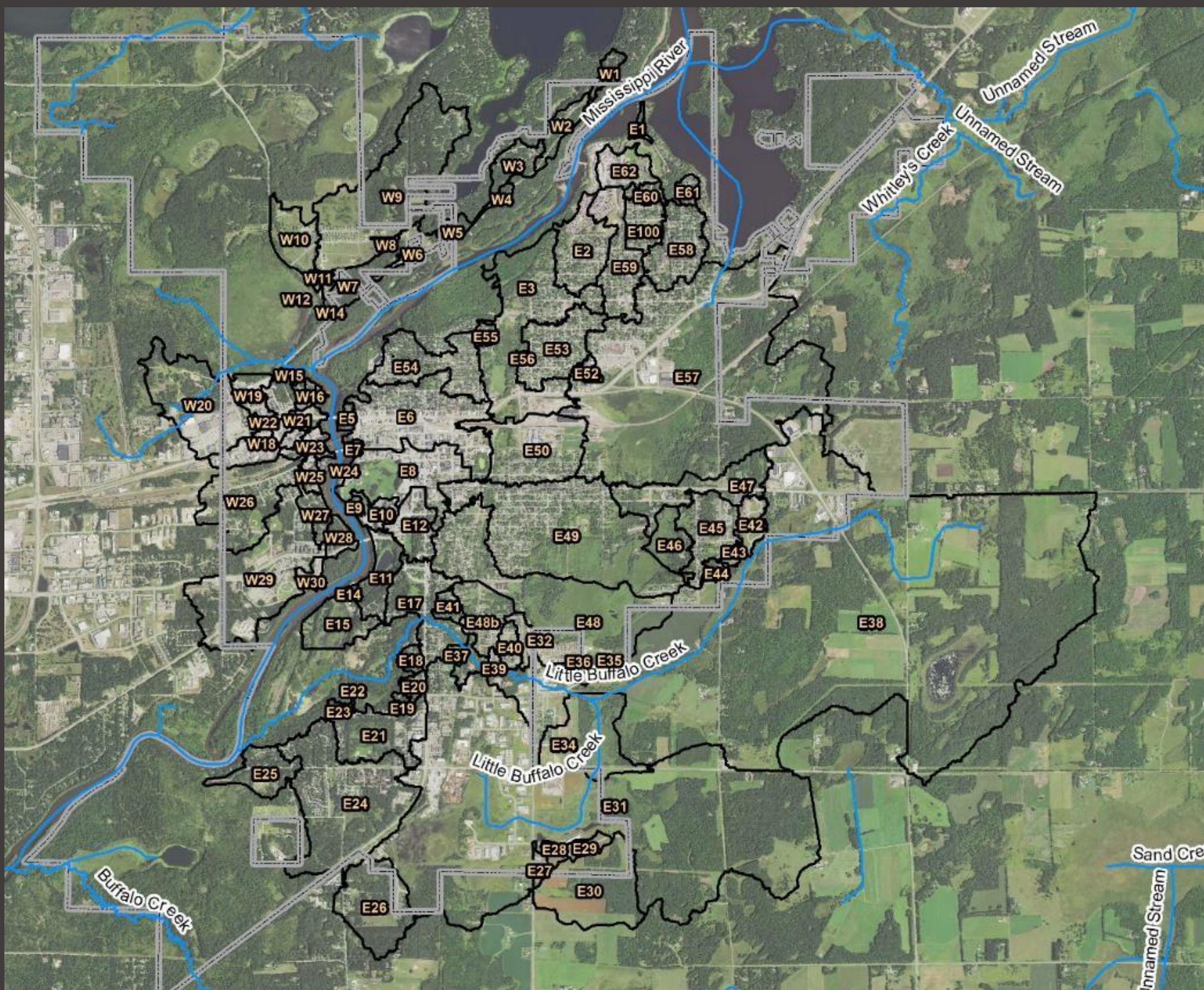
Brainerd, MN, Stormwater Retrofit Analysis
6/12/2020

City of Brainerd, MN, North Central Minnesota Joint Powers Board, & Mississippi Headwaters Board



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I. Introduction and Summary of Results

A. Document Organization

The document presents the development, results, and recommendations of the Brainerd Stormwater Retrofit Assessment (SRA) that focused on areas within the Brainerd city limits that convey stormwater. A previous study took place on the Buffalo Creek watershed; those results are presented elsewhere. The idea for the study originated with three interested parties, all of whom contributed funds for the SRA. These include the City of Brainerd, the North Central Minnesota Joint Powers Board, and the Mississippi Headwaters Board. An overall summary of the project and its results are presented in the Executive Summary, followed by desktop and field efforts to collect information and set up an initial P8 water quality model for major watersheds. Intensive modeling occurred on the top five priority subwatersheds identified, with recommended strategies presented.

B. Executive Summary

The Brainerd Stormwater Retrofit Assessment study (SRA) examined stormwater runoff across the city, dividing the surface area into 7 major watersheds and 76 subwatersheds (**Figure 1**). Areas north of downtown across the Mississippi River were not modeled because they are scarcely populated and relatively new developments that were subject to the City stormwater ordinance requirements. Initial coarse watershed modeling was then subjected to screening metrics, resulting in five top priority subwatersheds being identified for further intensive modeling that simulated varying best management practices (BMPs) to optimize implementation value. These subwatersheds are depicted in red in Figure 1, which includes the downtown area.

Within each priority subwatershed one or more BMPs were recommended for implementation by the City (**Table 1**). Results are presented as construction costs, maintenance costs, and $/pound of both total suspended sediments (TSS) and total phosphorus (TP). Note, however, that modeling caveats apply here. These recommendations were based on modeling assumptions (e.g. bioretention cells were assumed to cover 150-ft^2 of area for modelling purposes). Such details may change at the BMP design and implementation phase; refinements to modeling may be necessary to calculate final sediment and phosphorus reductions.

Figure 1. **Prioritized subwatersheds for implementation strategies.**

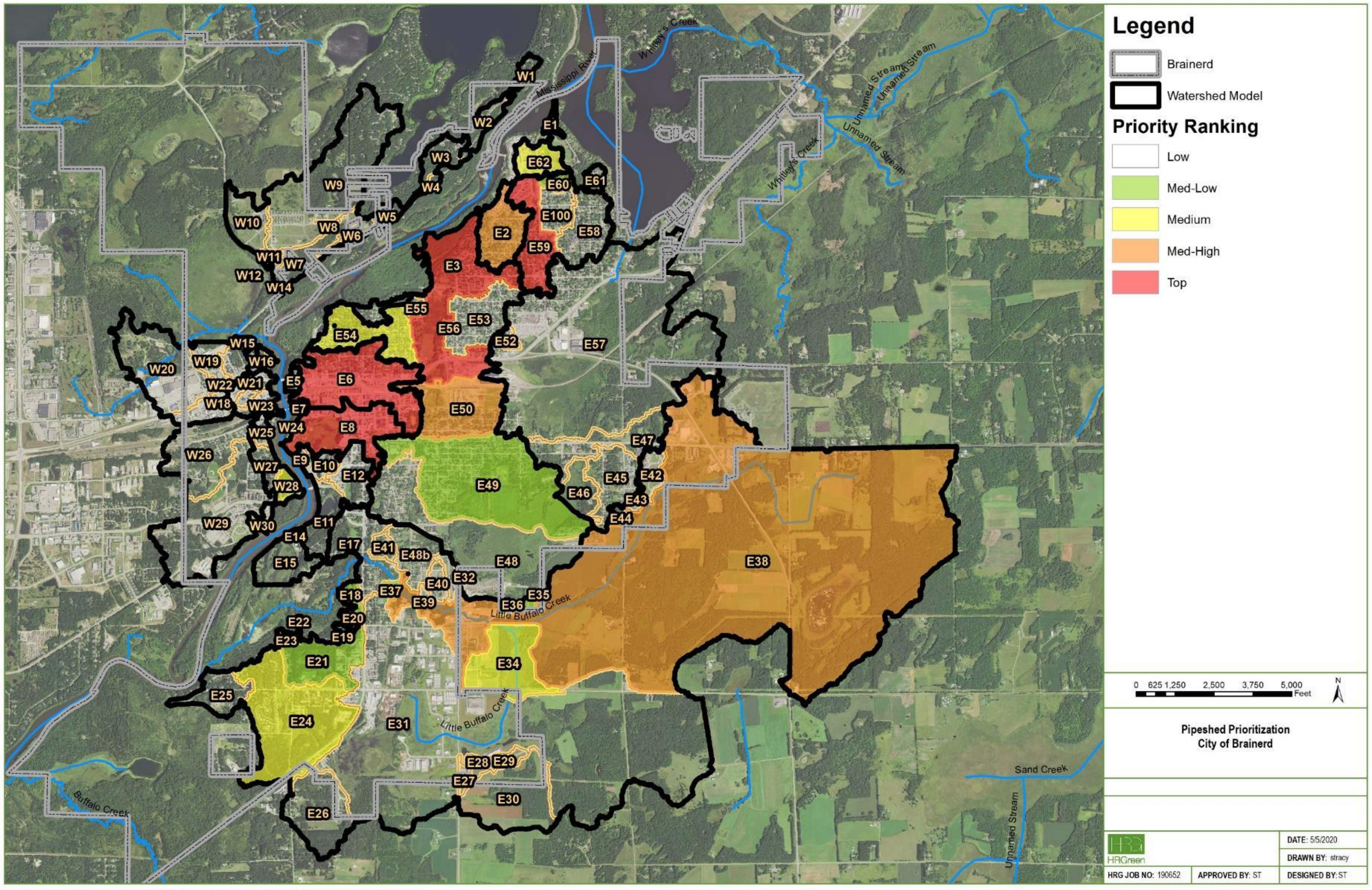


Table 1. Recommended Implementation Strategies

Subwatershed	Alternative	Construction Cost	Present Day Value	Pollutant Removal Relative to Outfall to River		$/lb-TSS	$/lb-TP
				TSS-Lbs Removed	TP-Lbs Removed		
E49/50	Site #1 Stormwater Wetland + IESF	$ 250,000	$ 281,380	54,832	152	$ 0.17	$ 62
E8	Bioretention and/or Stormwater Planters (13% TSS)	$ 47,250	$ 53,760	4,037	4	$ 0.44	$ 448
E6	Bioretention and/or Stormwater Planters (20% TSS)	$ 160,650	$ 182,785	10,877	8	$ 0.56	$ 762
E8	Site #2 Full Spectrum Detention (maximized to site)	$ 317,128	$ 353,745	14,894	30.1	$ 0.79	$ 392
E6	Full Spectrum Detention	$ 292,768	$ 329,385	10,449	15	$ 1.05	$ 732
E54	Site #2 P3001 IESF	$ 119,060	$ 87,019	2,484	13	$ 1.17	$ 223
E53	Bioretention and/or Stormwater Planters	$ 70,950	$ 85,273	1,674	4	$ 1.70	$ 711
E3	Bioretention and/or Stormwater Planters	$ 70,950	$ 85,273	1,674	4	$ 1.70	$ 711
E8	Permeable Parking (11% TSS)	$ 85,758	$ 336,151	3,258	7	$ 3.44	$ 1,601
E6	Permeable Parking (4a% TSS)	$ 85,758	$ 336,151	2,000	5	$ 5.60	$ 2,241
W15/18	Pond P4002 IESF	$ 184,710	$ 149,130	282	13.8	$ 17.63	$ 360
	Totals	**$ 1,684,982**		**106,461**	**256**		

It is recommended that the City implement strategies based on their comprehensive return on investment considering the above metrics. It is also recommended that the City continues to implement strategies identified within the *Buffalo Creek Subwatershed – Stormwater BMP Retrofit Analysis*, 2012 study given the numerous high-value strategies identified as well as the current analysis' findings for their correlated multi-value return on investment (**Figure 1**).

