2020 Facility Planning Project

Final Technical Memorandum

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1.0 EXECUTIVE SUMMARY

The purpose of this analysis was to use the existing watershed model of the Kinnickinnic River watershed to evaluate the potential impacts of stormwater management practices located in the Holmes Avenue Creek subwatershed and the Villa Mann Creek subwatershed on Wilson Park Creek. The analysis for the Holmes Avenue Creek subwatershed focused on the implementation of stormwater management practices in the area east of S. 13th Street and evaluated impacts on flood flows and water quality issues north of Layton Avenue, between S. 1st Street and S. 6th Street on Wilson Park Creek. Impacts on flood flows and water quality at the downstream end of Holmes Avenue Creek were also analyzed. The specific water quality issues evaluated include fecal coliform (FC), total phosphorus (TP), and total suspended solids (TSS).

The analysis for the Villa Mann Creek subwatershed evaluated impacts on flood flows and water quality at the downstream end of Villa Mann Creek based on widespread implementation of stormwater management practices across the subwatershed. The specific water quality issues evaluated include FC, TP, and TSS.

The cumulative impact on both flood flows and water quality, based on implementation of stormwater management practices on both Villa Mann Creek and Holmes Avenue Creek as described above, was also analyzed at the terminus of Wilson Park Creek.

1.1 Scenarios

The 2020 Facilities Plan team reviewed the model scenario runs developed in support of MMSD's 2020 Facilities Plan (2020 FP) and the Southeastern Wisconsin Regional Planning Commission's (SEWRPC) Regional Water Quality Management Plan Update (RWQMPU).

Additional scenarios were determined to evaluate impacts on flood flows and water quality on Wilson Park Creek. The 2020 FP team selected stormwater management measures based on previous analyses completed under the 2020 FP and RWQMPU. The scenarios analyzed include:

- **Scenario 1: Future Land Use** – Applies the 2020 land use developed for the 2020 FP with no other changes in management. It provides a baseline against which to compare the other scenarios.
- **Scenario 2: RWQMPU Preferred Alternative** – Based on future land use with the NR151 requirements for new development and redevelopment. This scenario also includes additional CSO and SSO reductions, runoff reduction from residential areas, and additional management measures resulting in fecal coliform and phosphorus reductions.
- **Scenario 3: Extreme Measures** – Builds on Scenario 2 with additional and augmented management measures.
- **Scenario 4: Extreme Measures (Scenario 3) plus parking surface storage** – Builds on Scenario 3 with retrofit parking lot storage.
- **Scenario 5: Extreme Measures plus rooftop storage** – Builds on Scenario 3 with retrofit rooftop storage.
- **Scenario 6: Extreme Measures plus parking surface storage and rooftop storage** – Builds on Scenario 3 with both parking lot and rooftop storage.
- **Scenario 7: Extreme Measures plus parking porous pavement and rooftop storage** – Builds on Scenario 3 with both porous pavement in parking lots and rooftop storage.

The information for Scenarios 1-3 was taken directly from the RWQMPU models. Scenarios 4-7 were developed from the RWQMPU Extreme Measures Scenario, which was the scenario from the RWQMPU that had the largest potential to improve water quality. To determine potential water quantity reductions, either parking lot storage (surface storage or underground storage with porous pavement), and/or rooftop storage were added to this scenario. Parking lot storage and rooftop storage were determined to be the most appropriate measures to reduce peak flows from commercial and industrial land uses, which were the targeted land uses in the two subwatersheds. The management measures were represented in the model by explicitly simulating the measures (in aggregate) and/or by adjusting the land use characteristics for the areas where they will be applied.

1.1 Results

Scenarios 2 and 3 result in only small changes in peak flood flows resulting from a 100-year rainfall event (Table 1). This is not surprising because runoff reduction measures in these scenarios primarily address new development and redevelopment, and the 2020 FP land use suggests little change in the existing urban land use of the Wilson Park Creek watershed. Retrofitting roof top and parking lot storage (scenarios 4 through 7) can provide moderate reductions in peak flows, depending on the extent to which upstream source areas are managed.

For water quality, scenarios 2 and 3 provide moderate to substantial reductions in pollutant loads. Provision of additional roof or parking lot storage (scenarios 4 through 6) provides only a small incremental reduction in loads as these management practices serve primarily to delay the delivery of pollutants; however, use of porous pavement (scenario 7) results in a notable reduction in solids loads.

Table 1 Maximum Percentage Reductions in Peak Flows and Pollutant Loads from Evaluated Scenarios Relative to Future Land Use (2020)

Management Scenarios	100-year Storm Peak	Total Phosphorus Load	Fecal Coliform Load	Total Suspended Solids Load
RWQMPU (Scenario 2)	-1.2%	-11.3%	-40.5%	-6.0%
Extreme Measures (Scenario 3)	-1.2%	-29.2%	-69.7%	-6.0%
Added Storage (Scenarios 4 – 6)	-22.6%	-29.0%	-69.6%	-6.4%
Rooftop storage plus Porous Pavement (Scenario 7)	-15.8%	-31.3%	-71.0%	-13.2%

The detailed examination of the impacts of various management alternatives on Wilson Park Creek at multiple analysis points presented below shows there are potential benefits, although their magnitude is somewhat limited. The following conclusions are made relative to the peak flow from the 100-year design storm and associated flooding potential:

1. NR 151 rules and the stormwater management measures modeled under the Southeastern Wisconsin Regional Planning Commission's (SEWRPC) Regional Water Quality Management Plan Update (RWQMPU) Preferred Alternative and Extreme Measures scenarios will have little impact on storm flow peaks in Wilson Park Creek because the watershed is largely built out and little new development or redevelopment is anticipated.
2. Additional short-term storage of water on roofs and parking lots in commercial and industrial areas can reduce the 100-year storm peak by up to 22 percent in Villa Mann Creek and almost 11 percent on Holmes Avenue Creek (given assumptions regarding participation). Changes in peak flow in the mainstem of Wilson Park Creek are small (4 percent just downstream of the confluence with Holmes Avenue and 1 percent at the terminus), primarily because only a small amount of the total upstream drainage area was selected for additional BMPs that provide storage.
3. The additional storage BMPs provide a greater fractional reduction in peak flows for storms smaller than the 100-year storm.

The following additional conclusions are made relative to water quality:

1. The RWQMPU Preferred Alternative and Extreme Measures scenarios would provide substantial improvement in fecal coliform and total phosphorus loads and concentrations in Wilson Park Creek.
2. Additional storage of stormwater on roofs and parking lots will not have a significant impact on pollutant loads; however, use of porous pavement in parking lots can reduce solids loads.
3. Short-term storage BMPs have the potential to increase the length of time with elevated pollutant concentrations by delaying some of the loading until after the storm peak when dilution flows are lower. Potential adverse impacts on pollutant concentrations could be mitigated by using porous pavement rather than surface storage on parking lots.

2.0 INTRODUCTION

The Milwaukee Metropolitan Sewerage District (MMSD) serves 1.1 million people in a 411 square mile planning area. In 2007, MMSD developed the 2020 Facilities Plan, which identifies the facilities, programs, operational improvements, and policies required by the year 2020 to meet the existing regulatory framework and permitting requirements.

In support of the 2020 Plan, the 2020 Facilities Plan Team developed watershed models of the entire planning area, including the Kinnickinnic River watershed. These models were developed using EPA's Hydrological Simulation Program – FORTRAN (HSPF) and Tetra Tech's enhanced version of HSPF known as the Loading Simulation Program in C++ (LSPC). After calibration and validation to existing conditions, these models were used to evaluate a variety of future management scenarios.

