minneapolis, Denver and Ocala watersheds.

Minneapolis, MN			% Removal			
Sump Depth (ft)	Structure Diameter (ft)	Pipe Diameter (inches)	1 acre	3 acres	7 acres	15 acres
4	4	15	39.4	7.8	1.6	0.1
5	5	18	55.6	19	5.6	1
3	6	24	60.8	24.6	8.5	2
6	6	24	70.9	37.7	15.9	5.3
6	8	30	80.5	52.7	28.3	13

Denver, CO			% Removal			
Sump Depth (ft)	Structure Diameter (ft)	Pipe Diameter (inches)	1 acre	3 acres	7 acres	15 acres
4	4	15	44.9	11.9	3.8	0.3
5	5	18	60.9	24.1	10.1	2.6
3	6	24	66.3	30	13.8	4.6
6	6	24	75.1	43.7	22.3	10.2
6	8	30	82.6	58.9	35.4	20.6

Ocala, FL			% Removal			
Sump Depth (ft)	Structure Diameter (ft)	Pipe Diameter (inches)	1 acre	3 acres	7 acres	15 acres
4	4	15	31.7	3.9	0.6	0.1
5	5	18	46.7	14.1	1.9	0.4
3	6	24	52.5	19.1	4.1	0.7
6	6	24	63.2	30.4	10.6	1.8
6	8	30	74.5	44.2	21.8	7.7

Appendix C Near Channel Erosion Practice Implementation Profiles

Greenwood Street Bank Site on the Red Lake River

Justification

A channel restoration stabilization assessment was performed for a riverbank on the Red Lake River within the City limits of Thief River Falls adjacent to Greenwood Street. The purpose of this assessment was to estimate the costs and benefits (Sediment and total phosphorus [TP] reduction) that would result from stabilizing the site. It is important to note that stabilizing this site would also protect a force main immediately behind the eroding bank, making it a higher priority for stabilization. The results of the assessment are summarized in this communique.

Summary of Results

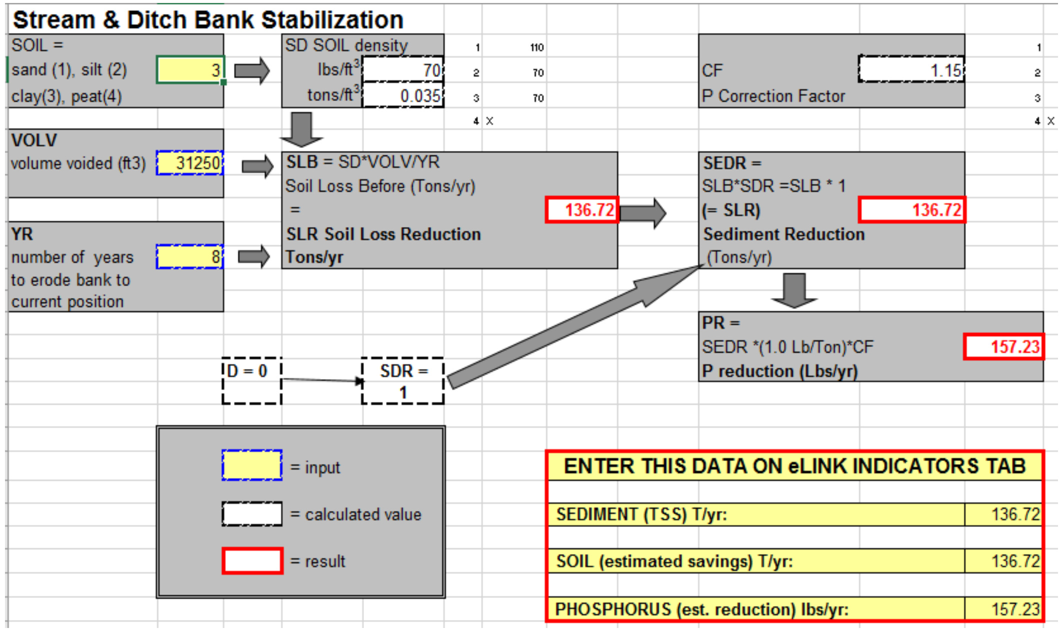
The sediment and TP reductions were estimated using the BWSR pollution Reduction Estimator. A conceptual cost was estimating using professional judgment. A full cost estimate would still be needed to implement the restoration project. This estimate is intended to be sufficient to move the project towards implementation.