II. Methods

A. Background

Issues and Goals Identification

To assist in driving the analysis of the City of Brainerd, MN stormwater infrastructure, and to identify potential opportunities to retrofit stormwater water quality best management practices (BMPs), meetings were held with City staff (City), the Crow Wing Soil and Water Conservation District (SWCD) and the Mississippi Headwaters Board (MHB). An initial meeting was held at the City Public Works office to review existing data and collect local knowledge. Information from this meeting was supplemented with additional conversations throughout the analysis to clarify stormwater conveyance and treatment issues and opportunities. In addition, priority ranking parameters and scoring criteria were developed to assist in screening subwatersheds for areas that likely yield multiple management goals. Though all subwatersheds (i.e., pipesheds) were modeled for existing pollutant loading the Mississippi River, the screening parameters guided which would be modeled to estimate treatment alternative performance.

Summary of Previous Studies

A stormwater retrofit analysis for the Little Buffalo Creek subwatershed, located in the southern areas of Brainerd, was performed in 2012 (*Buffalo Creek Subwatershed – Stormwater BMP Retrofit Analysis*, Shawn Tracy, 2012). The methods used in this study were quite similar to the present study. Since the study was completed several of the recommended BMPs have been implemented with significant improvements seen in Little Buffalo Creek water quality.

The Crow Wing County Local Comprehensive Water Plan (2013-2023) contains a stormwater management objective that with multiple actions. These include technical assistance, onsite guidance, financial incentives, educational materials and workshops, supporting scientific research, and developing public and private drainage solutions. Measurable outcomes include total number of implemented stormwater plans, implementing at least 15 plans yearly, hosting an annual workshop, and maintaining stormwater factsheets on the County website.
https://crowwing.us/241/Water-Quality-and-Water-Plan

The City of Brainerd Comprehensive Plan (2019) provides goals and policies pertaining to stormwater. One is the encouragement of the use of stormwater BMPs to improve local and regional water quality, while another is to encourage BMPs for managing runoff. Green infrastructure was emphasized, with descriptions of several stormwater BMP and the City's SWPPP.
https://www.ci.brainerd.mn.us/DocumentCenter/View/5324/Brainerd_ComprehensivePlan?bidId=
https://www.ci.brainerd.mn.us/183/Stormwater

The most recent annual plans and reports for the Crow Wing SWCD are from 2018. The SWCD often cites supporting the efforts of the Crow Wing County Water Plan. In the 2018 SWCD Work Plan, stormwater management is addressed through resource planning and targeting sub-watersheds, use of Clean Water Legacy Grants, targeting the Serpent Lake for projects, offering the Community Centered Runoff Mini-Grant Program, and emphasizing state cost sharing.

https://crowwingswcd.org/annual-reports-plans/

The Mississippi Headwaters Board Comprehensive Plan (2019) states that "proper stormwater management must be considered in compliance with state laws in reviews, approvals, and permits related to this Comprehensive Plan. It is recommended that best management practices and a storm-water management plan be considered." The Mississippi Headwaters Board has funded several stormwater retrofit studies in the past several years for communities along the upper Mississippi River; example communities include Bemidji, Grand Rapids, Baxter, and Little Falls.
http://mississippiheadwaters.org/files/regmanagement/2019%20final%20draft%20MHB%20Comp%20plan.pdf

The Water Restoration and Protection Strategy (WRAPS) study for the Mississippi River – Brainerd reach is underway by the Minnesota Pollution Control Agency, and is anticipated to be completed in 2020.
https://www.pca.state.mn.us/sites/default/files/wq-ws4-38b.pdf

The Minnesota Source Management Program (2013) identifies goals for addressing urban runoff. These include the development of comprehensive runoff management plans by small MS4 communities, the advancement of BMP and LID techniques, addressing stormwater load allocation reductions for TMDLs, establishing a technical assistance program, promotion of urban water quality through education programs, collaboration between stormwater runoff stakeholders, and BMP research.
https://www.pca.state.mn.us/sites/default/files/wq-cwp8-15.pdf

The BWSR Nonpoint Priority Funding Plan (2018) does not directly address stormwater. However, one of the two watershed examples provided in the report was the Bassett Creek Watershed Management Organization, which discussed the use of stormwater management techniques to improve water quality in their waterbodies.
https://bwsr.state.mn.us/sites/default/files/2019-01/180827%20FINAL%202018%20NPFP.pdf

B. Subwatershed Development and Watershed Model Grouping

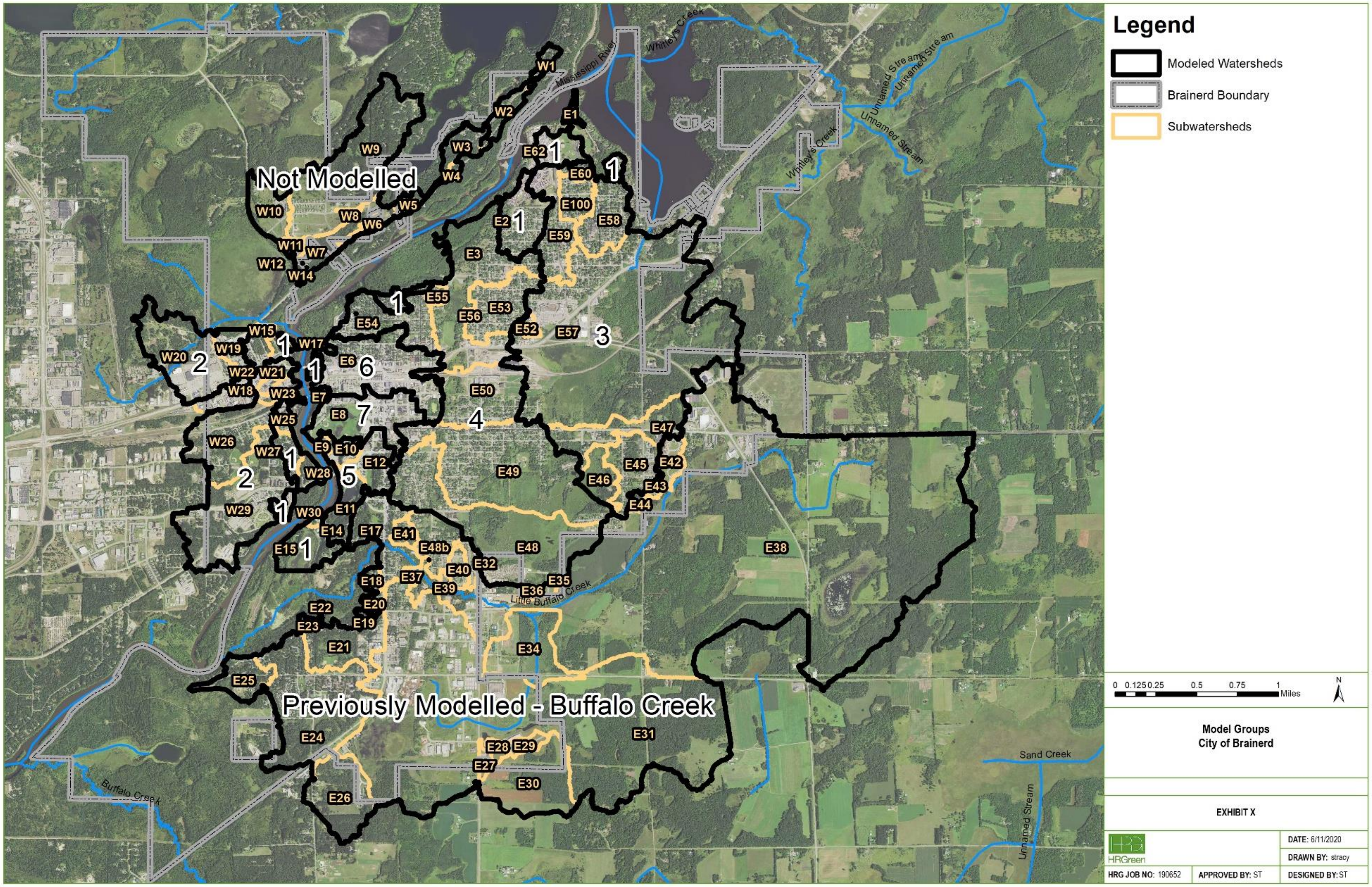
Subwatershed Delineation

The City's stormwater database (GIS) was used along with a digital elevation model in GIS to delineate subwatersheds (i.e. pipesheds) all commonly draining to an outfall of the Mississippi River (**Figure 8**). The resulting delineations then allow the City to account for watershed loading and future treatment on multiple scales: watersheds and subwatersheds.

Model Grouping by Watershed

Subwaterhseds were grouped into seven model groups related to their common outfall to the Mississippi River (**Figure 2**). This provides modeling estimates of average annual pollutant loading to the Mississippi River on a larger watershed scale, shortens model run time and makes it easier for the City to manage the models in the future.

Figure 2. Model groupings of subwatersheds.



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C. Desktop Analysis

Initial Retrofit Review

Stakeholder-defined parameters and scoring metrics were used to provide an initial screening for subwatersheds likely to yield the greatest return on investment for multiple-values (**Appendix B - Prioritization and Screening Factors**). The team decided that is useful to give all six metrics priority and this decision was carried out for the subsequent modeling effort. Following this, a review of the optimal, targeted areas suitable for retrofitting BMPs was performed via desktop using GIS and aerial imagery. The process involved scrutinizing various land uses and existing ponds and outfalls for indicators suggesting retrofit opportunities. Areas potentially conducive to retrofitting were recorded within a GIS Shapefile, along with their potential BMPs.

The potential rertrofit areas reviewed were as follows, in order of importance;

1. Outfalls
2. Existing ponds
3. Public lands
4. Residential lands
5. Commercial and Industrial lands

Existing Conditions Modeling

Each pipeshed's existing and proposed stormwater effluent water quality was modeled within P8 Urban Catchment Model (Walker, 2015). Soils (**Figure 9**), ground water protection areas (**Figure 10**), land cover (**Figure 11**) and parcel information (**Figure 12**) were included to perform this task. Land use classifications were derived from City Zoning Classifications and converted to WinSLAMM (PV Associates) codes to adopt empirically-derived parameters in the Midwest such as directly and indirectly-connect impervious ratios, sediment accumulation and decay rates, particle distribution of accumulated sediment and wash-off rates, sediment-pollutant affiliations by particle size, among others. NRCS soils obtained from the NRCS Web Soil Survey were used for classification of hydrologic soil groups. As-built surveys, where available, were obtained from the City and referenced for development of existing ponding and accounting for existing treatment of water quality.

The initial modeling results at the major watershed scale are presented in **Table 2**. While watersheds 2, 3, and 4 yielded the greatest quantities of sediment and phosphorus to the Mississippi River, watershed 4 yields the highest sediment loading per acre and 6 and 7 yielded the greatest pounds per acre for sediment and phosphorus (watershed 1 represents an aggregate of several, small, directly connected pipesheds).

Table 2. Major watershed modeling results for sediment and phosphorus yields.