The purpose of the current work is to use the existing model of the Kinnickinnic River watershed to evaluate the potential impacts of stormwater management in the Holmes Avenue Creek subwatershed and the Villa Mann Creek subwatershed on Wilson Park Creek, a highly developed tributary of the Kinnickinnic River (Figure 1). Water quality issues are of interest throughout this area. There is also a specific interest in impacts on flood flows north of Layton Avenue, between S. 1st Street and S. 6th Street on Wilson Park Creek.

The current work starts with evaluation of results using existing model scenario representations (Section 3). As in previous work, results of different management scenarios are compared based on runs across a common period of 1987-1997 weather. For the current effort, however, the weather input file was modified to artificially insert the 100-year design storm event at 21 June 1997 – allowing detailed evaluation of impacts of management on extreme storm event runoff. Additional management measures aimed at stormwater from highly impervious portions of the watershed were then added to create four new scenarios (Section 4).

There are two rain gauges used in the Wilson Park model, both available at a 15-minute time step (Milwaukee Mitchell Field and Milwaukee Gage #1203 at 245 W. Lincoln Ave.). To evaluate response to a 100-year design storm, the observed precipitation at both rain gauges for the June 21, 1997 storm event is replaced with a 100-year 24-hour design storm with a total depth of 5.88 inches, as determined by the SEWRPC TR-40 frequency analysis. The inserted time series reflects an SCS Type II synthetic rainfall distribution, while the observed values of other meteorological data are appropriate to warm, wet-weather conditions (email from Kim O. Siemens, CDM, 22 February 2010). The comparison among scenarios was made at four assessment locations (Table 2, Figure 2, and Figure 3).

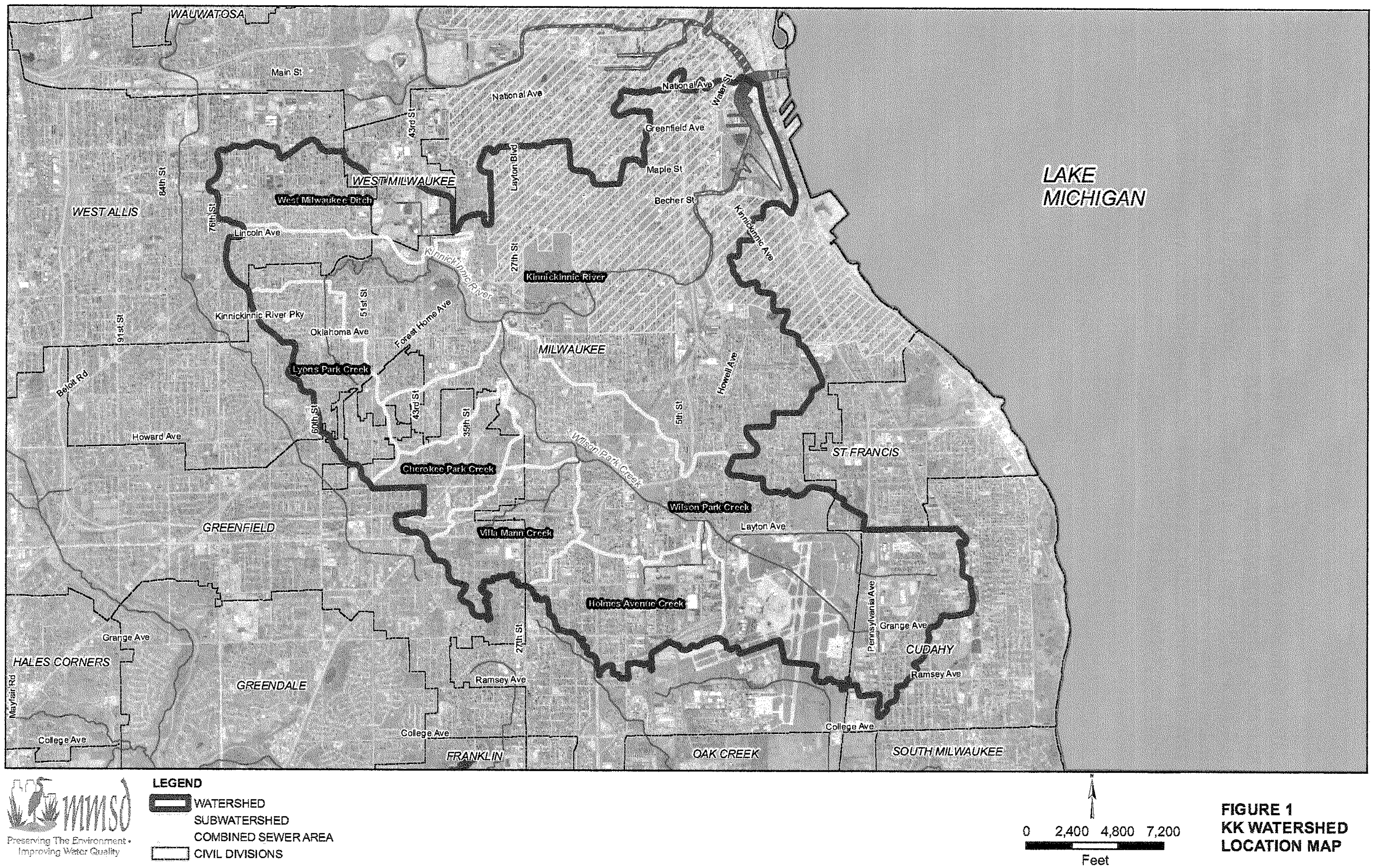


FIGURE 1
KK WATERSHED
LOCATION MAP

Table 2 Assessment Point Locations

Assessment Point	Description	Model Reach
KK-5	Outlet of Holmes Avenue Creek	830
KK-6	Outlet of Villa Mann Creek	820
R-823	Wilson Park Creek below Holmes Avenue Creek	823
KK-8	Wilson Park Creek downstream terminus	818