Results

Results	
TSS Reduction (T/yr)	137
TP Reduction (lbs/yr)	157
Cost	$161,060

Cost-Effectiveness	
TSS ($/T/yr)	$1,176
TP ($/lbs/yr)	$1,026

Sediment and Total Phosphorus Estimate



Cost Estimate

Item	Item Description	Unit	Quantity	Unit Price	Cost
	Mobilization	Lump Sum	1	$10,000	$10,000
Extending Bridge Curtain					
	Clearing	ACRE	0.1	$ 20,000	$2,000
	Common Excavation/Grading	CU YD	150	$20	$3,000
	Riprap Class IV	CU YD	150	$100	$15,000
	Granulated Filter	CU YD	75	$25	$1,875
	Seeding	Pounds	25	$20	$500
Toe Protection/Live Staking Flood Bench					
	Clearing	ACRE	0.1	$ 20,000	$2,000
	Common Excavation/Grading	CU YD	150	$20	$3,000
	Riprap Class VI Toe Protection	CU YD	60	$ 100	$6,000
	Granulated Filter	CU YD	20	$25	$500
	Seeding	Pounds	20	$20	$400
	Live Stakes, Willow, 2:1 Riprap slope (Joint Planting)	Each	200	$12	$2,400
	Hydraulic Soil Stabilizer	Pounds	250	$2	$500
Bendway Weirs					
	Riprap Class V Bendway Weir	CU YD	300	$ 180	$54,000
				Sub Total Construction	$ 101,175
				20% Contingency	$ 20,235
				Total Construction Cost	$ 121,410
Optional					
Bank setback of 10'					
	Clearing	ACRE	0.1	$ 20,000	$2,000
	Haul and Dispose of excess soil offsite	CU YD	900	$ 20.00	$ 18,000
	Seeding	Pounds	20	$20	$400
	Hydraulic Soil Stabilizer	Pounds	250	$2	$500
				Additional Subtotal	$20,900
Engineering of Project					
	Engineering	Per Hour	125	$ 150.00	$18,750
				Additional Subtotal	$ 18,750

Assumptions	
Project consist of:	
	Extending bridge protection 70 feet of river bank downstream to edge of fence on top .
	Installing 3 Bendway Weirs (10' long, 10' high, and 20' bottom width with a side slope of 1:1)\
	Installing riprap toe protection with live stake plants for 90' of riverbank at 18' width
	Regrading, plant seed and live stakes along eroding bank above toe protection
Assume Class VI riprap for bank protection	
Assume Class V for weirs	
Assume 20% Contingency to account for rough estimates of materials	

Hartz Park Bank Site on the Red Lake River

Justification

A channel restoration stabilization assessment was performed for a riverbank on the Red Lake River within the City limits of Thief River Falls adjacent to Hartz Park. The purpose of this assessment was to estimate the costs and benefits (Sediment and total phosphorus [TP] reduction) that would result from stabilizing the site. It is important to note that stabilizing this site would also protect further loss of soil from the park, a pedestrian bridge, and reduce sediment in the Thief River. The results of the assessment are summarized in this communique.

