Grand Rapids Stormwater Retrofit Assessment

HRG Project 170710

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PREPARED FOR

North Central Minnesota Joint Powers Board
Itasca Soil and Water Conservation District
City of Grand Rapids, MN

HRGreen

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SUMMARY

The North Central Minnesota Joint Powers Board (NCMJPB) commissioned an analysis of the City of Grand Rapids, MN investigating potential for the retrofit of new stormwater best management practices focused on improving water quality for the Mississippi River and the various lakes within its municipal boundary. The NCMJPB partnered with the Itasca Soil and Water Conservation District and the City of Grand Rapids for this analysis.

This analysis builds on an initial phase of similar work performed in 2014 (*Grand Rapids Stormwater Water Quality Best Management Practice Retrofit Analysis*, Mississippi Headwaters Board) that focused on treatment opportunities in 5 subwatersheds within the municipal boundary. Results of that initial phase of investigation follow up modeling at one outfall, discussion with Blandin Paper Company and discussions within the City resulted in:

1) Implementation of a stormwater wetland,
2) Elimination of one Pipeshed from further consideration (apparent minimal contribution of runoff to the Mississippi River),
3) Elimination of a regional treatment opportunity on Blandin property,
4) A hold on suggestions for a water re-use system at a school property given future use uncertainties, and,
5) A hold on a significant regional treatment facility located at an outfall that will be scheduled for design during the future development of the parcel it is located in.

The current analysis focuses on the remaining portions of the City with additional consideration of modification to existing ponds, additional public property alternatives for new treatment, and options within the built residential, commercial and industrial areas of the City.

The results of the analysis suggest that implementation of two sub-surface regional detention/infiltration systems take priority. Both of these systems treat major pipesheds that are currently directly-connected (no current water quality treatment) to the Mississippi River, yield favorable return on investment and focus maintenance efforts within City property. Several options exist to also retrofit many boulevard raingardens and stormwater tree planter boxes in several pipesheds that are similarly directly-connected to a water resource.

METHODS

DESKTOP ANALYSIS

Issues and Goals Identification

To assist in driving the analysis of the City of Grand Rapids, MN stormwater infrastructure, and to identify potential opportunities to retrofit stormwater water quality best management practices (BMPs), meetings were held with City staff and the Itasca Soil and Water Conservation District. 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.

Pipeshed Delineation

The City's stormwater database (GIS) was used along with a digital elevation model in GIS to delineate pipesheds grouped into two major drainages: north of the Mississippi River and south. Given the extent of the number of storm sewer outfalls within the City, a balance was struck in the total number of outfalls (and subsequent pipesheds) deemed appropriate for the City to manage its water quality and related reporting. A decision was made to delineate pipesheds draining to lakes and then, start a new pipepshed beginning from lakes' outfall downslope to either the next lake or the Mississippi River. The resulting piepsheds then allow the City to account for watershed loading and future treatment for specific resources within its municipal boundary.

Initial Retrofit Review

A review of areas suitable for retrofitting BMPs was performed via desktop using GIS and aerial imagery (Google Earth and Street View). 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 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

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 pipesheds, 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. Field reviews of 5 pipesheds previously analyzed in an earlier report were considered in this analysis, though all were eliminated from further review or with a focus away from the outfall (*Grand Rapids Stormwater Water*

Quality Best Management Practice Retrofit Analysis, Mississippi Headwaters Board, 2014). Specifically, PMA 45 (Pipeshed S12 in this analysis) was eliminated from this analysis as subsequent monitoring performed by the City of its outfall suggested that the Pipeshed contribution of runoff to the Mississippi River is minimal.

Modeling

Each Pipeshed's stormwater effluent water quality was modeled within P8 Urban Catchment Model (version 3.5; Walker, 2015). Land use classifications from the 2014 analysis were retained for this effort. 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 effect on water quality.

The existing conditions model was used to assess the performance of various BMP alternatives in relation to the average removal of pollutants over the entire time series. 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. In the case of sub-surface treatment alternatives, published removal efficiencies were used in-lieu of modeling.

Prioritization

BMP alternatives were prioritized based on their expected value as determined by:

1. **Initial Screening:** City-wide retrofit opportunities were screened to identify projects that evaluate for water quality performance within P8, as well as to generate costs and resulting treatment value.
    a. **Priority Retrofit Opportunities:** Discussions with the City suggested prioritizing those opportunities that treat moderately large drainage areas and were within city-owned land or allowed for retrofitting of existing BMPs on private land (e.g., modification of a detention basin).
    b. **Long Term Opportunities:** To inform long-term stormwater planning, non-priority retrofit opportunities were identified that treat neighborhood blocks or site-level drainage areas.
2. **Performance**: Select potential BMPs from the screening were reviewed for their 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. Pollutant removal was estimated by developing a conceptual design and then analyzed within P8 for an average precipitation year.
3. **Ease of maintenance**: WEF-PDV was used to estimate the costs of moderate levels of maintenance for annual, intermittent and periodic maintenance activities. 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).