Watershed Modeling Group	Acres	Export to Water Resource*			
		Total Suspended Sediment		Total Phosphorus	
		lbs/yr	lbs/acre	lbs/yr	lbs/acre
Watershed 1 (aggregated small, outlier pipesheds)	259	44,523	172	145	0.6
Watershed 2	5569	109,455	20	388	0.1
Watershed 3	1139	148,932	131	520	0.5
Watershed 4	1071	142,982	1343	466	0.4
Watershed 5	111	16,293	147	62	0.6
Watershed 6	164	54,361	331	173	1.1
Watershed 7	109	29,474	270	94	0.9

*Accounts for existing treatment.

D. Field Reconnaissance

A review of potential retrofit opportunities within the City was performed by visiting existing ponds, neighborhoods, commercial and industrial land uses. A map book of subwatersheds, stormwater infrastructure, flow paths and aerial imagery was referenced for this work. Ponds identified as potential for retrofitting were visited, as well as the majority of the remaining land use areas. Specific site limitations on the feasibility of constructing retrofit alternatives were also documented to inform limitations on sizing in modeling efforts.

E. Subwatershed Treatment Modeling, Valuation and Prioritization

Modeling

The existing conditions model was used to then used to assess the performance of various BMP alternatives for top-ranking subwatersheds from the initial screening. P8 uses settling time and filtration efficiencies to estimate load reductions of BMPs. In all cases, default settings for sediment-pollutant associations, particle settling times and particle filtration efficiencies were retained. Iterations of various treatment rates (expressed in percentages) were performed for each alterative up to either 60% total phosphorus/80% total suspended sediment removal (the point at which incremental return on investment greatly diminishes) or to a point representing the maximum potential build out capacity of a pipeshed (as determined either by an individual site for a regional treatment system was identified or by the total number of optimal locations for a pipeshed's small, distributed green infrastructure practices it would yield).

Valuation

Each modeled BMP alternative was then reviewed for cost-benefit value. Each potential project's present-day value divided by 30 years of pollutant removal served as the cost-benefit value. Present day value was calculated as the cost to design, build and provide maintenance over a 30-year period. The Water Environment Federation's present-day value tool (WEF-PDV) was used to calculate this value. Moderate levels of maintenance for annual, intermittent and periodic maintenance activities were assumed for this evaluation. Annual maintenance included minor inspection and correction activities.

Intermittent maintenance was set to occur every few years including moderate levels of site repair or cleanup. Periodic maintenance occurred 1 to 2 times over 30 years (e.g., dredging).

Prioritization Ranking

The prioritization process for proposed retrofit alternatives started with the subwatershed/pipeshed screening and was then informed further by treatment performance and life-cycle costs. Alternatives passing the first screening test that were then evaluated for performance were ranked in order of lowest cost per unit of pollutant removal (e.g., average annual $/lb-TSS).

III. Results

A. Watershed Group Priority Levels

While there were 76 total subwatersheds modelled in this study, we present here those subwatersheds that were deemed medium priority or greater (**Table 3**). The remaining subwatersheds not presented in the table were assigned a ranking of "Low Priority Level" and are not presented here.

Table 3. Subwatersheds given higher priorities for further examination.

Watershed Model Group	Pipeshed/Strategy Location	Priority Level
Watershed 1	E2	Med-High
	E62	Medium
	W28	Medium
Watershed 2	W15	Top
Watershed 3	E59	Top
	E60	Med-Low
Watershed 4	E3	Top
	E49	Med-Low
	E50	Med-High
	E54	Medium
Watershed 5	None	None
Watershed 6	E6	Top
Watershed 7	E8	Top
Buffalo Creek Watershed (previously modeled)	E18	Med-Low
	E20	Med-Low
	E21	Med-Low
	E22	Med-Low
	E23	Med-Low
	E24	Medium
	E34	Medium
	E35	Med-Low
	E36	Medium
	E37	Med-Low
	E38	Med-High

B. Top Priority Subwatersheds

The study has identified 5 top priority subwatersheds, based on the screening metrics, for targeting BMP implementation projects (**Table 4**). These include W15, E59, E3, E6, and E8. Each of these subwatersheds received more focused modeling to determine the best-valued BMPs and proposed locations.

Table 4. Top priority subwatersheds.

		Export to Water Resource*	
Subwatershed (contributing pipeshed)	Acres	Total Suspended Sediment (TSS-lbs/yr)	Total Phosphorus (TP-lbs/yr)
W15 & W18	57	19,857	63
E59	74	1,374	18
E3 (Group 4 except E48)	797	97,765	322
E6	164	54,361	173
E8	109	29,474	94

*Accounts for existing treatment.

Note that subwatersheds E6 and E8 represent the entirety of their watershed areas; these are located in the downtown area (**Figure 1**; **Figure 2**). Each of the 5 subwatersheds in Table 4 received additional focused modeling to determine the best combination of BMPs for location, costs, and value.

C. Subwatershed W15 and Subwatershed W18 Strategies

This subwatershed is part of Watershed 2 and are located west of the River (**Figure 3**). The average annual loadings are 19,857lbs-TSS/year and 63 lbs-TP/year. Based on the modeling exercise we suggest that an iron-enhanced sand filter be considered for further implementation analyses (**Table 5**). IESF's primary treatment value is in dissolve phosphorus removal, though it can be expected that additional removal of fine particles will occur.

Table 5. Subwatersheds W15 and W18 Strategy Annual Performance

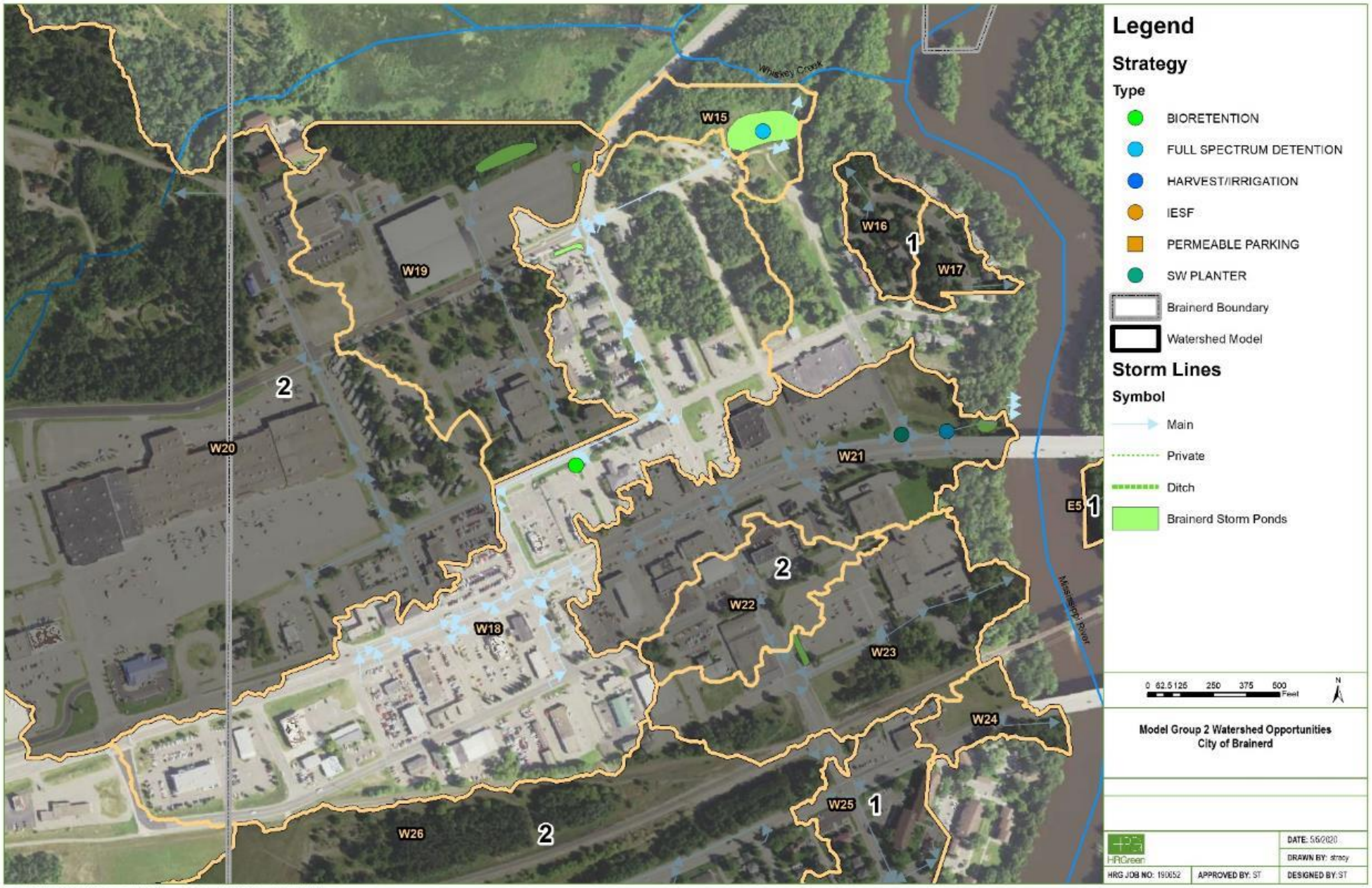
	Pollutant Removal Relative to Outfall to River[a]					
	TSS		TP			
Alternative	Additional % Removed	Additional Lbs Removed	Additional % Removed	Additional Lbs Removed	Total Surface Area (ac)	Total BMPs
Pond P4002 IESF	<1	282	22	13.8	2615	1

[a]Results shown are for the expected level of treatment above and beyond existing pond treatment [existing pond is estimated at 15,531 LB-TSS (78%) and 29.6 LB-TP (47%) removal annually]. Dissolved phosphorus (P0 particle size in model) removal efficiency assumed to be 60%, as per MPCA guidelines. Addition of an Iron Enhanced Sand Filter (18-inches deep with underdrain routed to existing outlet structure) designed to filter 3-acft of flow. Assumes 3-ft of live pool bounce.

Alternative	TSS Treatment Level (%)	Construction Cost	Maintenance Costs (30-yr)		Present Day Value	$/lb-TSS	$/lb-TP
			Annual	Intermittent (10-yr cycle)			
Pond P4002 IESF	<1	$184,710	$780	$52,000	$149,130	$18	$360

1. Engineering design fees included.
2. New outlet will be needed to accommodate the IESF design (@$8,000).
3. Media replacement every 10-years.

Figure 3. Subwatersheds W15 and W18 BMPs



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D. Subwatershed E59 Strategies

This subwatershed is part of Watershed 3 and is located in the northeast are of the City (**Figure 4**). The average annual loadings are 1,374 lbs-TSS/year and 18 lbs-TP/year. Based on the modeling exercise we suggest that an alum dosing station be considered for further implementation analyses (**Table 6**).