Summary of Results

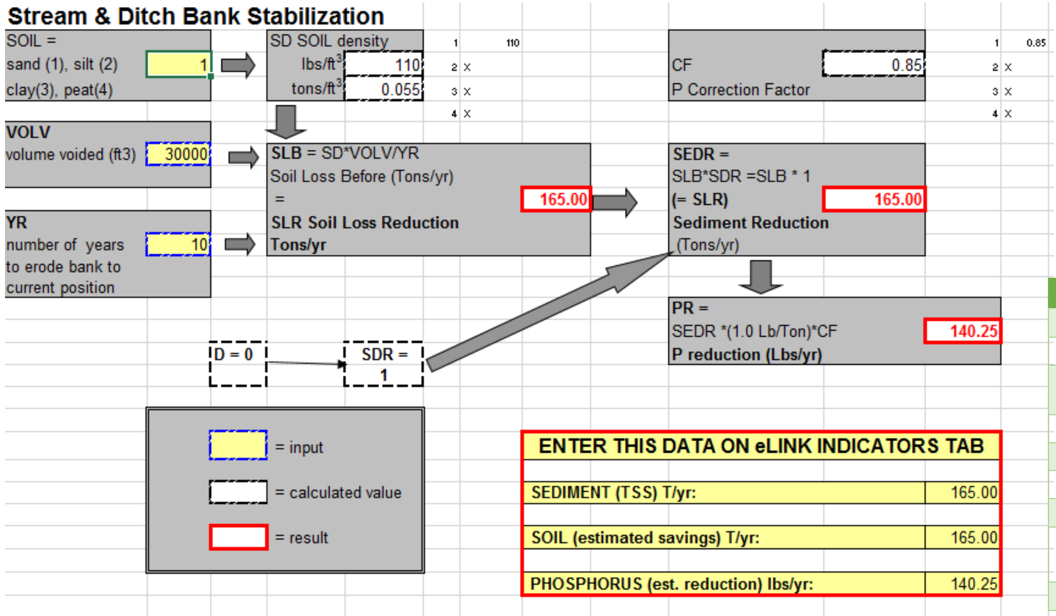
The sediment and TP reductions were estimated using the BWSR pollution Reduction Estimator. A conceptual cost was estimating using professional judgment. A full cost estimate would still be needed to implement the restoration project. This estimate is intended to be sufficient to move the project towards implementation.

Results

Results	
TSS Reduction (T/yr)	165.00
TP Reduction (lbs/yr)	140.25
Cost	$144,240

Cost-Effectiveness	
Tss ($/T/yr)	$874
TP ($/lbs/yr)	$1,028

Sediment and Total Phosphorus Estimate



Cost Estimate

Item	Item Description	Unit	Qnty	Unit Price	Cost
	Mobilization	Lump Sum	1	$20,000	$20,000
Toe Protection/Live Staking Flood Bench					
	Clearing	ACRE	0.1	$20,000	$2,000
	Common Excavation/Grading	CU YD	150	$20	$3,000
	Riprap Class VI Toe Protection	CU YD	75	$100	$7,500
	Granulated Filter	CU YD	40	$25	$1,000
	Seeding	Pounds	20	$20	$400
	Live Stakes, Willow, 2:1 Riprap slope (Joint Planting)	Each	400	$12	$4,800
	Hydraulic Soil Stabilizer	Pounds	250	$2	$500
Bendway Weirs					
	Riprap Class V Bendway Weir (3x 40' length)	CU YD	450	$180	$81,000
				Sub Total Construction	$120,200
				40% Contingency	$24,040
				Total Construction Cost	**$144,240**

Assumptions

Project consist of:

- Installing 3 Bendway Weirs (40' long, 10' high, and 20' bottom width with a side slope of 1:1)
- Installing riprap toe protection with live stake plants for 100' of riverbank at 20' width
- Regrading, plant seed and live stakes along eroding bank above toe protection

Assume Class VI riprap for bank protection

Assume Class V for weirs

Assume 40% Contingency to account for conceptual cost estimate

Wenzloff Bank Site on the Red Lake River

Justification

A channel restoration stabilization assessment was performed for a riverbank on the Red Lake within the City limits of Thief River Falls. The purpose of this assessment was to estimate the costs and benefits (Sediment and total phosphorus [TP] reduction) that would result from stabilizing the site. It is important to note that stabilizing this site would also protect a number of homes on top of the banks and reduce sediment in the Red Lake River. The results of the assessment are summarized in this communique.