Several opportunities were considered for the City of Grand Rapids:

Stormwater Tree Planter Boxes – A form of bioretention relying on filtration and/or infiltration of stormwater runoff. Street gutter runoff enters a sediment collection area (forebay) before entering the filtration media area where plant uptake, microbial decomposition and soil sorptive processes extract a portion of pollutants before either infiltrating or passing treated water via an outlet back to the storm sewer. The box is typically constructed with concrete walls. The system can include an overflow riser and/or a perforated drain tile that connect to the storm sewer. Plantings may include trees, shrubs, grasses and forbs and are typically designed with fewer species in larger planting groups to increase maintenance ease. Tree plantings offer the additional benefit of increasing shade near parking and walking areas.

Boulevard Raingardens – Similar to stormwater tree planter boxes, raingardens relying on filtration and/or infiltration of stormwater runoff and are designed very similarly to them. The main difference is that raingardens do not use concrete walls/boxes, though may require a short retaining wall. It is also important for the inclusion of a forebay and simple planting plans to increase the ease of maintenance and life span.

Parking Lot Retrofits – Parking lot runoff can be treated in a number of ways. In general, runoff can be collected along the perimeter of the lot or within islands using bioretention or via detention below the driving surface. Sub-surface systems may include collecting water via catch basins or through the use of permeable pavement systems (asphalt, concrete, pavers, reinforced grass pavement) that deliver runoff to a detention cell that infiltrates or filters stormwater. Sub-surface detention storage can be 100% void space, through the use of proprietary systems or reclaimed stormwater pipes, or filled with larger, granitic aggregate with approximately 40% void space depending on the system.

Pond Retrofits – Opportunities to increase storage and add filtration functions within existing ponds occur within the city of Grand Rapids. Increased storage can come in the form of expansion of pond area/depth, modification of the outlet structure or drawing down dead storage (permanent pool) ahead of a high probability storm event. In most cases within developed urban settings, expansion of pond area and depth is limited by infrastructure. Modification of outletss allow for inclusion of a water quality outlet (e.g., orifice within an existing weir wall) and raising of the existing overflow, where adjacent land allows for ponding expansion. Reconfiguration of inlets to avoid shortcutting treatment may sometimes be possible. Drawing down dead storage ahead of storm events with a pre-determined probability and magnitude to greatly increase storage can be accomplished through automated systems such as OPTI-RTC (https://optirtc.com/). This system modifies the existing outlet structure with a draw down orifice controlled by telecommunications hardware linked to the city's computer network which is linked to NOAA weather forecasting. An operating system on a desktop or virtual computer allows an operator to set controls and manual overrides. It is typically most economical to have more than one BMP outfitted with the outlet hardware, but the system is expandable to accommodate new or additional retrofit BMPs. Filtration can be integrated into ponds through the use of iron-enhanced sand filter benches, whether within the perimeter of the pond or downstream from it. In any case, it is important that the system be designed and maintained to allow the filter bed to dry between storm events to avoid development of anoxic conditions which can lead to phosphorus leaching as well as the formation of a hard surface shell that must be manually broken up to restore functionality. The lifetime of the filter material is dictated by the quantity of phosphorus it is exposed to as driven by landscape composition and area. Over time phosphorus binding sites on the iron decrease and the media must be replaced. Designs should consider the 30-year costs of maintenance and media replacement for various sizes of filters to maximize value.

Sub-surface Regional Treatment Systems – 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. Permeable pavements typically come in five forms: asphalt, concrete, gravel-pave, grass-pave or pavers. Asphalt, concrete and pavers have been used for foot and vehicular traffic and parking areas, while reinforced gravel- and grass-pave systems have primarily been used for overflow parking or high foot traffic areas. In all cases, typical designs call for an aggregate base with approximately 40% void space for water storage. Systems can allow for infiltration, filtration or both. Filtration systems tie back into the stormsewer.

Table 1. Retrofit options, level of priority and screening criteria for suitability.