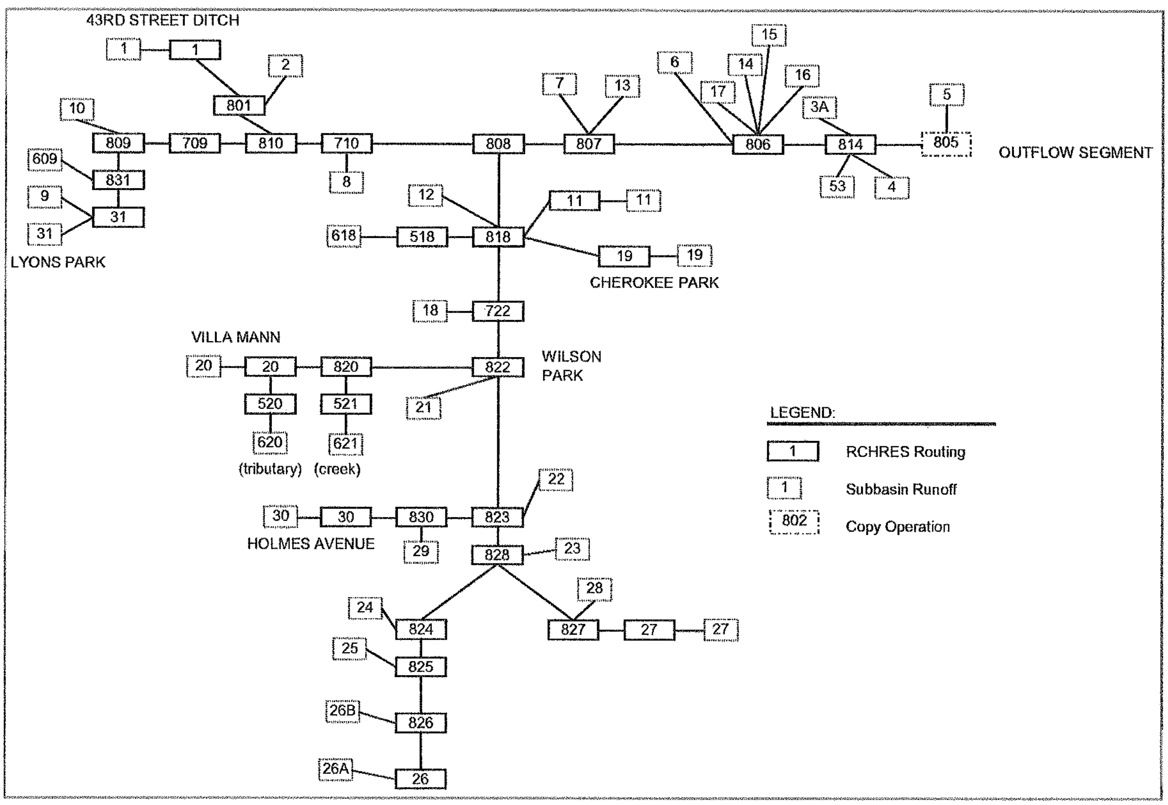


Figure 2 Schematic Representation of the Kinnickinnic River Model

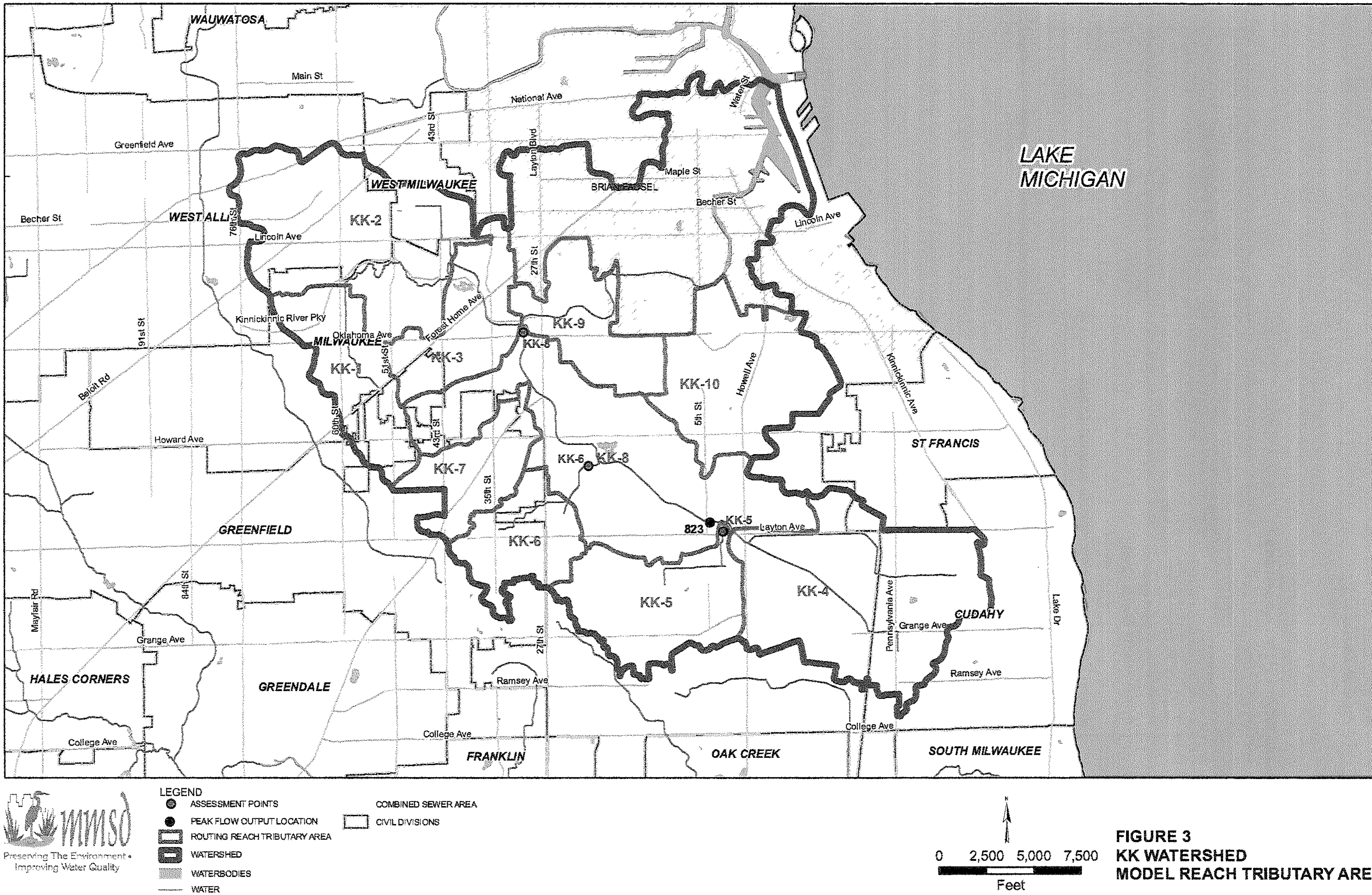


FIGURE 3
KK WATERSHED
MODEL REACH TRIBUTARY AREA

3.0 EXISTING SCENARIOS

Four existing model scenarios were rerun using the revised weather data with the 100-year storm inserted.

3.1 Scenario 1: Future Land Use

The Future Land Use scenario applies the 2020 land use developed for the 2020 Plan with no other changes in management. This scenario was implemented as part of the previous work, but not reported as part of the Regional Water Quality Management Plan Update (RWQMPU). It provides a baseline against which to compare the other scenarios.

3.2 Scenario 2: RWQMPU Preferred Alternative

The RWQMPU Preferred Alternatives starts with the combination of future (2020) land use and the NR151 requirements for new development and redevelopment. NR 151 Non-Agricultural Performance Standards have requirements for both peak discharge control and infiltration of stormwater from new development and redevelopment. Methods were developed to represent the performance of infiltration and retention basins on a per-acre basis at the model subbasin scale. Throughout the Kinnickinnic River watershed, soil infiltration rates are too low to meet NR 151 requirements. Therefore, new development is simulated as served by detention basins.

Water quality requirements of NR151 are focused on TSS removal – but other sediment-associated pollutants will also be removed. For existing development within the NR 151 area there is a removal requirement of 40 percent of TSS. For new development, the goal is an 80 percent TSS reduction. The net reduction relative to conditions without NR 151 is substantially less, because the city of Milwaukee already made progress at controlling solids loading. Based on information gathered for the RWQMPU, the city was achieving a 15% city-wide TSS reduction. Further, the reductions do not apply to sediment loads generated from channel erosion. More detailed information regarding the representation of NR 151 in the water quality model can be found in the RWQMPU.

The RWQMPU Preferred Alternative enhances the basic NR 151 requirements with additional CSO and SSO reductions. Several other components are also relevant to the Wilson Park Creek simulation:

- Stormwater disinfection units were specified for the most highly impervious areas of the Wilson Park Creek subwatershed to address bacterial loading. Although installation of disinfection units was not ultimately recommended in the plan, the associated reductions were left in the model and were attributed to the elimination of additional unknown sources of bacteria.
- Reductions in fecal coliform loads are assumed to be achieved in urban subbasins through urban illicit discharge controls. For the RWQMPU Preferred Alternative, a 33 percent reduction is assumed to be obtained from the total land area in urban subbasins. This reduction is assumed to encompass various other management efforts, including pet litter management and waterfowl control.

- In urban areas, 5 percent of the future impervious surface area is assumed to be converted to urban grass. This change reflects greater intensity of use of rain gardens and rain barrels.
- A low phosphorus fertilizer ordinance is assumed to achieve a 10 percent reduction in phosphorus loads from urban grass.

Note that the Wilson Park Creek watershed is nearly fully developed under current conditions. Thus, the NR 151 requirements relevant to new development and redevelopment have little impact. The RWQMPU enhancements to basic NR 151 requirements include only minor modifications to hydrology associated with decreased effective impervious surface area.