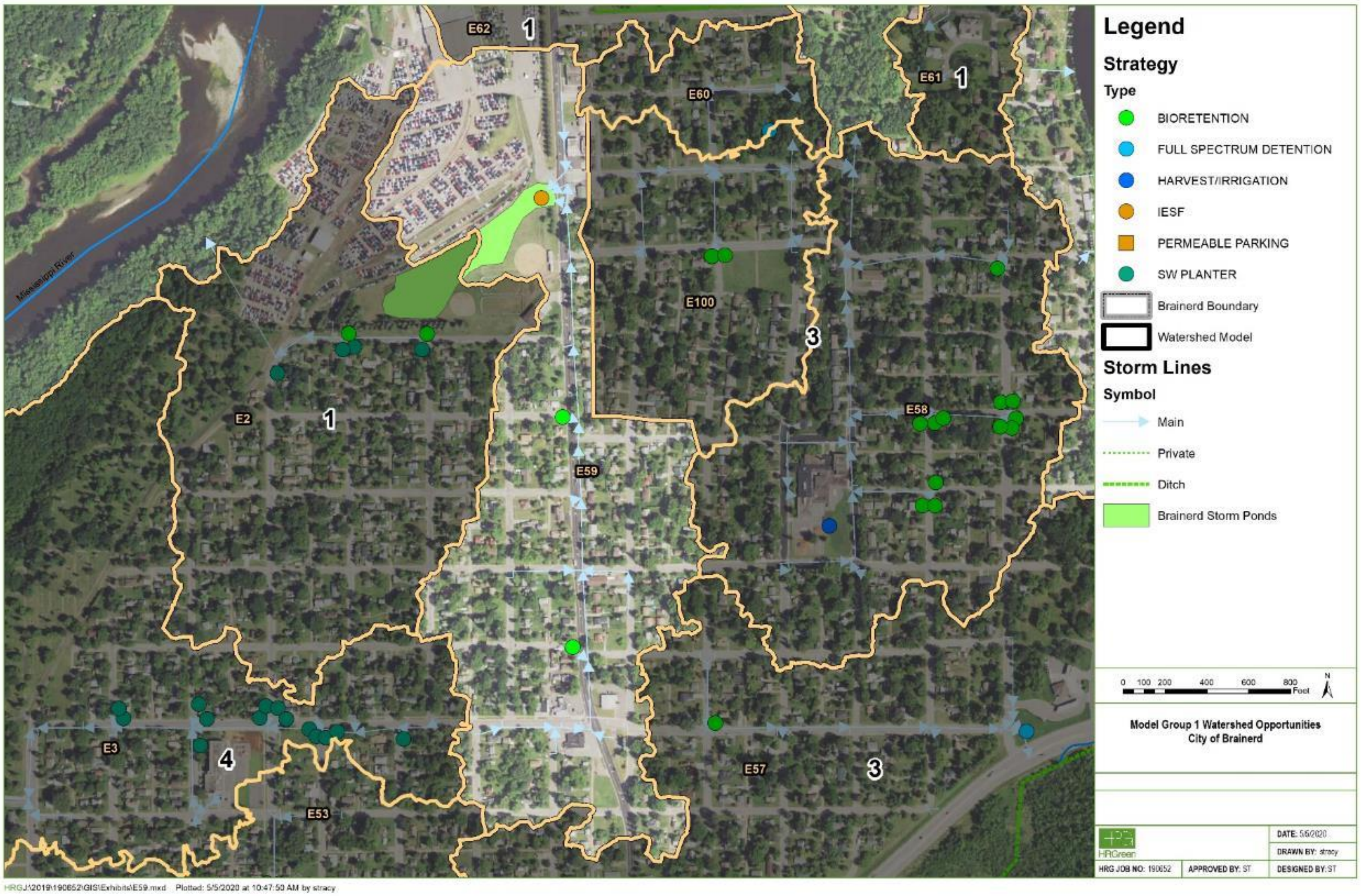
Given the complex 2-way inlet-outlet configuration of this pond, no modeling was performed to predict estimates of potential sediment and phosphorus reduction related to Alum dosing (note that an Iron-enhanced Sand Filter was considered for this site but appears to infeasible given outlet hydraulics). Alum dosing is intended for phosphorus reduction though the TMDL targets sediment. Should the City or partners wish to provide additional phosphorus treatment, the following are recommendations for a full feasibility analysis:

- Monitor inflow and outflow during several storm events, monitor water quality, then perform jar testing to determine dosing.
- Jar testing, residence of minimum of 6 hours, alum dose based on phosphorus loading and settling time of particles and suspend/dissolved phosphorus. This will also inform dosing station's chemical storage tank size and dosing mechanical delivery system and associated costs.

Table 6. Subwatershed E59 Strategy Annual Performance

	Pollutant Removal Relative to Outfall to River					
Alternative	TSS		TP		Total Surface Area (ac)	Total BMPs
	% Removed	Lbs	% Removed	Lbs		
Site #1 Pond P0021 Alum Dosing Station[a]	N/A	N/A	N/A	N/A	N/A	N/A

Figure 4. Subwatershed E59 BMPs



E. Subwatershed E3, E49, E50, E53, E54 Strategies

This subwatershed is part of Watershed 4 and is centrally located in the City (**Figure 5**). The average annual loadings are 97,765 lbs-TSS/year and 322 lbs-TP/year. Based on the modeling exercise we suggest that iron-enhanced sand filters and bioretention be considered for further implementation analyses (**Table 7**).

Table 7. Subwatershed E3 Strategy Annual Performance

Alternative	Pollutant Removal Relative to Outfall to River				Total Surface Area (ac)	Total BMPs
	TSS		TP			
	% Removed	Lbs	% Removed	Lbs		
Site #1 E49/E50 Stormwater Wetland + IESF[a]	38	54,832	33	152	2	2
Site #2 E54 P3001 IESF[b]	<1	2,484	<1	13	0.01	1
E53 Bioretention	1	1,674	1	4	0.03	11
E3 Bioretention	1	1,674	1	4	0.03	11

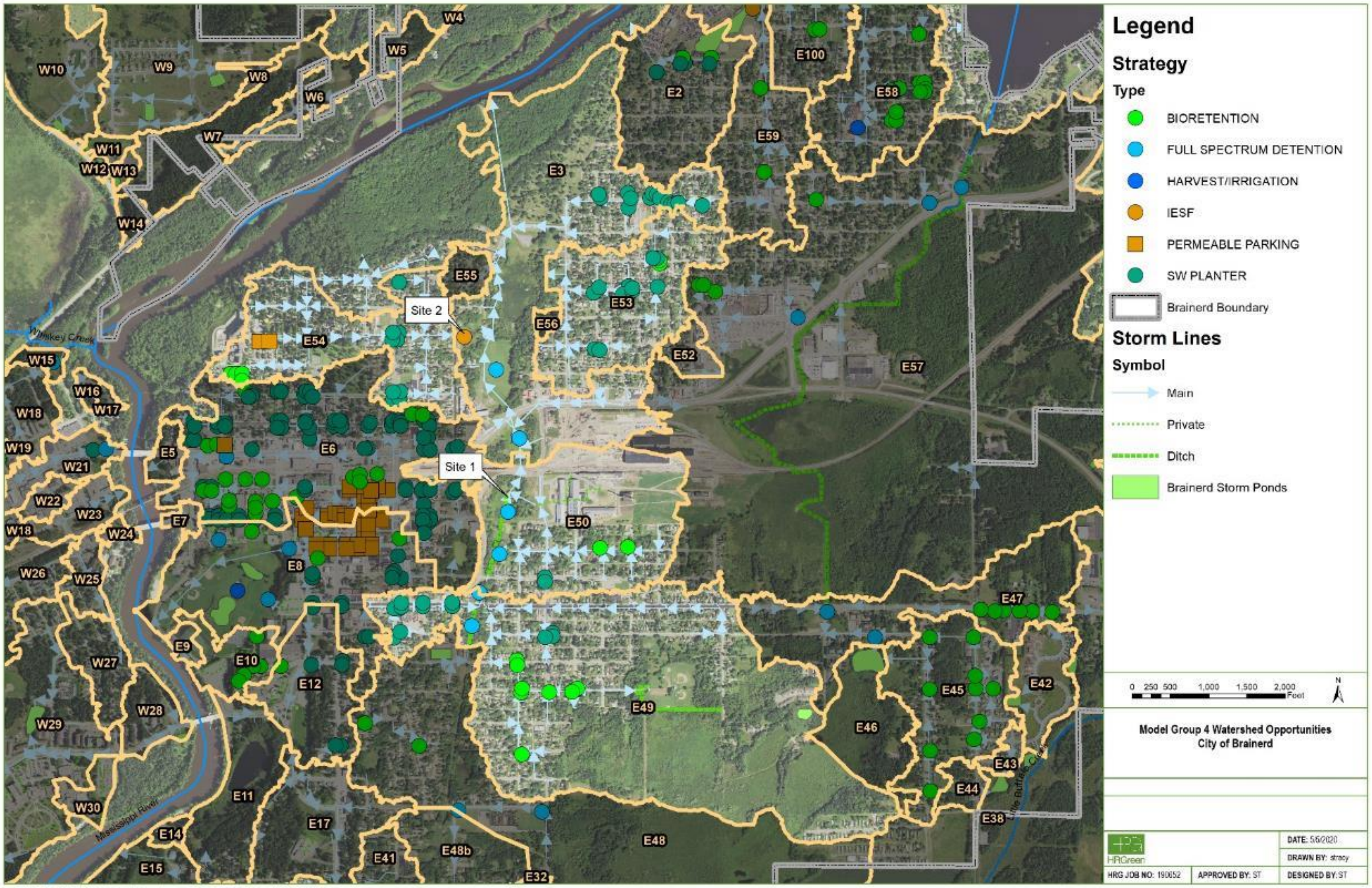
[a]2-acre wetland (Permanent pool surface 2-acres and 2 feet deep; Permanent pool surface area 1-acre, 3 feet deep) with 100-lnft X 10-ft, 2-ft of iron-sand and new riser outlet structure with assumed 4-in/hr infiltration rate (requires full feasibility study and surface flooding model to validate).

[b]Addition of a 4-ft by 100-ft Iron Enhanced Sand Filter on southern pond cell (18-inches deep with underdrain routed to a new compound outlet structure). Assumes both ponds are hydrologically connected and allowing 3-ft of live pool bounce.

Alternative	TSS Treatment Level (%)	Construction Cost	Maintenance Costs		Present Day Value	$/lb-TSS	$/lb-TP
			Annual	Intermittent			
Site #1 E49/E50 Stormwater Wetland + IESF	38	$250,000	Y1-5, $3,000; Y5+, $1,000	$3,920 (5-yr)	$281,380	$0.20	$360
Site #2 E54 P3001 IESF	<1	$119,060	$780	$20,000 (10-yr)	$87,019	$1.20	$223
E53 Bioretention and/or Stormwater Planters	1	$70,950	Home Owner	$5,500 (5-yr)	$85,273	$1.70	$710
E3 Bioretention and/or Stormwater Planters	1	$70,950	Home Owner	$5,500 (5-yr)	$85,273	$1.70	$710

1. City owns and operates all facilities.
2. Annual discount rate of 5.5%.
3. Stormwater Wetland
    a. Pricing derived from recently designed and constructed wetland in Grand Rapids, MN.
    b. Maintenance: Y1-Y5, monthly plant and weed management, 1 inspection. Y5 onwards, two plant and weed management visits per year, annual inspection and sediment bay clean out every 5 years.
    c. Contingency and design fees included.
4. Bioretention costing $43/ft^2; no retaining walls are assumed in this area.
    a. Designed as a filtering system with underdrain, media and connection to manhole structures. A valve control should be included in the underdrain system in case local soils facilitate infiltration. If infiltration is viable within 32 hours, treatment will double and the resulting $/LB-Pollutant value will improve.
    b. Rain Guardian™ Bunker forebay.
    c. Planting completed by property owners with supervision (combination of plugs and 4-inch pots for grasses, sedges and forbs; #1 pots for shrubs).
    d. No design fee or contingency included assuming City and/or SWCD will provide design.
    e. Annual maintenance is assumed to be by property owner. Intermittent by City.
5. Iron-enhanced Sand Filter:
    a. Design fees included, no contingency included given ease of site construction and small footprint.
    b. Annual and intermittent maintenance by City includes annual surface loosening and periodic replacement of media every ten years.