<table>
<tr><th>Prioritization</th><th>Option</th><th>Site Suitability Criteria</th></tr>
<tr><td rowspan="3">1st Level</td><td>Pond retrofit: Iron-enhanced sand filter</td><td>Space available for new bench that does not limit initial design flood mitigation goals.
Allowable rise in live storage elevation.
Absence of tailwater at outlet to allow filter to dry between storm events.</td></tr>
<tr><td>Pond retrofit: Opti-RTC drawdown control</td><td>Does not limit initial design flood mitigation goals.
Allowable rise in live storage elevation.
Adaptable Inlet and outlet configuration.</td></tr>
<tr><td>Sub-surface Detention/Infiltration</td><td>Suitable publicly-owned land.
Infiltration: suitable soils.
No known groundwater/sub-surface limitations.</td></tr>
<tr><td rowspan="3">2nd Level</td><td>Parking Lot Retrofit</td><td>Perimeter with adequate space for above-ground BMPs
Catch basins along perimeter with significant drainage for bypass to BMP.
No known groundwater/sub-surface limitations.</td></tr>
<tr><td>Boulevard Raingarden</td><td>Drainage to site is equivalent to $\geq$ 5 property fronts.
Site is located proximal to, but upstream from, a catch basin.
At least 15 feet of space behind curb with no obstructions in landscape.
Land behind curb does not slope downhill.
Land behind curb does not exceed 3:1 in upslope.</td></tr>
<tr><td>Stormwater Tree Planter</td><td>Drainage to site is equivalent to $\geq$ 5 property fronts.
Site is located proximal to, but upstream from, a catch basin.
At least 5 feet of space between curb and sidewalk.</td></tr>
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RESULTS

ISSUES AND GOALS IDENTIFICATION

PIPESHED DELINEATION

The City of Grand Rapids was divided into two large watersheds by the Mississippi River. Land surface digital elevation models (DEM) were corrected for drainage imposed by storm sewers and for artificial limitations on drainage in the DEM where the modeled surface was filled over a known culvert. Outfalls served as the outlet to the various stormsewer trunks and branches. The north watershed was divided into 24 pipesheds and the southern watershed was divided into 28 (Figure 1). These pipesheds served to clip land use and soils data to assist in stormwater modeling and can be seen as stormwater management areas during city capital improvement planning/implementation and MS4-NPDES reporting.

CITY-WIDE RETROFIT OPPORTUNITIES

A total of 175 individual stormwater water quality focused best management practice opportunities were identified within the city of Grand Rapids. The north watershed provides 136 opportunities including 48 stormwater tree planter boxes in areas with limited boulevard green space, 6 parking lot retrofits, 5 pond retrofits, 113 likely suitable and optimal sites for boulevard raingardens, and 3 sub-surface regional treatment systems (Figure 2). The southern watershed provides 39 opportunities including 4 stormwater tree planter boxes and 30 likely suitable and optimal sites for boulevard raingardens and 5 pond retrofits (Figure 3). Not every location for stormwater tree planter boxes or raingardens was visited during this analysis and will require field verification for site suitability. In addition, it is expected that additional locations for these BMPs exist in north and south watersheds, though not recommended N18b (non-contributing, isolated subwatershed) or S12 (limited outflow to the Mississippi River). Note that limited locations for BMPs are listed in terms of optimal locations, should their consideration become necessary.

Priority Retrofit Opportunities

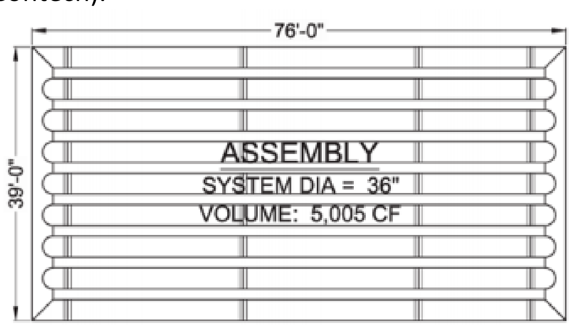
First Level priorities were reviewed at existing ponds and, in GIS, opportunities below ground along main stormsewer lines. Each pond ideally located for possible modification for either/both iron enhanced sand filters and/or Opti-RTC controls was then visited to determine constructability, using the site suitability criteria described above. Though there are a few ponds located in the Northern subwatershed, none had sufficient room for increased storage likely needed for either retrofit option or had sufficient land space to include a filtration bench. The Southern subwatershed had several potential ponds that were reviewed in similar fashion. Field visits, including inlet and outlet surveys, suggest however, that each pond identified as candidates for these retrofit options was infeasible for several reasons. First and foremost, modification of existing live storage bounce would cause the primary function of the pond (i.e., flood control) to be compromised as the result of pond overtopping perimeter berms, leading to localized flooding of property. In other cases, downstream water body normal water elevations currently limit pond discharge via tail water conditions that could back up water within the pond, as well as within upstream stormwater pipes, potentially leading to catch basin surcharging. The last cases leading to pond modification infeasibility were the presence of high quality wetland plant communities covering the entirety of the live storage and transition zones. Modifications to the hydraulics (i.e., detention depths and duration) would lead to negative impacts on these communities and rendered these ponds infeasible for modification.

Two locations were identified for sub-surface detention and/or infiltration in the North subwatershed. Both locations occur within either the road footprint or within City-owned open space. Each system would treat substantial pipeshed areas comprised of heavily urbanized land uses that are currently directly connected to the Mississippi River. An additional, smaller location for such a system was also identified between these two locations, though determined infeasible given that the parking lot where the system would be located is currently built over likely contaminated wood material from industrial processes. The City could consider including plans for site remediation and inclusion of a third sub-surface detention system at this location in the future.