Summary of Results

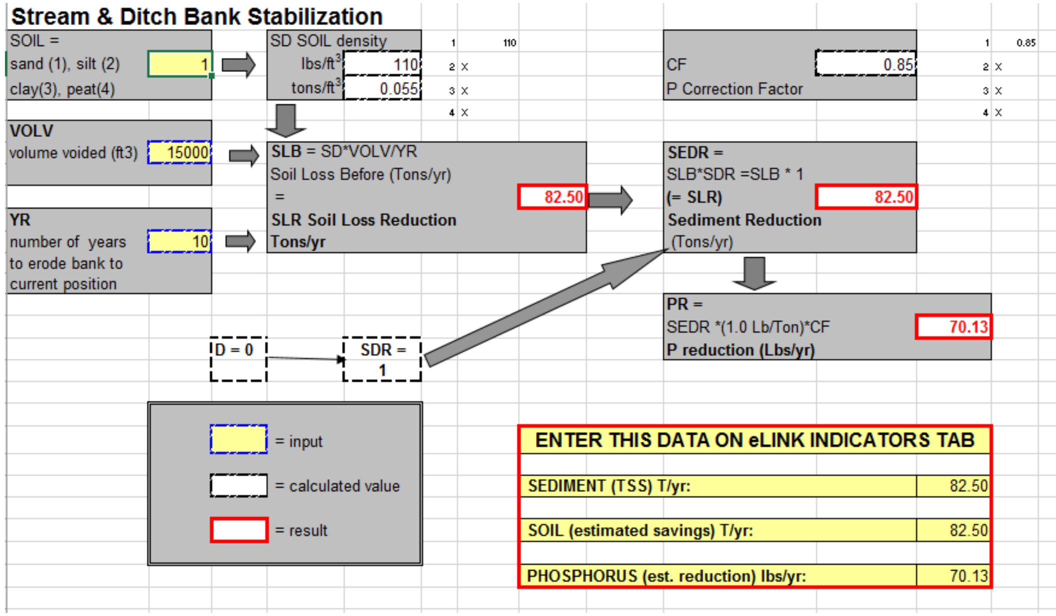
The sediment and TP reductions were estimated using the BWSR pollution Reduction Estimator. A conceptual cost was estimating using professional judgment. A full cost estimate would still be needed to implement the restoration project. This estimate is intended to be sufficient to move the project towards implementation.

Results

Results	
TSS Reduction (T/yr)	82.50
TP Reduction (lbs/yr)	70.13
Cost	$140,160

Cost-Effectiveness	
Tss ($/T/yr)	$1,699
TP ($/lbs/yr)	$1,999

Sediment and Total Phosphorus Estimate



Cost Estimate

Item	Item Description	Unit	Qnty.	Unit Price	Cost
	Mobilization	Lump Sum	1	$20,000	$20,000
Toe Protection/Live Staking Flood Bench					
	Clearing	ACRE	0.2	$20,000	$4,000
	Common Excavation/Grading	CU YD	100	$20	$2,000
	Riprap Class VI Toe Protection	CU YD	60	$100	$6,000
	Granulated Filter	CU YD	20	$25	$500
	Seeding	Pounds	20	$20	$400
	Live Stakes, Willow, 2:1 Riprap slope (Joint Planting)	Each	200	$12	$2,400
	Hydraulic Soil Stabilizer	Pounds	250	$2	$500
Bendway Weirs					
	Riprap Class V Bendway Weir (3x 40' length)	CU YD	450	$180	$81,000
		Sub Total Construction			$116,800
		40% Contingency			$23,360
		Total Construction Cost			**$140,160**

Assumptions	
Project consist of:	
	Installing 3 Bendway Weirs (40' long, 10' high, and 20' bottom width with a side slope of 1:1)
	Installing riprap toe protection with live stake plants for 100' of riverbank at 20' width
	Regrading, plant seed and live stakes along eroding bank above toe protection
Assume Class VI riprap for bank protection	
Assume Class V for weirs	
Assume 40% Contingency to account for conceptual cost estimate	