Figure 5. Subwatershed E3 BMPs



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F. Subwatershed E6 Strategies

This subwatershed is part of Watershed 6 and is centrally located in the City (**Figure 6**). The average annual loadings are 54,361 lbs-TSS/year and 173 lbs-TP/year. Based on the modeling exercise we suggest that bioretention, permeable parking, and full-spectrum detention be considered for further implementation analyses (**Table 8**). Refer to **Appendix C – Sub-surface Treatment Modeling Assumptions** for additional details.

Table 8. Subwatershed E6 Strategy Annual Performance and Strategy Value

	Pollutant Removal Relative to Outfall to River					
Alternative	TSS		TP		Total Surface Area (ac)	Total BMPs
	% Removed	Lbs	% Removed	Lbs		
Bioretention and/or Stormwater Planters	20	10,877	5	8	0.060	17
	30	16,308	9	16	0.125	36
	40	21,740	16	27	0.235	68
Permeable Parking	4	2,000	3	5	0.037	5
	4	2,333	4	7	0.074	10
Full Spectrum Detention (maximized to site)*	19	10,449	12	15	0.110	1

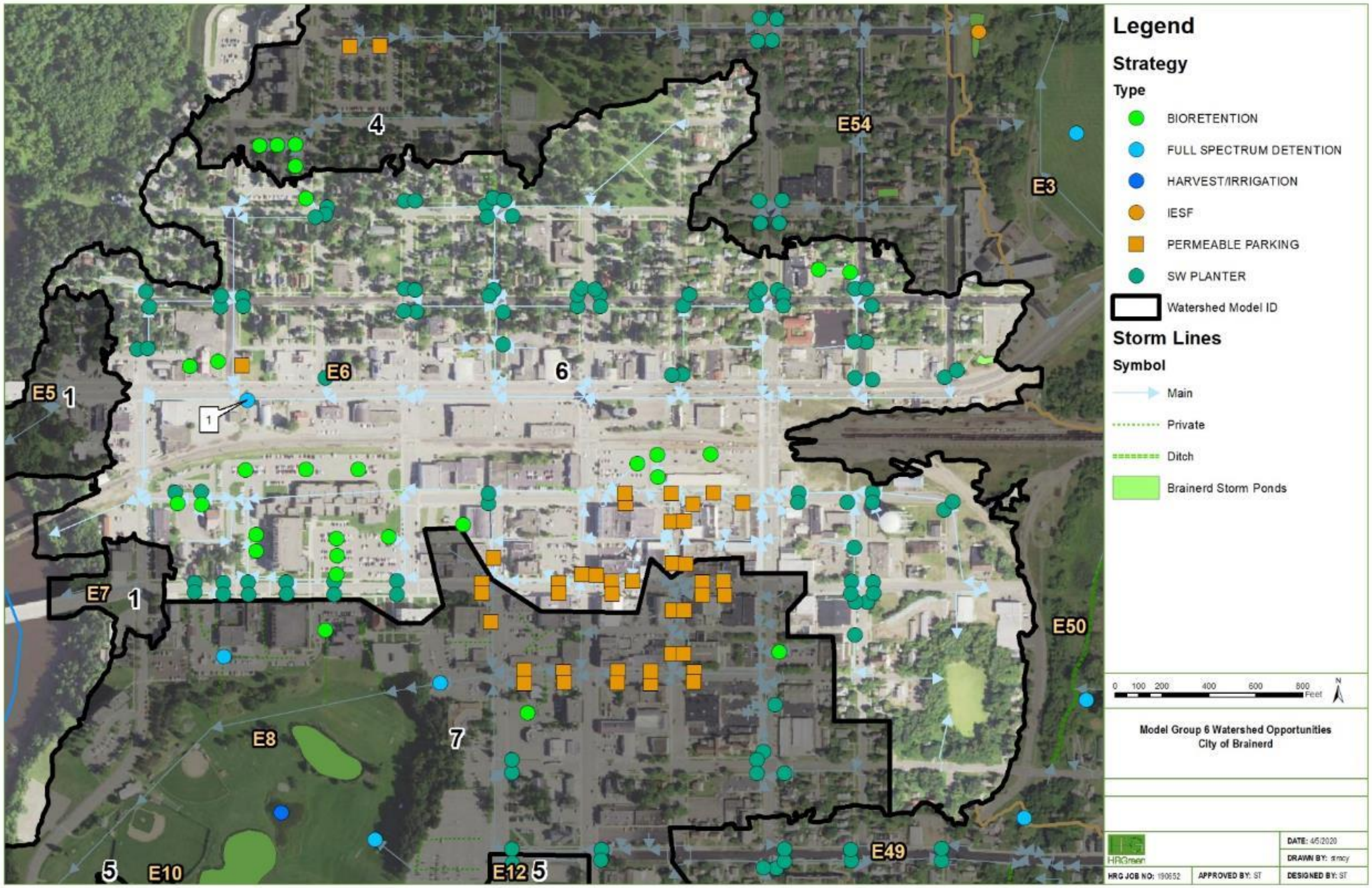
*Five, 60-in diameter by 120-lnft pipes (total of 0.27-acft storage), spaced 2 feet apart, with 1.25-in/hr infiltration. 12-inch outlet orifice places at center of one pipe (requires full feasibility study to validate). See Site 1 on Figure 5.

Alternative	TSS Treatment Level (%)	Construction Cost	Maintenance Costs		Present Day Value	$/lb-TSS	$/lb-TP
			Annual	Intermittent			
Bioretention and/or Stormwater Planters	20	$160,650	Home Owner	$8,500 (5-yr)	$182,785	$0.56	$761
	30	$340,200	Home Owner	$18,000 (5-yr)	$397,311	$0.81	$828
	40	$642,600	Home Owner	$ 34,000(5-yr)	$974,504	$1.49	$1,203
Permeable Parking	4	$85,758	$17,280	$13,541 (30-yr)	$336,151	$5.60	$2,241
	4	$171,464	$34,560	$27,073 (30-yr)	$672,248	$9.60	$3,201
Full Spectrum Detention	19	$292,768	$2,020	$3,440 (5-yr)	$329,385	$1.05	$732

Assumes:

1. City owns and operates all facilities.
2. Annual discount rate of 5.5%.
3. Bioretention costing $63/ft^2; retaining walls are assumed in this area.
    a. For conservancy, all bioretention is assumed to be designed as a filtering system with underdrain, media and connection to manhole structures. A valve control should be included in the underdrain system in case local soils facilitate infiltration. If infiltration is viable within 32 hours, treatment will double and the resulting $/LB-Pollutant value will improve.
    b. Rain Guardian™ Bunker forebay.
    c. Planting completed by property owners with supervision (combination of plugs and 4-inch pots for grasses, sedges and forbs; #1 pots for shrubs).
    d. No design fee or contingency included assuming City and/or SWCD will provide design.
    e. Annual maintenance by property owner. Intermittent maintenance is assumed to be performed by City.
4. Assumes no infiltration, no contingency fee or design fee; volunteer planting and annual maintenance, forebay, underdrain and connection to stormsewer and with retaining walls.
5. Bioretention maintenance: Property-owner responsibility and intermittent City remediation every 5 years = $500.
6. Permeable pavement maintenance: Vacuuming once per month for 6-month non-winter period, asphalt replacement at 30-years.
7. Full Spectrum Detention maintenance: Inspection once every three years, sediment removal once per year, corrective maintenance assumed once every 5 years.

Figure 6. Subwatershed E6 BMPs



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G. Subwatershed E8 Strategies

This subwatershed is part of Watershed 7 and is centrally located in the City (**Figure 7**). The average annual loadings are 29,474 lbs-TSS/year and 94 lbs-TP/year. Based on the modeling exercise we suggest that bioretention, permeable parking, and full-spectrum detention be considered for further implementation analyses (**Table 9**). Refer to **Appendix C – Sub-surface Treatment Modeling Assumptions** for additional details

Table 9. Subwatershed E8 Strategy Annual Performance and Strategy Value

Alternative	Pollutant Removal Relative to Outfall to River				Total Surface Area (ac)	Total BMPs
	TSS		TP			
	% Removed	Lbs	% Removed	Lbs		
Bioretention and/or Stormwater Planters	7	2,011	2	2	0.007	2
	14	4,037	4	4	0.018	5
	20	6,025	7	7	0.035	10
Permeable Parking	11	3,258	7	7	0.037	5
	14	4,215	12	11	0.074	10
Site #2 Full Spectrum Detention (maximized to site)*	50	14,894	32	30.1	0.13	1

*Seven, 60-in diameter by 100-lnft pipes (0.32 ac-ft of storage), spaced 2 feet apart, with 1.25-in/hr infiltration. 12-inch outlet orifice places at center of one pipe (requires full feasibility study to validate).

Site #1 – small drainage area and likely too low return on investment compared to Site #2.

Site #4 – ground water elevation very close to surface (via NRCS Soils Survey). No live storage capacity available without constructing levees in floodplain. Limited increase in storage capacity by expanding ponds.

Site #3 – drains to open field, then existing ponds. See Site #4.