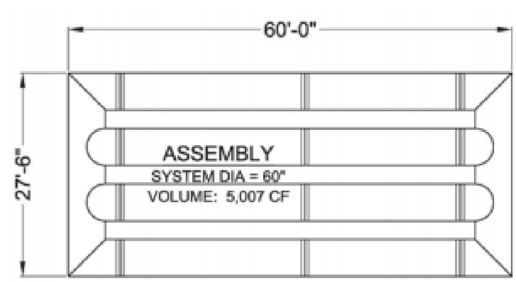
For the two best locations, it is recommended that a corrugated metal pipe (CMP; Aluminized Steel Type 2) be considered for detaining and/or infiltrating stormwater. It is further recommended that the system de designed with the first pipe in the system (or a manifold of 2 pipes) be reserved as a sediment 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

Long Term Opportunities

The City has tremendous potential for retrofitting perimeters of parking lots, boulevard raingardens and stormwater tree planters. The City has included boulevard and roundabout raingardens in the past, illustrating its openness to these options. The majority of opportunity exists in the North subwatershed, though options exist in the residential areas of the South subwatershed as well. Retrofitting of these options should first focus on those pipesheds that are currently directly connected to a water resource and without plans for regional-scale treatment. Locations of these distributed systems were identified in this study and focused on placement in upstream proximity to catch basins and serving sufficient drainage area. Implementation of these systems can be facilitated through partnership with the Itasca Soil and Water Conservation District either in coordination with the City's pavement management program or independently.

For small, distributed green-infrastructure projects such as these, the following recommendations are presented to optimize performance, life span and ease of maintenance:

1. Sediment forebays, such as the *Rain Guardian – Turret* (http://www.rainguardian.biz/), should be incorporated in lieu of turf strips or rocked depressions. This particular system is designed to capture sediment in an easily cleaned out forebay and to never cause flow bypass, as is commonly seen with turf grass or non-forebay curb-cut raingardens. In non-forebay curb cut systems, sediment quickly builds up at the inlet, bluegrass grows though it and the inlet builds up a dam leading to gutter flow bypass within 2-3 years.
2. Planting plans should prioritize native species but include cultivated, familiar landscaping plants, be very simple in their design and prioritize sedges supplemented with taller grasses, small shrubs and pollinating flowers. History has shown in Minnesota that a well-designed planting arrangement using these principles leads to higher public acceptance and maintenance commitment.

Retrofit Recommendations

Summary of Pipeshed Retrofit Opportunity Review

The following table summarizes the results of this study, the Phase One retrofit assessment and City decisions on implementation timing of the Phase One recommendations. All identified options that were reviewed were documented in GIS shapefiles for the city (Figure 2, Figure 3).

Table 2. Summary of retrofit opportunity review by pipeshed.

Subwatershed	Priority	Retrofit Options / Notes
N1, N2, N4, N5, N19-24	N/A	Largely undeveloped lands.
N3	Level 2	Largely undeveloped lands but with residential around lake. Raingarden locations identified.
N6, N7, N9	Level 2	Raingarden locations identified.
N8	Level 2	Minimal locations for raingardens and stormwater planters.
N10-12	N/A	No opportunities identified, though possible coordination with MNDOT on swale checks.
N13	Level 1	Sub-surface detention/infiltration. Raingardens and stormwater tree planters could be implemented to supplement the sub-surface treatment system. Phase 1 assessment of detention system located within Blandin Paper property subsequently deemed infeasible due to plant expansion plans.
N14	Level 1	Sub-surface detention/infiltration for main sewer line. Raingardens and stormwater tree planters could be implemented in smaller tributary line in its southwest corner.
N15, N16	Level 2	Minimal locations for raingardens. Phase 1 assessment stormwater wetland implemented 2017 in N16.
N17	Level 2	Minimal locations for raingardens and stormwater planters.
N18	N/A	No opportunities identified, though possible coordination with MNDOT on swale checks.
N18b	N/A	Non-contributing to surface waters.
S1-5, S7-11, S26-28	N/A	Largely undeveloped or low density.
S6	Level 2	Raingardens may be possible in this pipeshed, though topography may limit their suitability.
S12	N/A	Largely seldom contributing to surface waters as determined by City monitoring post Phase 1 assessment.
S13	Level 2	Minimal locations for raingardens and stormwater planters.
S15	Level 2	Locations for raingardens.
S16	N/A	Large wetland manages stormwater.
S17	Level 2	Potential locations for stormwater planters.
S18	Level 2	Potential locations for stormwater planters. Pond retrofit deemed infeasible.
S19	N/A	Pond retrofits deemed infeasible.
S20	Level 2	Potential locations for stormwater planters, though not visited in this

Subwatershed	Priority	Retrofit Options / Notes
		assessment. See suitability criteria (Table 1).
S21, S25	N/A	Infeasible.
S22	N/A	Regional treatment within the City compost site scheduled for implementation on site development.
S23, S24	N/A	Infeasible – airport.