3.3 Scenario 3: Extreme Measures

The Extreme Measures model run is an extension of the RWQMPU run with additional and augmented management practices. Those relevant to the Wilson Park Creek subwatershed are as follows:

- **Urban Illicit Discharge Control**: 66 percent reduction in fecal coliform (double the reduction assumed in Scenario 2).
- **Fertilizer Management**: 50 percent reduction in phosphorus loads from lawns in the Kinnickinnic River watershed.
- **Non-contact Cooling Water**: Phosphorus loads in permitted discharges of non-contact cooling water are assumed to be zero in the Kinnickinnic River watershed.

The Extreme Measures run does not include any direct modifications to hydrology.

4.0 ADDITIONAL SCENARIOS

Additional model scenarios created for this project focused on options for peak flow retention on existing highly impervious areas (commercial/industrial roofs and parking lots). A total of four combinations were tested, as described below.

4.1 BMP Representation

The subject area, much of which is adjacent to the General Mitchell Airport, has largely already been developed in highly impervious commercial and industrial land uses. Little additional development is expected. Given the already built nature of these watersheds, prospective rules on stormwater management for future development (e.g., NR151 rules) will have little effect on runoff volume or water quality in this watershed. Instead, major changes can only occur as a result of stormwater retrofits to address existing built areas.

The additional BMPs addressed in this memorandum address retrofits in two specific areas: rooftop storage and parking lot storage. Both are primarily designed to delay the storm event washoff peak – although the ability to achieve this is influenced by the complex superposition of storm hydrographs arriving from many tributary watersheds with different timing. Neither class of BMP is focused on water quality improvement, although some water quality benefit may accrue depending on how the temporary storage is configured. The details of the approaches to simulating these BMPs are described below.

Rooftop Storage

Retrofit rooftop storage is constrained by the need to maintain safe roof loadings on existing structures. This is achieved by specifying a maximum storage limit and a drawdown time. Green roofs, with plantings that enhance evapotranspiration and provide some pollutant reduction benefits, are not simulated here because of the difficulty in obtaining high participation rates in retrofit applications, along with the limitations associated with heavy snow loads. Therefore, rooftop storage is simulated as a specialized type of detention storage, with outflow limited by downspout restrictions. This configuration is assumed to provide essentially no reduction in pollutant loads, although it will affect the timing of pollutant loads as well as transport losses downstream associated with timing of load delivery.

For example purposes, rooftop storage is assumed to be adopted in the target watersheds over 25 percent of the commercial and industrial rooftop area, with a maximum storage depth of 6 inches to meet structural constraints (MMSD, 2007). The land use coverage used for the 2020 FP model does not distinguish between the portions of impervious surface in commercial and industrial areas that are either roofs or parking lots. A detailed spatial coverage of building and parking lot impervious surface area was provided for subbasin 830, indicating that approximately 30 percent of the impervious area was roofs and 70 percent was parking/transportation. Therefore, the 25 percent rooftop storage participation rate was applied to 30 percent of the commercial/industrial/government/institutional impervious area in the target subbasins: 20, 520, 521, 822, and 830. (Reach 820 is also within the area for BMP application; however, this reach is a routing reach without direct contributing drainage.) Figure 4 shows the subbasins that were targeted for stormwater management measures for this analysis.

Rooftop storage was simulated on a unit area basis, and the results scaled up to represent the actual area treated within the model. The scaling is nonlinear in relation to flood peak timing, so the assumption was made that timing reflects the time of concentration appropriate to a 1-acre area with a slope of 0.5 percent.

Roof drains (4" orifice with orifice coefficient of 0.66) were sized to provide drawdown of the storage volume in 10 hours (Camp Dresser and McKee, 2004). Above the storage volume, overflow occurs by high capacity drains that limit the maximum depth to 6 inches, approximated by a weir equation. No pollutant removal was represented.

Parking Lot Storage

The many industrial and large commercial parking lots in the watershed provide ample room for potential temporary detention of stormwater. Parking lot storage was assumed to occur with a 50 percent participation rate, with a maximum of 4 inches of storage occurring on 50 percent of the participating parking lots. (A storage depth of 4 inches is compatible with safe, although inconvenient, use during storm events.) Storage thus occurs on 25 percent of the parking lot area, but is equivalent to 2 inches of storage across the 50 percent of participating parking lots. Non-storage areas within participating parking lots are assumed to drain to the storage areas.

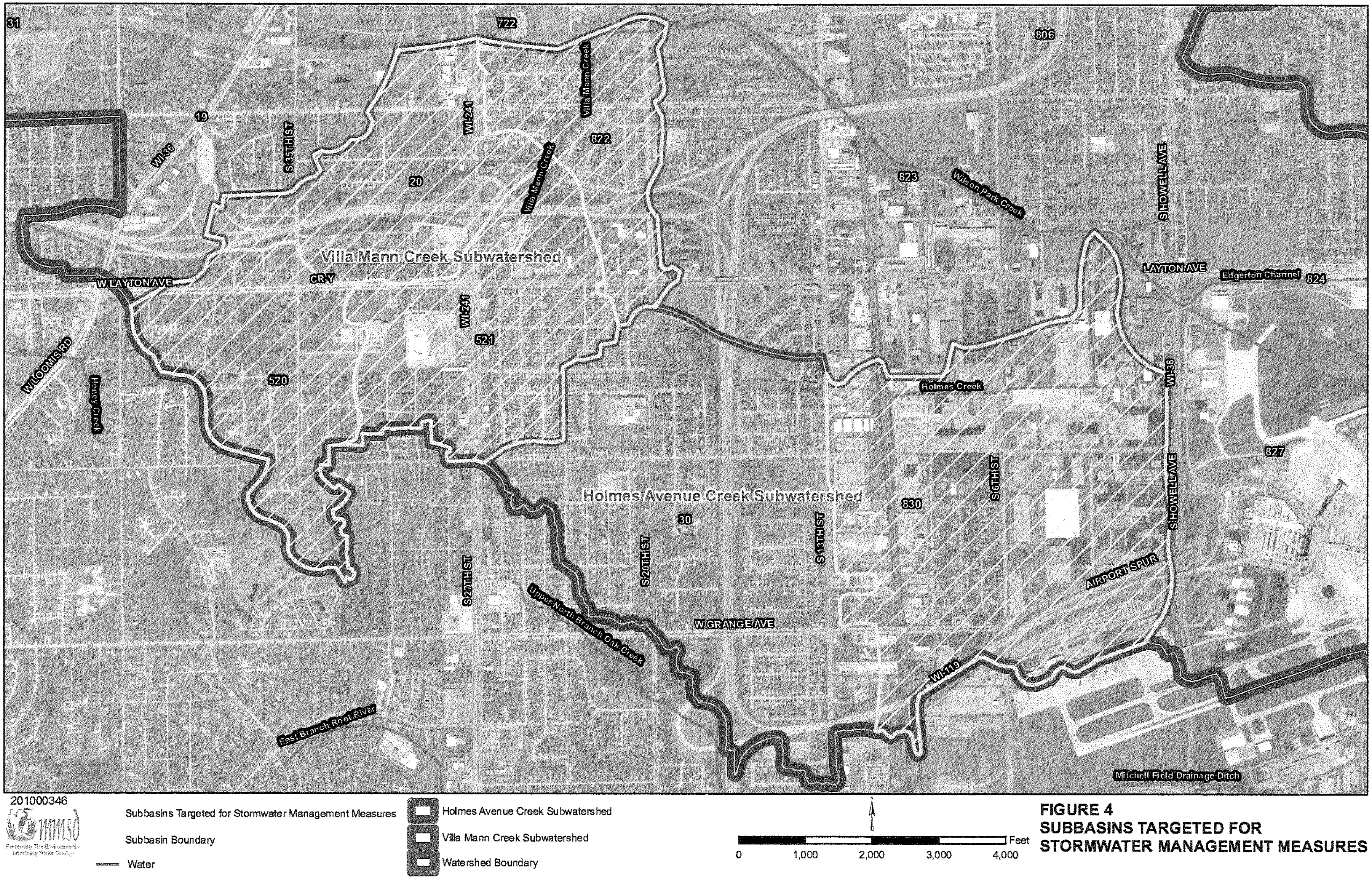


FIGURE 4
SUBBASINS TARGETED FOR STORMWATER MANAGEMENT MEASURES

Parking lot storage was represented in two alternative ways – as surface storage and as subsurface storage using porous pavement. For on-surface storage, detention is achieved through use of curbs and engineered curb cuts. Thus, the parking area is a modified detention basin with a maximum drawdown time of 24 hours. Flows in excess of storage capacity are simulated as being discharged by an overflow trapezoidal weir that allows passage of the 25-year flow at a depth of 0.3 feet. Surface storage is generally easy and inexpensive to retrofit, through use of outlet restrictors, but is not assumed to provide any pollutant mass reduction.