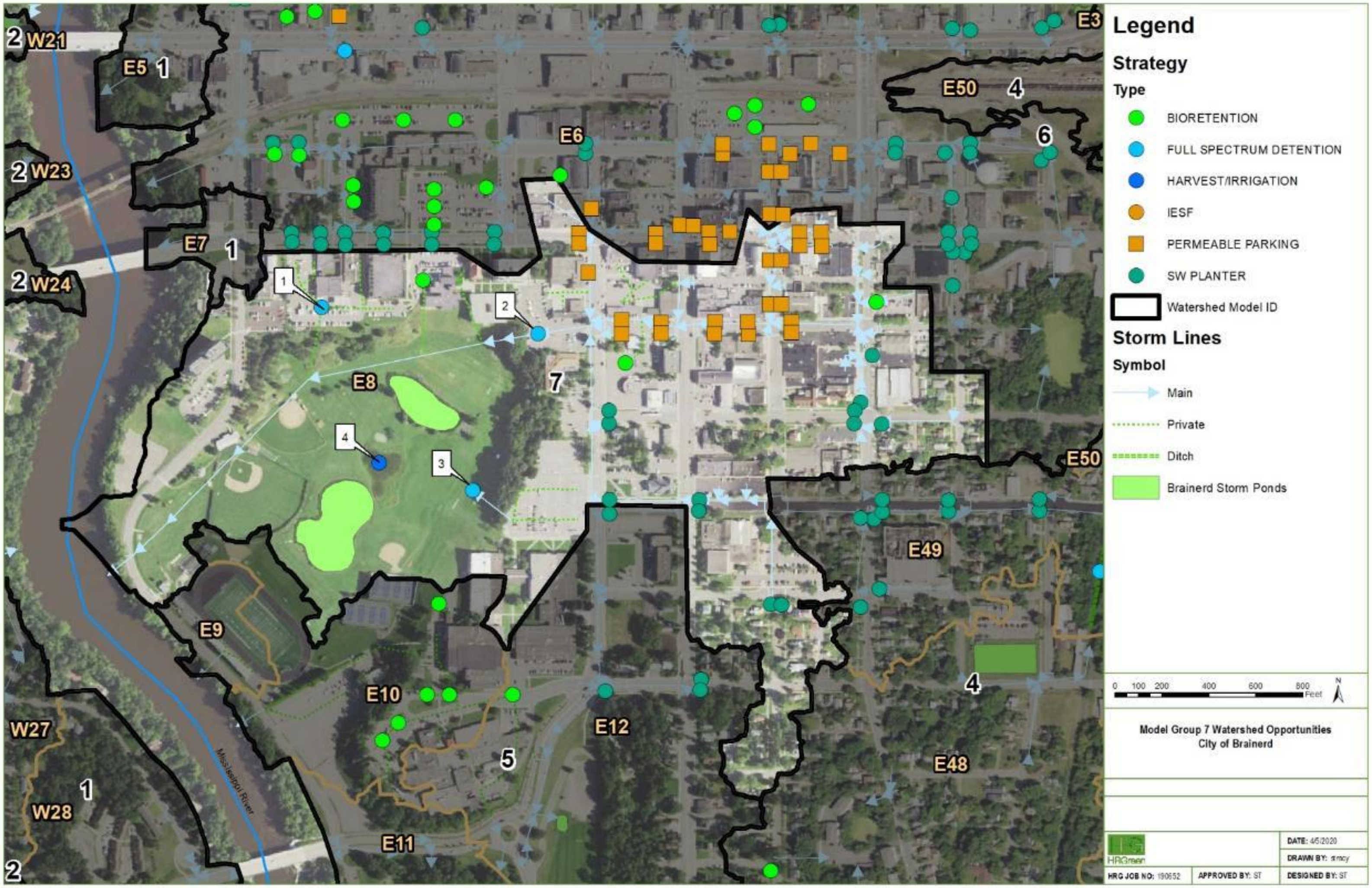
Alternative	TSS Treatment Level (%)	Construction Cost	Maintenance Costs		Present Day Value	$/lb-TSS	$/lb-TP
			Annual	Intermittent			
Bioretention and/or Stormwater Planters	7	$18,900	Home Owner	$1,000 (5-yr)	$21,504	$0.36	$358
	14	$47,250	Home Owner	$2,500 (5-yr)	$53,760	$0.44	$448
	20	$94,500	Home Owner	$5,000 (5-yr)	$107,521	$0.59	$512
Permeable Parking	11	$85,758	$17,280	$12,541 (30-yr)	$336,151	$3.44	$1,600
	14	$171,464	$34,560	$27,073 (30-yr)	$672,248	$5.32	$2,037
Site #2 Full Spectrum Detention (maximized to site)	50	$317,128	$2,020	$3,440 (5-yr)	$353,745	$0.79	$392

Assumes:

1. City owns and operates all facilities.
2. Annual discount rate of 5.5%.
3. Stormwater planters costing $35/ft^2 plus a 20% contingency fee and 20% Design Fee.
4. Bioretention costing $63/ft^2; retaining walls are assumed in this area.
    a. Designed as a filtering system with underdrain, media and connection to manhole structures. A valve control should be included in the underdrain system in case local soils facilitate infiltration. If infiltration is viable within 32 hours, treatment will double and the resulting $/LB-Pollutant value will improve.
    b. Rain Guardian™ Bunker forebay.
    c. Planting by property owners (plugs and 4-inch pots for grasses, sedges and forbs; #1 pots for shrubs).
    d. No design fee or contingency included assuming City and/or SWCD will provide design.
    e. Annual maintenance by property owner. Intermittent maintenance by City.

5. Permeable pavement maintenance: Vacuuming once per month for 6-month non-winter period, asphalt replacement at 30-years.
6. Full Spectrum Detention maintenance: Inspection once every three years, sediment removal once per year, corrective maintenance assumed once every 5 years.

Figure 7. Subwatershed E8 BMPs



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IV. Summary and Recommendations

The results of this analysis considered multiple values for various strategies on retrofitting water quality best management practices (BMPs) within the City of Brainerd. The primary consideration when prioritizing strategies is their value relative to life-cycle cost and treatment performance. As the Mississippi River segment running through Brainerd is impaired for sediment, the cost of implementing strategies was evaluated relative to 30-years of costs and total suspended sediment treatment (TSS). The results were then ranked from highest value to lowest (i.e., lowest cost per pound of TSS to highest; **Table 10**). Given each of the City's subwatersheds were first evaluated based on their ability to provided multiple values beyond water quality treatment and subsequently prioritized, the City can be assured that each alternative strategy presented in this report yields the greatest comprehensive return on investment.

The overall cost of implanting each strategy identified in this report is approximately $3,000,000 with an expected TSS reduction of approximately 150,000 pounds and total phosphorus reduction of approximately 300 pounds (depending on selection of alternatives where more than one treatment level option exists for a strategy). These values reflect treatment above existing treatment provided by several existing ponds and raingardens within the City.

It is recommended that the City develops a capitol improvement plan for retrofitting water quality BMPs based on the results of this report as well as in combination with the top alternatives identified within the *Buffalo Creek Subwatershed – Stormwater BMP Retrofit Analysis.* Continued collaboration with the Crow Wing Soil and Water Conservation District and the Mississippi Headwaters Board will be vital to implementation success and funding acquisition outside of stormwater utility fees.

Table 10. Summary of Stormwater BMP Projects (in order of highest value of TSS treatment to lowest).

Subwatershed	Alternative	Construction Cost	Present Day Value	Pollutant Removal Relative to Outfall to River		$/lb-TSS	$/lb-TP
				TSS-Lbs Removed	TP-Lbs Removed		
E49/50	Site #1 Stormwater Wetland + IESF	$ 250,000	$ 281,380	54,832	152	$ 0.17	$ 62
E8	Bioretention and/or Stormwater Planters (7% TSS)	$ 18,900	$ 21,504	2,011	2	$ 0.36	$ 358
E8	Bioretention and/or Stormwater Planters (13% TSS)	$ 47,250	$ 53,760	4,037	4	$ 0.44	$ 448
E6	Bioretention and/or Stormwater Planters (20% TSS)	$ 160,650	$ 182,785	10,877	8	$ 0.56	$ 762
E8	Bioretention and/or Stormwater Planters (720% TSS)	$ 94,500	$ 107,521	6,025	7	$ 0.59	$ 512
E8	Site #2 Full Spectrum Detention (maximized to site)	$ 317,128	$ 353,745	14,894	30.1	$ 0.79	$ 392
E6	Bioretention and/or Stormwater Planters (30% TSS)	$ 340,200	$ 397,311	16,308	16	$ 0.81	$ 828
E6	Full Spectrum Detention	$ 292,768	$ 329,385	10,449	15	$ 1.05	$ 732
E54	Site #2 P3001 IESF	$ 119,060	$ 87,019	2,484	13	$ 1.17	$ 223
E6	Bioretention and/or Stormwater Planters (40% TSS)	$ 642,600	$ 974,504	21,740	27	$ 1.49	$ 1,203
E53	Bioretention and/or Stormwater Planters	$ 70,950	$ 85,273	1,674	4	$ 1.70	$ 711
E3	Bioretention and/or Stormwater Planters	$ 70,950	$ 85,273	1,674	4	$ 1.70	$ 711
E8	Permeable Parking (11% TSS)	$ 85,758	$ 336,151	3,258	7	$ 3.44	$ 1,601
E8	Permeable Parking (14% TSS)	$ 171,464	$ 672,248	4,215	11	$ 5.32	$ 2,037
E6	Permeable Parking (4a% TSS)	$ 85,758	$ 336,151	2,000	5	$ 5.60	$ 2,241
E6	Permeable Parking (4b% TSS)	$ 171,464	$ 672,248	2,333	7	$ 9.60	$ 3,201
W15/18	Pond P4002 IESF	$ 184,710	$ 149,130	282	13.8	$ 17.63	$ 360

V. Appendices

A. Figures

Figure 8: Subwatersheds, Topography, Water Resources, and Stormwater Infrastructure

Figure 9: Soils

Figure 10: Ground Water Protection Areas/DWSMA

Figure 11: Land Cover Classification

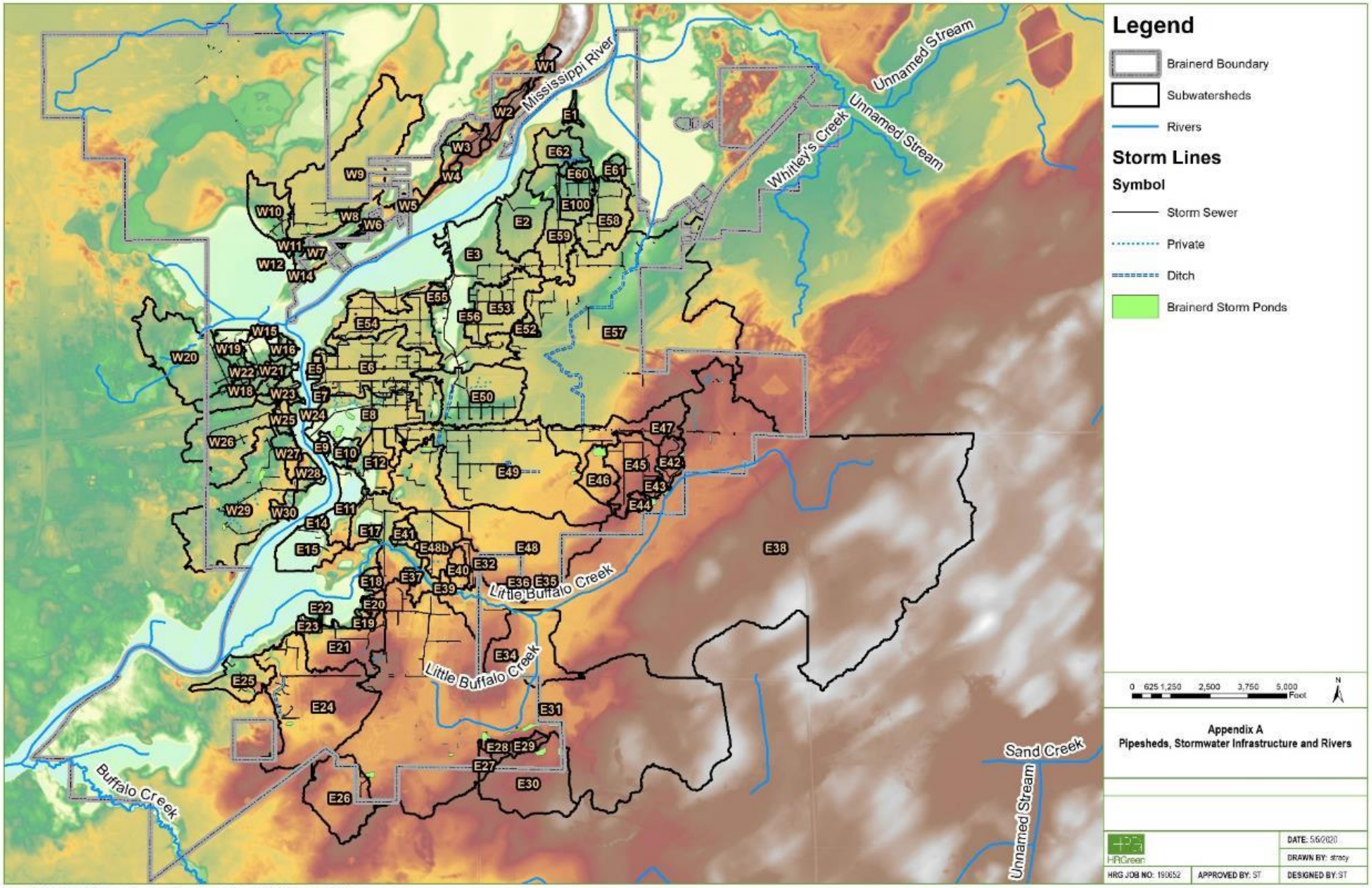
Figure 12: Public and Tax Forfeit Parcels

B. Prioritization and Screening Factors

C. Sub-surface Treatment Modeling Assumptions

APPENDIX A

Figure 8. Subwatersheds, Topography, Water Resources, and Stormwater Infrastructure.