Recommendations

The following two projects are recommended for consideration. These projects treat substantial portions of the City that are currently directly connected to the Mississippi River, attain tremendous treatment levels, prove to be valuable in terms of return on investment and are located within City property. These also constitute the last major regional treatment options for the City as much of the South subwatershed is managed by pond systems or wetlands. The North subwatershed has at least one non-contributing pipeshed and several medium and local-sized BMPs in place, though there remain several directly connected sewer lines to either lakes or the Mississippi River. The largest of these connections, in terms of the combination of drainage area and land use effects on pollutant generation and transport, are described below.

Pipeshed N13

Subwatershed N13 is 140 acres in area and comprised of dense build out with commercial and residential land uses. Stormsewer drains the subwatershed from northwest to southeast directly into the Mississippi River. Though there are several small parcels of city-owned land and one tax forfeit parcel, none are optimally located to treat drainage areas of substantial size and/or pollutant load generation.

Potential Strategy

There are at least three forms of retrofits possible for this subwatershed: boulevard raingardens, stormwater planters and sub-surface treatment. Raingardens and stormwater planters are recommended to be included within the City's CIP as streets are refurbished or via neighborhood retrofit efforts in partnership with the Itasca SWCD. The subwatershed's stormsewer combines to the main trunk (60-inch) under 2nd Street NW, between 1st Ave NW and Highway 169, where a below-ground detention system could be installed. NRCS data suggest silt-loam soils within the top 2-feet with fine sandy-loam underneath. Estimated ground water depths exceed 80-inches. Infiltration rates of the complete profile are possibly between 0.57 – 1.98 inches per hour depending on compaction, soil structure, or seasonally-high ground water. Given these assumptions, a corrugated metal pipe (CMP) detention and infiltration system is possible at this location. A soil boring and infiltration analysis will be required to refine these results.

Cost-Benefit

To model the potential performance of a detention-only sub-surface system, iterations of double manifold units comprised of 60-inch pipe covering 60 linear feet by 28 feet (5,000 ft^3 of storage) were made to estimate total annual treatment. The outlet of each iterative system was limited to 24-inches and positioned at the center of the storage pipe to meet the downstream trunk system pipe's invert elevation. For the detention option, this will mean a permanent pool below the outlet that may need to be pumped for maintenance. If, however, final design pipe selection and installation invert elevations allow, this outlet orifice may be positioned closer to the bottom of the storage system for more passive draw down. For the infiltration option, it is assumed that infiltration rates will be 1.25-inches per hour (average of the expected NRCS published range for soils at this site). Buildable site constraints led to maximizing both the detention and infiltration options to the same footprint. The decision to maximize treatment for infiltration also informed this decision.

It is important to clarify that no hydrologic and hydraulic modeling was performed in this study to make this sizing. Further analysis will be required to ensure proper outlet sizing that avoids upstream surcharging of the subwatershed's stormsewer. It is also important to note that final pipe sizing may be affected by existing stormsewer invert elevations, obstructions and ground water.

Table 3. Pipeshed N13 Existing Conditions Annual Runoff and Loading

Subwatershed	Acres	Runoff volume (ac-ft/yr)	Total Suspended Sediment (lbs/yr)	Total Phosphorus (lb/yr)
N13	140	170	61,466	196

Table 4. Pipeshed N13 Treatment Results

Option	Runoff Volume Reduced (ac-ft/yr)	Total Suspended Sediment Treated (lbs/yr)	Total Phosphorus Treated (lb/yr)
Sub-surface detention (630 ft x 30 ft)	0	31,690 (52%)	39.3 (20%)
Sub-surface infiltration (630 ft x 30 ft)	56.7 (33%)	39,104 (64%)	78.7 (40%)

Table 5. Pipeshed N13 Cost-benefit

Option	Design+Install	30-yr Present Day Value (PDV_{50})	$PDV_{50}/^{a}TP_{50}$
Sub-surface detention	$735,350	$765,307	$390
Sub-surface infiltration	$811,800	$814,757	$207

[a]TP_{30} represents 30-years of total phosphorus treatment.

[b] Based on personal communication with Contech representative for one cell (27.5' by 60' footprint and comprised of 250' of total pipe totaling 4860 ft^3 of storage for detention systems and 7,725 ft^3 of storage for infiltration systems with rock backfill; assumes 2-ft of fill on top of system; $22,400 for one such cell including all pipe, stubs, risers, fabrication, and delivery to the job site; excavation). It is recommended that the first pipe (30 ln-ft and assumed 1200 ft^3 of volume) of the system be used as a sediment forebay with access for annual sediment removal (estimated at 450 ft^3 per year). Annual maintenance is assumed to be $1,480 including: $260 of inspection (2 per year), $480 inlet/outlet cleaning (2 per year) and one forebay sediment removal ($740). Corrective and infrequent maintenance expenses occur as follows:

Table 6. Cost schedule of maintenance activities for N13 sub-surface treatment.