Parking lot storage may also be implemented through use of porous pavement, with storage in an underlying gravel layer. Although more expensive to install and requiring maintenance to retain infiltration capacity, this has the advantage of providing water quality benefits, particularly filtration of particulate material. Subsurface storage may also achieve further benefits through infiltration. Soils in the Kinnickinnic watershed generally have moderate to low infiltration capacity, but reported subwatershed-wide average saturated hydraulic conductivity values for undisturbed soils in the subwatersheds chosen for BMP application are around 0.2 in/hr. Plantings that provide infiltration as well could be incorporated in addition to the porous pavement to create "green parking lots".

Storage under porous pavement is assumed to be equivalent to 4 inches of water under 50 percent of the area (the same storage volume as for surface storage), occurring in gravel with a porosity of 41.2 percent. Because native infiltration rates are low, the subsurface storage is designed with underdrains (4" diameter), designed to drain the storage over 48 hours. Thus, a slower drainage rate is assumed for subsurface than for surface storage because there is less urgency to restore un-flooded parking area.

Porous pavement applications evaluated in Wilson Park Creek would be retrofits on altered and compacted urban soils. As such it is likely that infiltration capacity into the subsoil will be small. Therefore, we assumed only a low rate of infiltration of 0.02 in/hr consistent with the mid-range of ultimate infiltration rates for D soils given by Musgrave (1955). The drawdown time through the underdrain was adjusted to account for losses to infiltration.

Pollutant removal rates for porous pavement depend on whether the water quality volume is fully infiltrated. Where the water quality volume is fully infiltrated, removal rates in the 75 to 90 percent range are often reported. However, the use of underdrains significantly reduces the net removal rates. A review of the literature (Hirschman et al., 2008) and best professional judgment suggests rates of 35 percent for TSS and 25 percent for phosphorus and nitrogen are reasonable. Removal of other pollutants is scaled to the removal rate for TSS. Although not included in this analysis, pollutant removal rates may be improved if there is a filtering medium provided under the pavement.

4.2 BMP Application Area

The new retention BMPs were applied only in model subbasins 20, 520, 521, 822, and 830 (see Figures 2 and 4 above). These are the areas dominated by commercial/industrial imperviousness as opposed to residential development. Relative to the total drainage area above each of the specified analysis points, the area for potential BMP application is limited. At participation rates of 25 percent for rooftop storage and 50 percent for parking lot storage, the upstream drainage area covered by new BMPs ranges from 10 percent (KK-5) to 2.1 percent (KK-8), as shown in Table 2. As a result, the net effects on hydrology at the analysis stations are expected to be small. It should be noted, however, that examination of aerial photography suggests that the land use provided by SEWRPC for the 2020 modeling effort may underestimate impervious cover (and overestimate urban grass) in the headwaters of Wilson Park Creek, likely due to global assumptions about the impervious fraction within specific land use classifications.

Table 3 Additional BMP Application Areas above Analysis Points

Analysis Station	Total Upstream Area (acres)	Potential BMP Impervious Application Area (acres)	Percentage at 25%/50% Participation
KK-5	1,101	259	10.0%
KK-6	679	147	9.2%
KK-8	9,019	438	2.1%

4.3 New BMP Scenarios

The additional storage BMPs described above were added on to Scenario 3 (Extreme Measures) in several different combinations. This resulted in the following four additional scenarios:

Scenario 4: Extreme Measures (Scenario 4) plus parking surface storage

Scenario 5: Extreme Measures plus rooftop storage

Scenario 6: Extreme Measures plus parking surface storage and rooftop storage

Scenario 7: Extreme Measures plus parking porous pavement and rooftop storage.

5.0 HYDROLOGY RESULTS

The different scenarios result in very little change in total long-term runoff. This is not surprising because Scenarios 2 – 3 address primarily new development and redevelopment, of which there is very little in Wilson Park Creek, while Scenarios 4 – 7 primarily change flow timing, rather than flow volume. Only for Scenario 7, which diverts some parking lot runoff to infiltration, is there a small but noticeable reduction in total flow volume.

Peak flow reductions for the 100-year flood event are summarized in Table 4, Figure 5, and Figure 6. The RWQMPU Preferred Alternative is predicted to result in a reduction of only around 1 percent in the 100-year peak relative to Scenario 1, primarily because very little new development is predicted for this area. Results for Scenarios 3 and 4 are essentially identical to Scenario 2, as the added components in these scenarios are mostly focused on water quality, rather than flow. Scenarios 5 through 7 show that rooftop and parking lot storage does reduce peaks further, with the greatest reductions (about 22 percent) occurring in Villa Mann Creek for combined roof and parking lot storage. An 11 percent peak flow reduction on Holmes Avenue Creek and a 4 percent reduction just downstream of Holmes Avenue Creek on Wilson

Park Creek are predicted. Only minor changes are seen further downstream at KK-8 because only a small proportion of the tributary area is controlled. (Note the reduced vertical scale on Figure 6.)

Table 4 100-year Flood Peaks (cfs) and Percent Reduction Relative to Scenario 1

Scenario	KK-5 (R830)	KK-6 (R 820)	R 823	KK-8 (R 818)
1 – Future Land Use	2,322	1,540	3,645	4,602
2 - RWQMPU	2,305 (-0.8%)	1,521 (-1.2%)	3,599 (-1.2%)	4,576 (-0.6%)
3 – Extreme Measures	2,305 (-0.8%)	1,521 (-1.2%)	3,599 (-1.2%)	4,576 (-0.6%)
4 – Extreme Measures plus Parking Lot Storage	2,159 (-7.0%)	1,321 (-14.2%)	3,538 (-2.9%)	4,552 (-1.1%)
5 – Extreme Measures plus Rooftop Storage	2,195 (-5.5%)	1,382 (-10.2%)	3,556 (-2.4%)	4,563 (-0.8%)
6 – Extreme Measures plus both Parking Lot and Rooftop Storage	2,071 (-10.8%)	1,192 (-22.6%)	3,494 (-4.1%)	4,538 (-1.4%)
7 – Extreme Measures plus both Rooftop Storage and Porous Pavement	2,211 (-4.8%)	1,297 (-15.8%)	3,531 (-3.1%)	4,543 (-1.3%)