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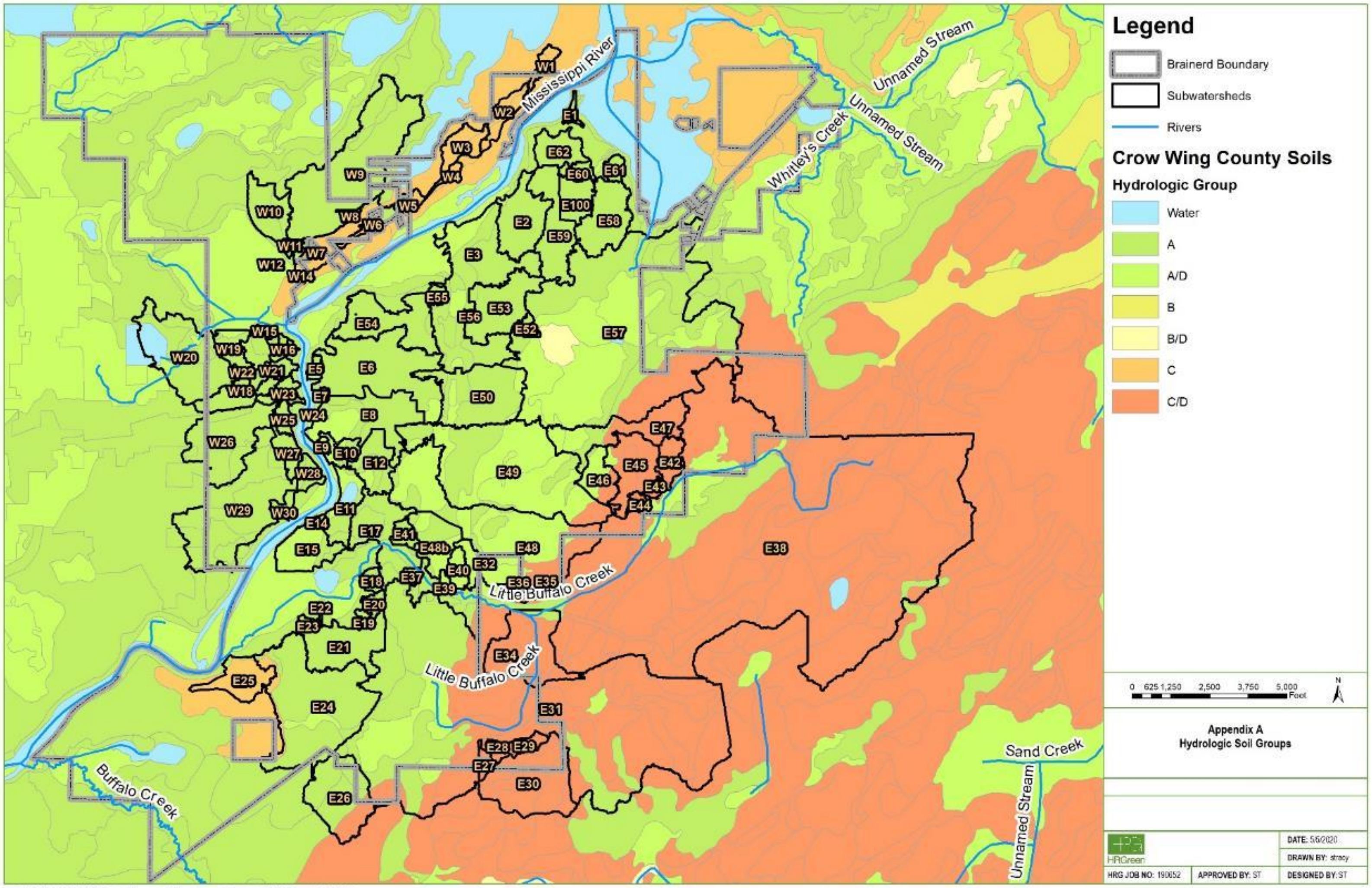
APPENDIX A

Figure 9. Soils



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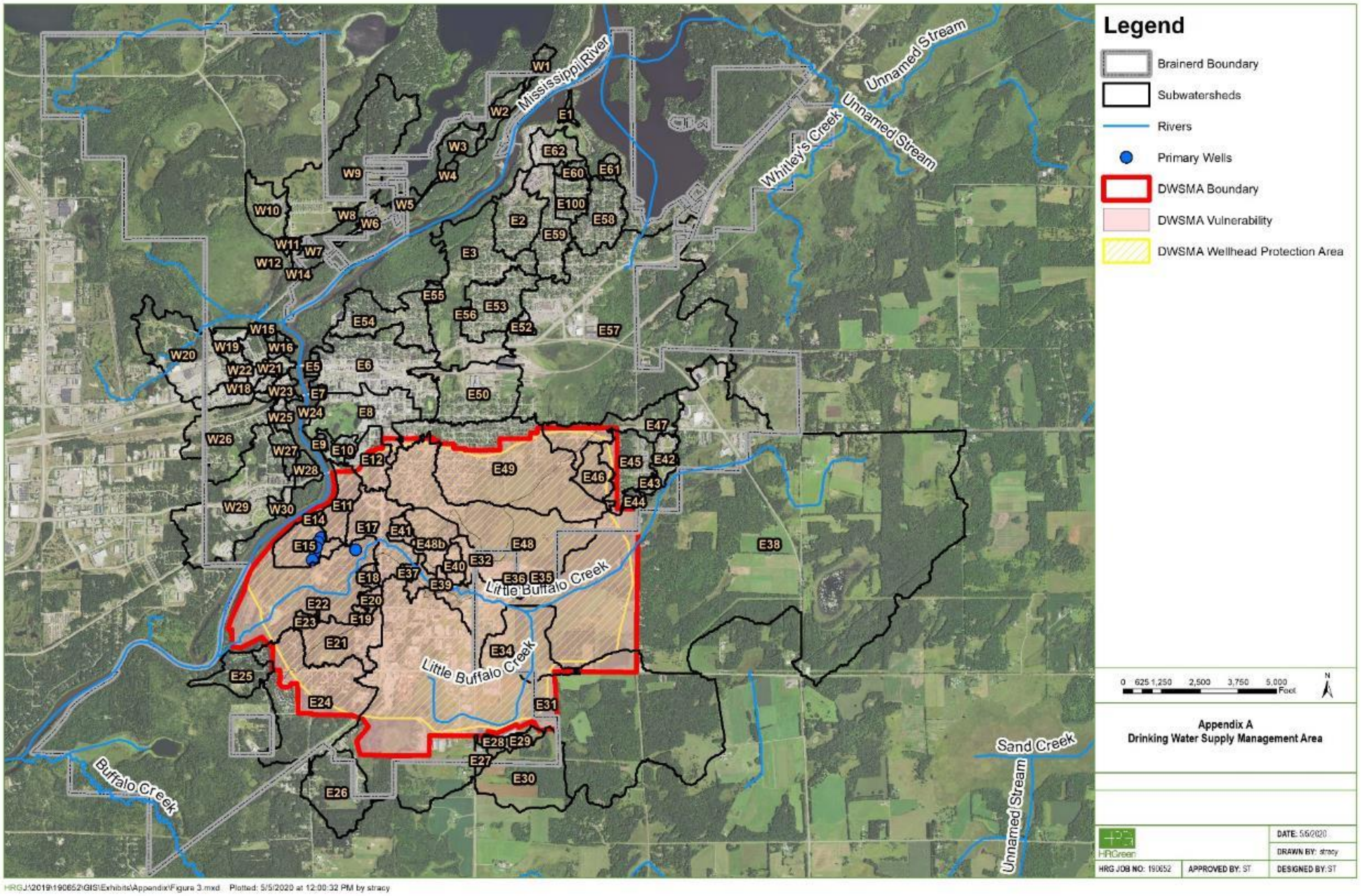
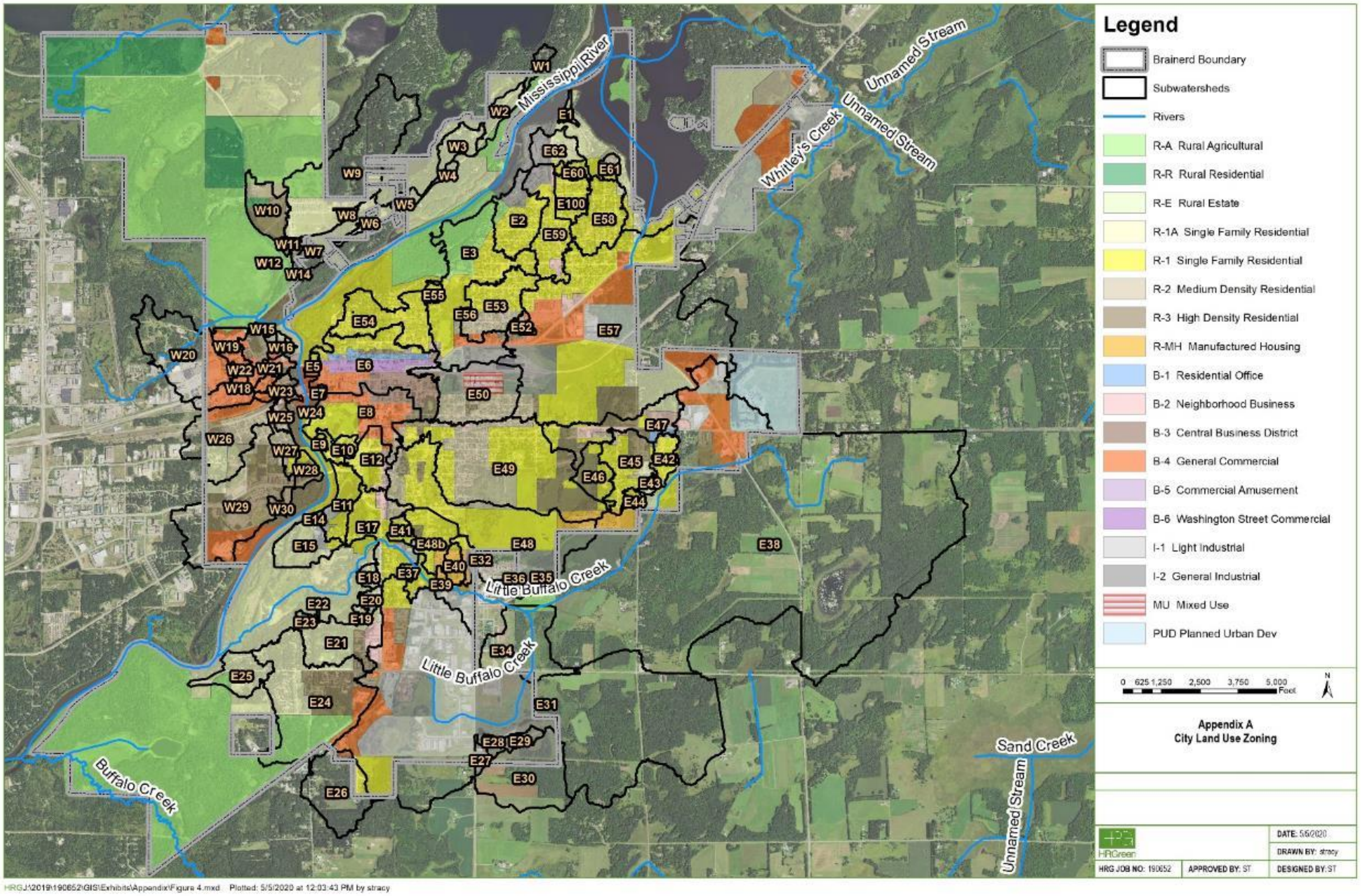
APPENDIX A