Year	Annual	Intermittent	Year	Annual	Intermittent
1	$1,480	$0	26	$1,480	$0
2	$1,480	$0	27	$1,480	$390
3	$1,480	$390	28	$1,480	$0
4	$1,480	$0	29	$1,480	$0
5	$1,480	$989	30	$1,480	$1,379
6	$1,480	$390	31	$1,480	$0
7	$1,480	$0	32	$1,480	$0
8	$1,480	$0	33	$1,480	$390
9	$1,480	$390	34	$1,480	$0
10	$1,480	$989	35	$1,480	$989
11	$1,480	$0	36	$1,480	$390
12	$1,480	$390	37	$1,480	$0
13	$1,480	$0	38	$1,480	$0
14	$1,480	$0	39	$1,480	$390
15	$1,480	$1,379	40	$1,480	$989
16	$1,480	$0	41	$1,480	$0
17	$1,480	$0	42	$1,480	$390
18	$1,480	$390	43	$1,480	$0
19	$1,480	$0	44	$1,480	$0
20	$1,480	$989	45	$1,480	$1,379
21	$1,480	$390	46	$1,480	$0
22	$1,480	$0	47	$1,480	$0
23	$1,480	$0	48	$1,480	$390
24	$1,480	$390	49	$1,480	$0
25	$1,480	$989	50	$1,480	$989

Pipeshed N14

Subwatershed N14 is 290 acres in area and comprised of dense build out with commercial and residential land uses. Storm sewer drains the subwatershed along two pipe tributaries that join as a trunk line before discharging to the Mississippi River. The larger of the tributaries drains 260 acres from north to south. The remaining pipeshed drains from northwest to southwest before joining the trunk line. Both tributaries have city-owned land just upstream of their confluence, though the smaller drainage area's land contains contaminated material underneath a parking lot where potential BMPs would be considered post-remediation.

Potential Strategy

As in N13, there are at least three forms of retrofits possible for this subwatershed: boulevard raingardens, stormwater planters and sub-surface treatment. Raingardens and stormwater planters are recommended to be included within the City's CIP as streets are refurbished or via neighborhood retrofit efforts in partnership with the Itasca SWCD. Given the smaller drainage area's need for sub-soil remediation, no sub-surface or infiltration BMPs are recommended within the parking lot on City land immediately upstream of the trunk line. Raingardens and stormwater planters should be considered for the mid-subwatershed areas for this tributary. The main subwatershed's stormsewer combines to the main trunk (66-inch) within open space along the north side of 2nd Street NE, between 1st Ave NE and 3rd Ave NE, where a below-ground detention system could be installed. NRCS data suggest urban-modified soils. Estimated ground water depths exceed 80-inches. Given the highly modified and somewhat unpredictable nature of these soils, infiltration rates range between 0.57 – 5.95 inches per hour depending on compaction, soil structure, or seasonally-high ground water. Unlike N13, it is more difficult to accurately estimate a smaller range of infiltration rates. Given these assumptions, a corrugated metal pipe (CMP) detention and infiltration system is possible at this location, though a soil boring and infiltration analysis will be required to refine these results.

Cost-Benefit

As in N13, to model the potential performance of a detention-only sub-surface system, iterations of double manifold units comprised of 60-inch pipe covering 60 linear feet by 28 feet (5,000 ft^3 of storage) were made to estimate total annual treatment. The outlet of each iterative system was limited to 24-inches and positioned at the center of the storage pipe to meet the downstream trunk system pipe's invert elevation. For the detention option, this would mean a permanent pool below the outlet that may need to be pumped for maintenance. If, however, final design pipe selection and installation invert elevations allow, this outlet orifice may be positioned closer to the bottom of the storage system for more passive draw down. If site soils are suitable for infiltration in place of detention, it is assumed that infiltration rates will be 1.25-inches per hour (average of the expected NRCS published range for soils at this site). Buildable site constraints led to maximizing both the detention and infiltration options to the same footprint. Unlike N13, the detention option was maximized to fit 1.35 acres of footprint on the site, while the infiltration option was maximized in terms of highest incremental cost breakpoint (65% TP) resulting in a smaller footprint (0.83 acres). The N14 maintenance cost schedule was also assumed the same as previously presented for N13 systems, though there will be a small increase in costs associated with sediment disposal given the larger drainage area.

It is important to clarify that no hydrologic and hydraulic modeling was performed in this study to make this sizing. Further analysis will be required to ensure proper outlet sizing that avoids upstream surcharging of the subwatershed's stormsewer. It is also important to note that final pipe sizing may be affected by existing stormsewer invert elevations, obstructions and ground water.