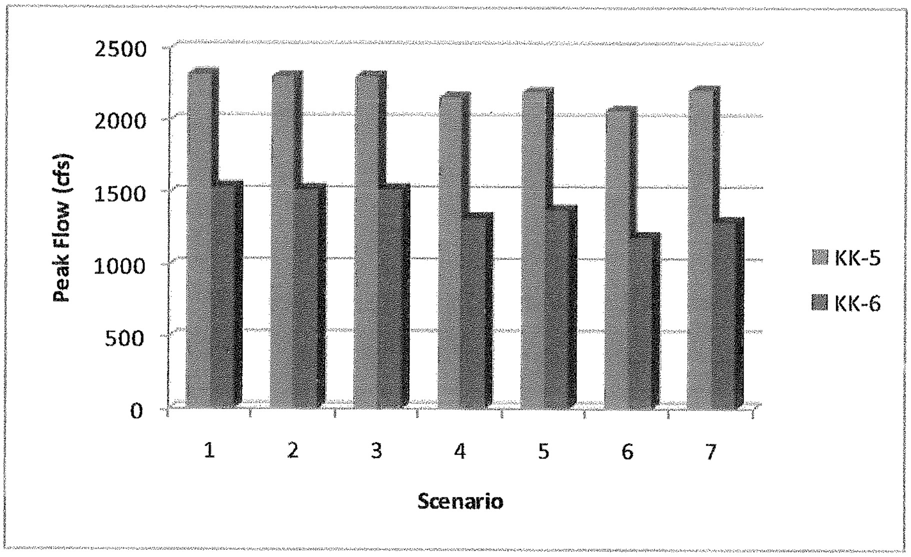


Figure 5 Peak Flow Responses to 100-year Event, Villa Mann and Holmes Avenue Creeks

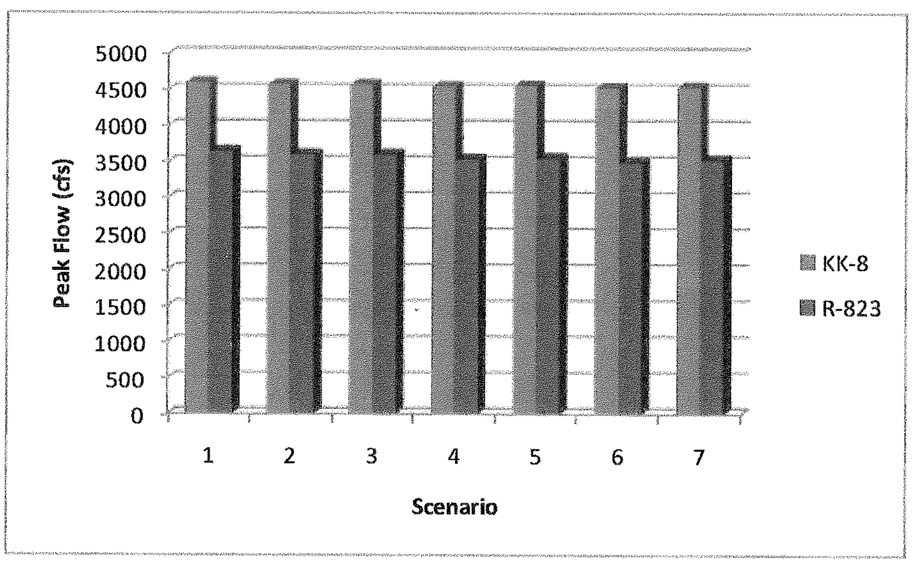


Figure 6 Peak Flow Response to 100-year Event, Wilson Park Creek

A detailed examination of the flood hydrograph – on both arithmetic and logarithmic scales – is shown for Villa Mann Creek and Holmes Avenue Creek in Figure 7. These figures show only the future baseline (Scenario 1), RWQMPU (Scenario 2), and Scenario 7, which is representative of "Added Measures," as the results from other scenarios are similar. Parking lot and rooftop storage in Scenario 7 clips the flood peak, but extends the receding tail of the hydrograph as the flow is released from storage.

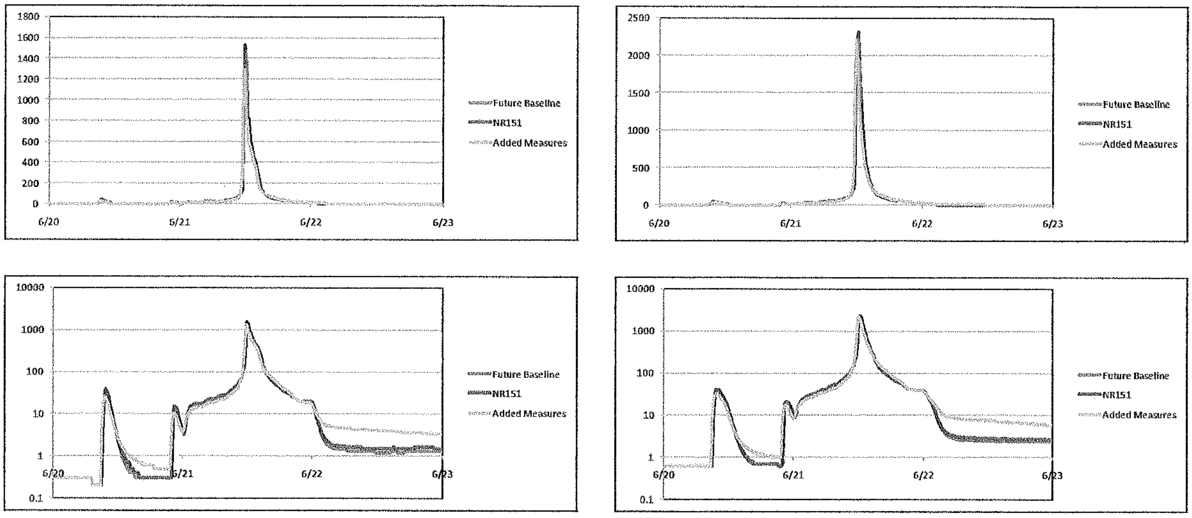


Figure 7 **Hydrograph for 100-year Storm Event for Villa Mann Creek (KK-6, left) and Holmes Avenue Creek (KK-5, right)**

The different storage options tested in Scenarios 4 through 7 provide differing recession curves, as shown in Figure 8. This reflects the drawdown timing specified for the different BMP configurations.

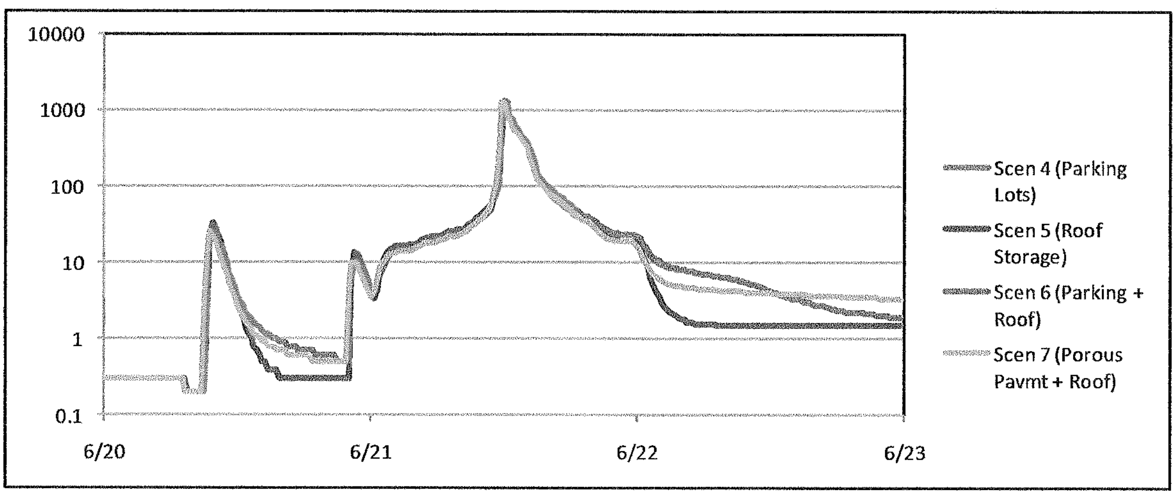


Figure 8 **Comparison of 100-year Event Hydrographs for Scenarios 4 through 7, Villa Mann Creek**

Only relatively small storage volumes are specified for rooftop and parking lot storage. These tend to be overwhelmed by extreme flow events. A greater impact is to be expected for moderate storm events that can be more completely captured by the stormwater management practices. As an example, predictions for a storm of 15 August 1993 (0.87 inches at General Mitchell Airport) are shown in Figure 9. This storm had a predicted peak (for future land use without additional management practices) of 237 cfs at KK-5, versus 2,322 cfs for the 100-year event. The combination of rooftop storage and porous pavement achieves a reduction of 31 percent in the peak at KK-5 (Holmes Avenue Creek) and 40 percent in the peak at KK-6 (Villa Mann Creek). Peak flows on Wilson Park Creek are reduced by 15 percent at R 823 (just downstream of Holmes Avenue Creek) and by 12 percent further downstream at KK-8 (terminus of Wilson Park Creek).