Figure 10. Ground Water Protection Areas/DWSMA



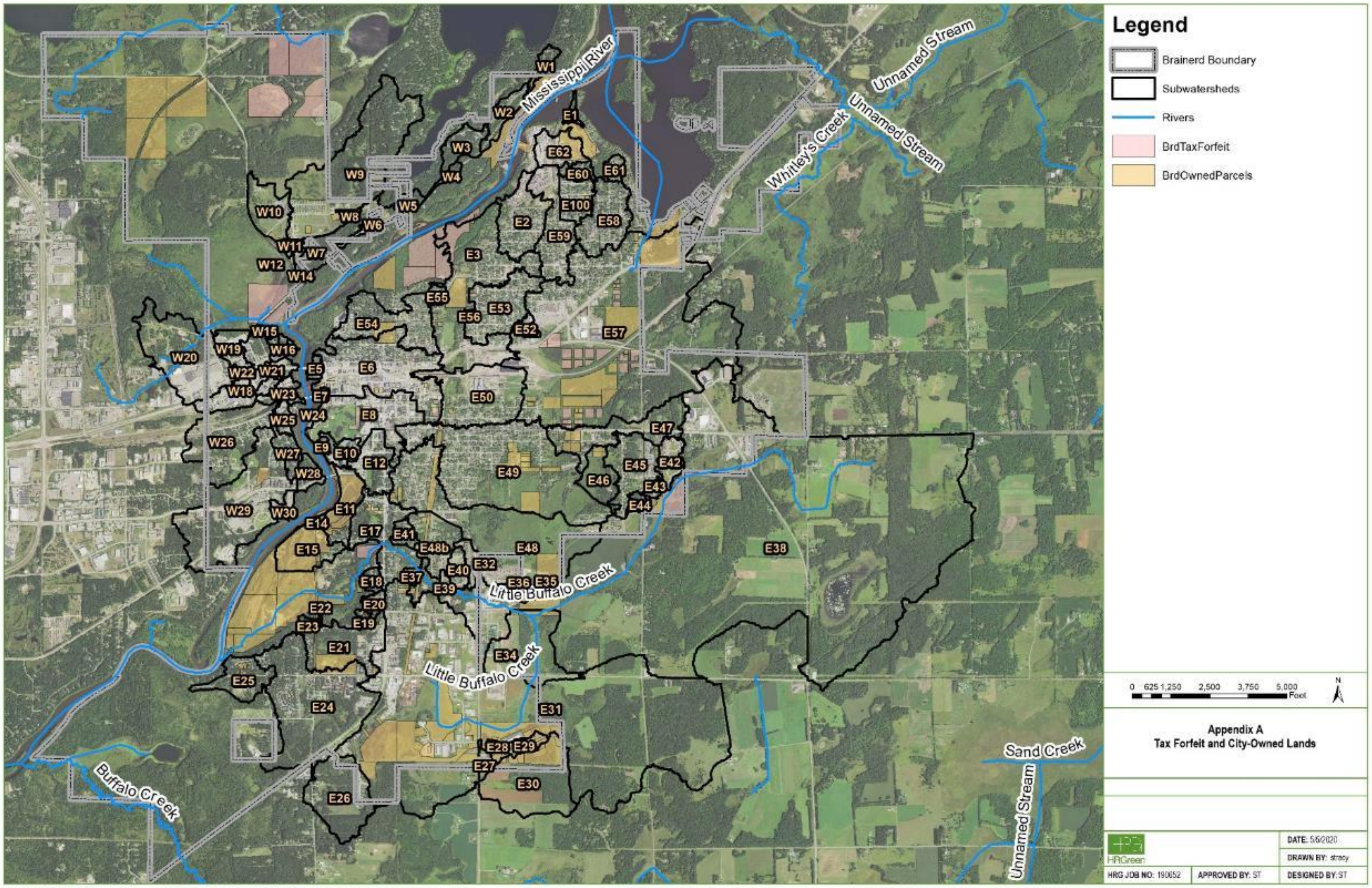
APPENDIX A

Figure 11. Land Cover Classification



APPENDIX A

Figure 12. Public and Tax Forfeit Parcels



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Appendix B - Prioritization and Screening Factors

			Base Score					Weighting Multiplier
Metric	**Logic**	**Score Logic**	**1.0**	**0.75**	**0.5**	**0.25**	**0**	
Impervious reduction via Pavement Management Plan opportunities	This metric identifies where there may be opportunity for a realized savings on pairing water quality retrofits/upgrades during road replacement or utility projects.	High priority score to areas with identified CIP projects	Very high percentage of roads within area is part of CIP		Around half of roads within area is part of CIP		No roads within area is part of CIP	1
End of pipe opportunities	This metric identifies where regional treatment opportunities exist, which are typically less expensive than most retrofitting options.	High priority score to areas that other watersheds flow through, or can or does contain a regional treatment location, or represents a subwatershed bordering the river acting as a discharge point	Subwatersheds with a regional treatment opportunity located near the end of the watershed, as well as subwatersheds that other subwatersheds flow through	Subwatersheds with full spectrum detention and borders the river, but only services its own area	Subwatersheds with full spectrum detention and may or may not service other areas, but do not border the river	Only borders the river, but does not contain any other additional end-of-pipe benefits	Does not contain regional treatment and other watersheds do not flow through this area	5
Existing pond retrofit opportunities	Pond retrofits regularly return the greatest value on investment. They are easy to install, they exist on public land and are easy to maintain.	High priority score to areas that contain existing ponds	Either two ponds or one regional pond are present inside the subwatershed for retrofit opportunities	N/A	One non-regional pond is present inside the subwatershed for retrofit opportunity	N/A	No ponds present	1
Aesthetic and/or ecological enhancement benefit opportunities	These opportunities are easy to accommodate with above-ground green infrastructure or stormwater wetlands at no extra cost.	Areas with higher number of above ground naturalized strategies identified	The subwatershed with the most planter box or rain garden opportunities per acre is awarded 1 point	N/A	Subwatersheds are given a pro-rated score based upon the number of opportunities the best subwatershed has. A subwatershed with half the opportunities per acre of the best subwatershed will receive a 0.5		No planter box or rain garden opportunities are present within the watershed	0.75
Recent development requiring modern treatment permitting	Developments that were implemented under modern stormwater regulations are generally assumed to meet treatment levels equivalent of 1-inch of rain runoff. Though that resulting volume and pollutant load differs between land cover, it is generally assumed these areas are lower priority because treating runoff to higher levels than this generally yield rapidly decreasing incremental cost-benefit value.	Newly developed areas are deprioritized from analysis due to improved regulations	Developed under no stormwater regulation	N/A	N/A	N/A	Developed under new stormwater regulation	1
High concentration of industrial and public lands	Government buildings, libraries, and schools are public facilities. Working on public parcels is substantially easier when it comes to marketing and assurances of regular maintenance. Public projects also provide tangible examples of stormwater BMPs agencies and the City may choose to promote.	Areas with a higher number of institutional or public areas are prioritized higher	Very high percentage of land use within area is Institutional, public, park, school, etc.	N/A	Around half of area within watershed is institutional, public, park, school, etc.	N/A	No land use within area is institutional, public, park, school, etc.	0.5

Appendix C – Sub-surface Treatment Modeling Assumptions

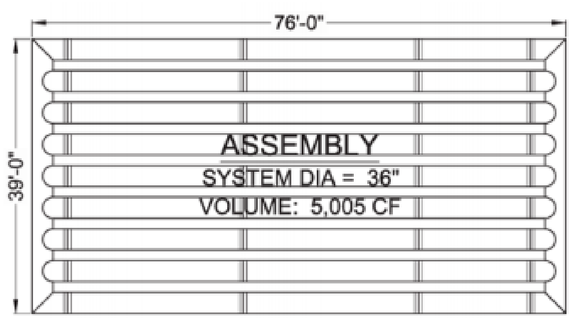
Full Spectrum Detention

Highly urbanized landscapes can dictate the use of sub-surface storage of stormwater for rate and quality control. There are several proprietary systems available that typically come in the form of linked prefabricated arches, pipes or reinforced boxes with 100% void space. In several cases in Minnesota, reclaimed stormwater pipes salvaged from utility upgrades have been used for this purpose. The selection of a system is driven primarily by structural needs, seasonally high ground water elevations and whether an open-bottomed, infiltration system or close-bottom detention system is desired and feasible. These systems have also been used to store water to settle sediments, and then pumped to a second open bottomed cell for infiltration. They have also been used to harvest water for irrigation augmentation, alleviating ground water consumption and also reducing volume to improve water quality.

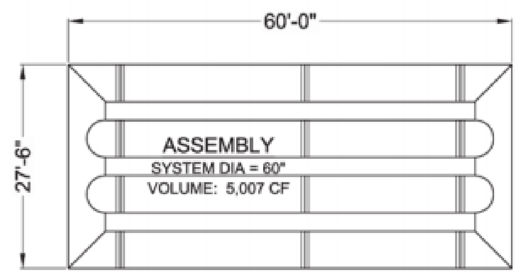
It is recommended that a corrugated metal pipe (CMP; Aluminized Steel Type 2) be considered for detaining and/or infiltrating stormwater. It is further recommended that the system de designed with the first pipe in the system (or a manifold of 2 pipes) be reserved as a sediment forebay to reduce impacts to infiltration, as well as facilitate ease of system maintenance. CMP detention systems are available from several manufacturers. The following description is from Contech Engineered Solutions:

- Various pipe coatings and materials are available to accommodate site-specific needs: Aluminized Steel Type 2 (ALT2), Galvanized, CORLIX® Aluminum, and Polymeric. Aluminized Steel Type 2 is recommended in areas using salt on roadways.
- Wide range of gages, corrugations, and shapes, in diameters 12” – 144”.
- Pipe can be fully or partially perforated for infiltration or groundwater recharge applications.
- Custom access risers and manifolds provide direct access for maintenance.
- Outlet control devices can be incorporated within the system, eliminating the need for a separate structure.
- Customizable - a variety of fittings allow CMP to match most layout configurations.
- May be designed for heavy loading and high maximum cover.

To maximize storage while minimizing site impacts and the costs of excavation, welding, structures and fittings, etc., pipe diameters should be maximized in similar fashion to System 2, below (*source*: Contech).



System 1



System 2