Table 7. Pipeshed N14 Existing Conditions Annual Runoff and Loading

Subwatershed	Acres	Runoff volume (ac-ft/yr)	Total Suspended Sediment (lbs/yr)	Total Phosphorus (lb/yr)
N14	260	204	72,313	232.2

Table 8. Pipeshed N14 Treatment Results

Option	Runoff Volume Reduced (ac-ft/yr)	Total Suspended Sediment Treated (lbs/yr)	Total Phosphorus Treated (lb/yr)
Sub-surface detention (1.35-ac)	0	38,481 (73%)	68.1 (40%)
Sub-surface infiltration (0.83-ac)	82.7	43,532 (82%)	110.8 (65%)

Table 9. Pipeshed N14 Cost-benefit

Option	Design+Install	30-yr Present Day Value (PDV_{50})	$PDV_{50}/^{*}TP_{50}$
Sub-surface detention	$2,100,000	$2,130,000	$626
Sub-surface infiltration	$1,416,000	$1,446,000	$261

[a]TP_{30} represents 30-years of total phosphorus treatment.

[b] Based on personal communication with Contech representative for one cell (27.5' by 60' footprint and comprised of 250' of total pipe totaling 4860 ft^3 of storage for detention systems and 7,725 ft^3 of storage for infiltration systems with rock backfill; assumes 2-ft of fill on top of system; $22,400 for one such cell including all pipe, stubs, risers, fabrication, and delivery to the job site; excavation). It is recommended that the first pipe (30 ln-ft and assumed 1200 ft^3 of volume) of the system be used as a sediment forebay with access for annual sediment removal (estimated at 450 ft^3 per year). Annual maintenance is assumed to be similar to that presented for N13, with slightly greater expenses related to sediment disposal.