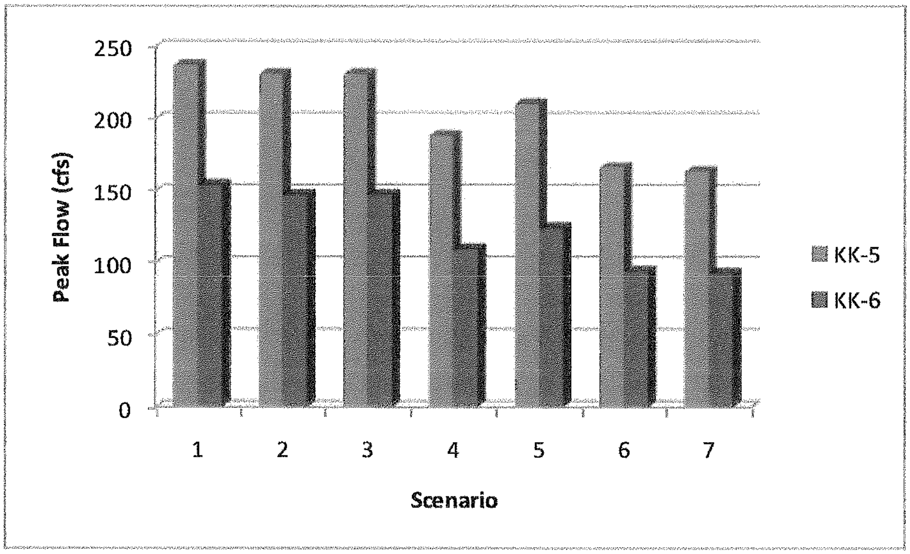


Figure 9 Peak Flow Responses to 0.87-in Storm of 15 August 1993, Villa Mann Creek (KK-6) and Holmes Avenue Creek (KK-5)

To summarize, the RWQMPU Preferred Alternative will have only a small impact on future storm peaks in Wilson Park Creek during the 100-year event, mostly because the watershed is already built out to a high level of imperviousness. Inclusion of rooftop and parking lot storage can provide a noticeable reduction in peaks within the Villa Mann and Holmes Avenue Creek subwatersheds, although the impact is muted on the Wilson Park Creek subwatershed because treatment is applied to only a small portion of the upstream watershed area. A greater impact is to be expected for moderate storm events that can be more completely captured by the stormwater management practices.

6.0 WATER QUALITY RESULTS

In contrast to hydrology, the Extreme Measures (Scenario 3) simulations show reductions in pollutant loading due to the aggressive pollutant reduction components contained in that scenario. Rooftop storage and parking lot storage are not expected to provide reduction in pollutant load, except where stored water is infiltrated; however, they do alter the timing of the delivery of the pollutant load, which can alter time-weighted concentrations and instream uptake of pollutants.

Results for long-term annual load of total phosphorus (Figure 10) are typical of other pollutants in this watershed. Small reductions, relative to future conditions without NR 151, are obtained for the RWQMPU scenario (Scenario 2). A relatively large reduction is then seen for the Extreme Measures scenario (Scenario 3), amounting to about a 22 percent reduction at KK-5, about 25 percent at KK-6, and about 29 percent at KK-8. The additional storage scenarios provide little change in average load – with the exception of the scenario with porous pavement (Scenario 7), which provides about an additional 6 percent reduction in loads at KK-6 and somewhat smaller additional reductions in loads at the other analysis points.

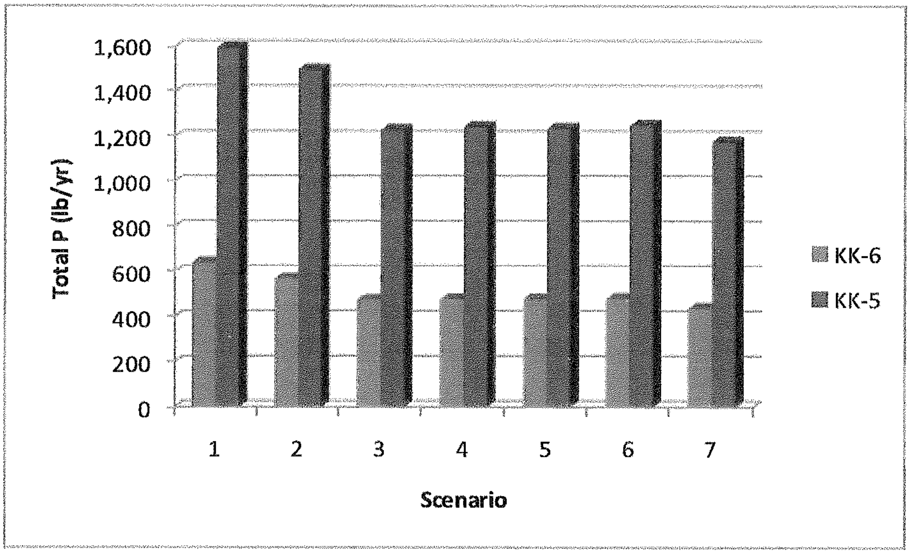


Figure 10 Future Annual Average Phosphorus Load in Villa Mann Creek (KK-6) and Holmes Avenue Creek (KK-5)

Table 5 provides a more complete summary of the annual pollutant loadings under the different scenarios tested, while Table 6 shows the percent change relative to Scenario 1 (future conditions without additional management measures). Fecal coliform bacteria load follows a pattern similar to phosphorus, as this constituent is also addressed by additional efforts under the RWQMPU and Extreme Measures scenarios. For TSS, total N, and copper, there is a small reduction associated with RWQMPU measures, but loads associated with Scenarios 2 through 6 are nearly identical. Only with the addition of some infiltration through porous pavement in Scenario 7 are additional reductions achieved.