Figure 1. City of Grand Rapids Pipesheds and Topography

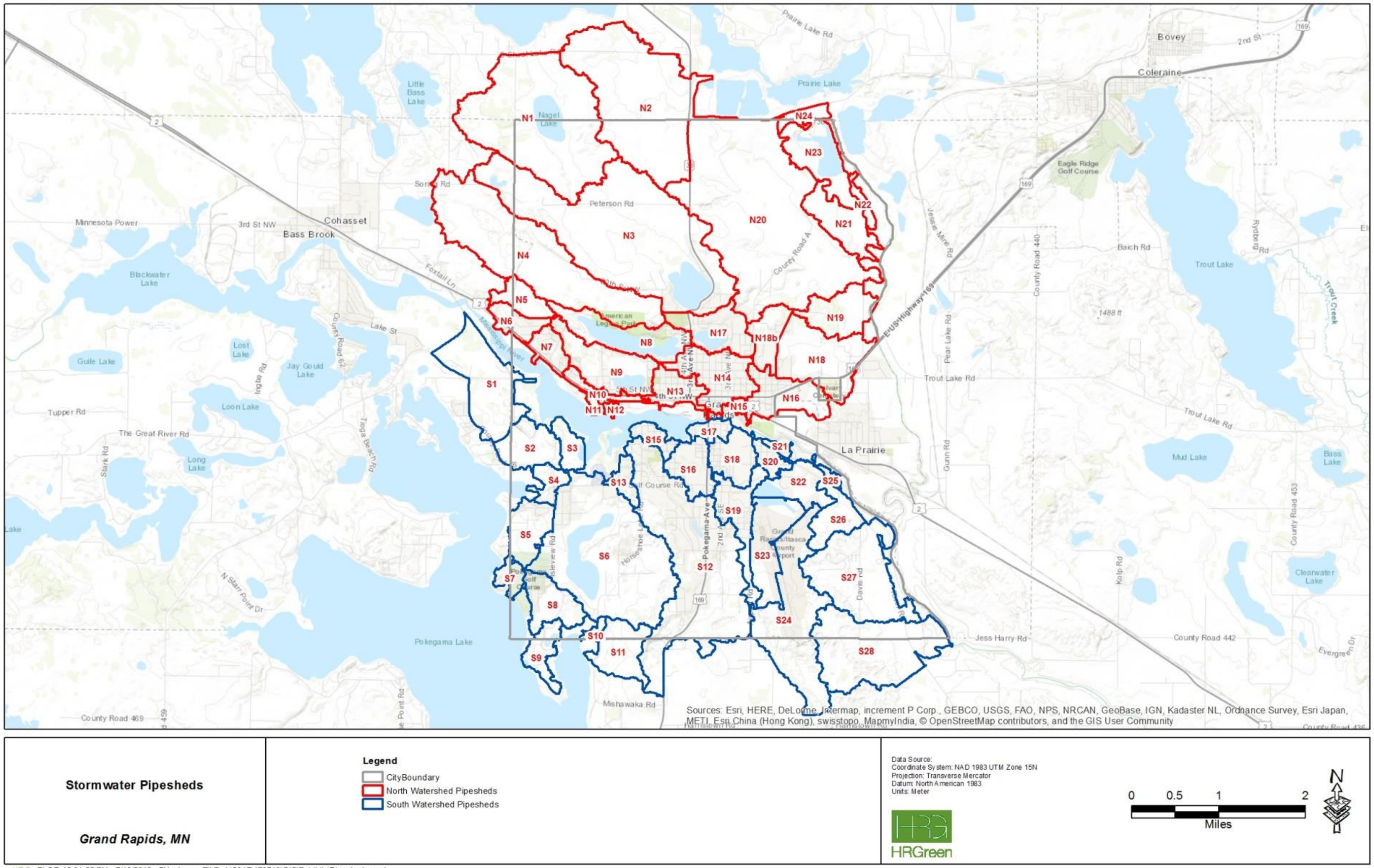


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Figure 2. North watershed potential stormwater retrofit options.

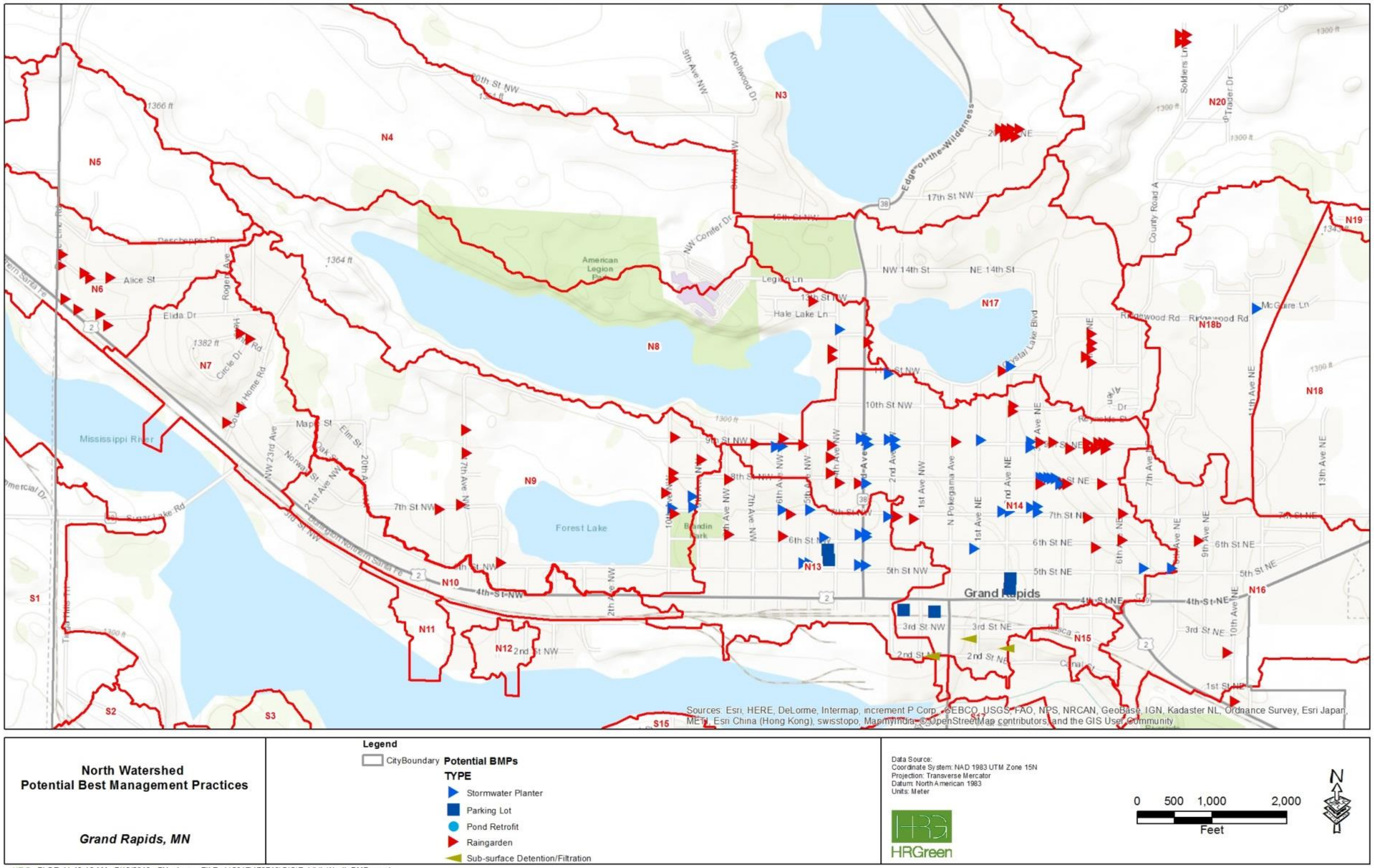

Figure 3. South watershed potential stormwater retrofit options.