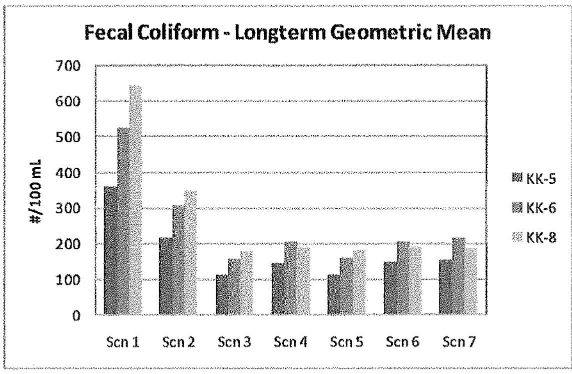
Table 5 Annual Pollutant Loading Summary for 2020 Conditions

Scenario	Total P (lbs/yr)	Total N (lbs/yr)	TSS (tons/yr)	Fecal Coliform (#/yr)	Copper (lb/yr)
	KK-8 (Wilson Park Creek)				
Scenario 1	7,294	44,749	1,150	1.44E+15	267
Scenario 2	6,586	42,233	1,081	8.55E+14	245
Scenario 3	5,167	42,527	1,081	4.35E+14	245
Scenario 4	5,181	42,109	1,076	4.38E+14	245
Scenario 5	5,176	42,208	1,081	4.37E+14	245
Scenario 6	5,190	41,786	1,076	4.40E+14	245
Scenario 7	5,064	41,200	1,038	4.23E+14	237
	KK-6 (Villa Mann Creek)				
Scenario 1	642	4,089	122	1.71E+14	26
Scenario 2	569	3,829	117	1.10E+14	25
Scenario 3	477	3,858	117	5.56E+13	25
Scenario 4	480	3,683	119	5.56E+13	25
Scenario 5	479	3,730	118	5.56E+13	25
Scenario 6	482	3,554	119	5.55E+13	25
Scenario 7	441	3,353	106	4.97E+13	22
	KK-5 (Holmes Avenue Creek)				
Scenario 1	1,592	8,846	257	2.95E+14	51
Scenario 2	1,496	8,521	249	1.93E+14	49
Scenario 3	1,230	8,591	249	9.80E+13	49
Scenario 4	1,243	8,387	248	1.01E+14	49
Scenario 5	1,237	8,424	249	1.00E+14	49
Scenario 6	1,249	8,218	248	1.03E+14	49
Scenario 7	1,176	7,864	224	9.31E+13	44

Table 6 Percent Change in Annual Pollutant Loading Relative to Scenario 1

Scenario	Total P (lbs/yr)	Total N (lbs/yr)	TSS (tons/yr)	Fecal Coliform (#/yr)	Copper (lb/yr)
	KK-8 (Wilson Park Creek)				
Scenario 2	-9.7%	-5.6%	-6.0%	-40.5%	-8.4%
Scenario 3	-29.2%	-5.0%	-6.0%	-69.7%	-8.4%
Scenario 4	-29.0%	-5.9%	-6.4%	-69.5%	-8.3%
Scenario 5	-29.0%	-5.7%	-6.0%	-69.6%	-8.3%
Scenario 6	-28.8%	-6.6%	-6.4%	-69.4%	-8.2%
Scenario 7	-30.5%	-8.0%	-9.8%	-70.5%	-11.1%
	KK-6 (Villa Mann Creek)				
Scenario 2	-11.3%	-6.4%	-3.8%	-35.9%	-6.5%
Scenario 3	-25.7%	-5.7%	-3.8%	-67.5%	-6.5%
Scenario 4	-25.2%	-9.9%	-2.7%	-67.5%	-6.0%
Scenario 5	-25.4%	-8.8%	-3.4%	-67.5%	-6.1%
Scenario 6	-24.9%	-13.1%	-2.3%	-67.6%	-5.6%
Scenario 7	-31.3%	-18.0%	-13.1%	-71.0%	-15.3%
	KK-5 (Holmes Avenue Creek)				
Scenario 2	-6.0%	-3.7%	-3.4%	-34.5%	-5.1%
Scenario 3	-22.7%	-2.9%	-3.4%	-66.7%	-5.1%
Scenario 4	-21.9%	-5.2%	-3.5%	-65.7%	-5.1%
Scenario 5	-22.3%	-4.8%	-3.5%	-66.0%	-5.1%
Scenario 6	-21.5%	-7.1%	-3.6%	-64.9%	-5.1%
Scenario 7	-6.1%	-11.1%	-13.2%	-68.4%	-14.1%

The changes in loads are accompanied by changes in concentrations. For fecal coliform bacteria, there is a progressive reduction in load across scenarios 1 through 3, and this provides a corresponding reduction in the long-term geometric mean and the average number of days per year that the (recreation season) geometric mean criterion of 200 organisms per 100 mL is met (Figure 11). The different rooftop and parking lot storage options cause only small changes in these statistics.



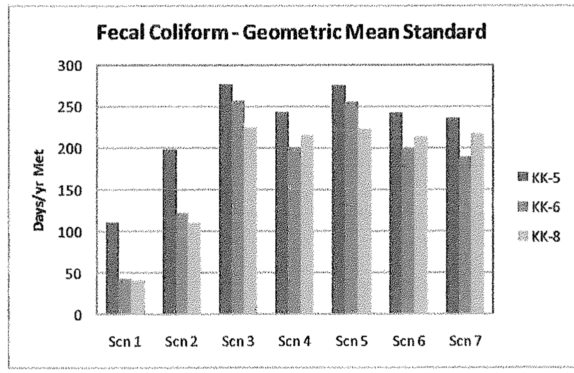


Figure 11 Fecal Coliform Bacteria Concentration Response

The stormwater detention options (scenarios 4 through 7) also introduce changes in the timing of delivery of load, which does not always have positive impacts. A good example is provided by TSS, for which the different scenarios have only small differences in total loads. However, examination of the long term mean concentrations (Figure 12) shows a notable increase in the average concentration for the two scenarios including surface storage on parking lots (Scenario 4 and Scenario 6). This occurs because the parking lot storage, which has a drawdown time of 24 hours but does not reduce loads, effectively delays delivery of a significant portion of the total load to the receding limb of the hydrograph, where the mass is diluted into a smaller total instream flow, resulting in higher concentrations. This effect is somewhat mitigated by porous-pavement style parking lot storage, which does provide reductions in TSS loads.

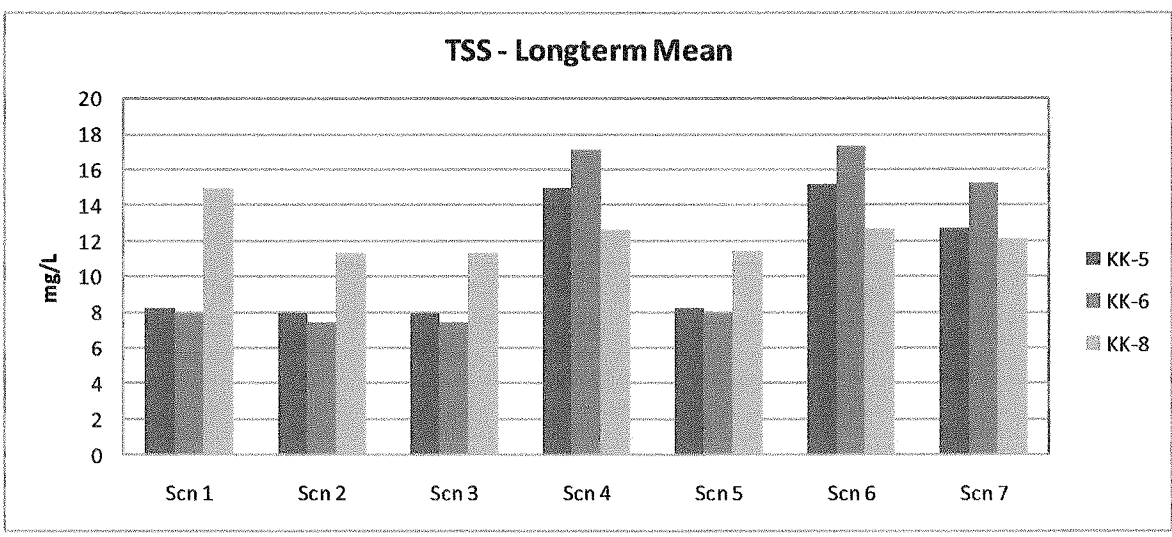


Figure 12 Total Suspended Solids Concentration Response

A summary of the daily average concentration results, evaluated against many of the reporting metrics used in the RWQMPU, is provided in Table 7.

Table 7 Summary of Water Quality Results

Measure	Units/ Criteria	SCN 1			SCN 2			SCN 3			SCN 4			SCN 5			SCN 6			SCN 7		
		KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8
Fecal Coliform																						
Long term geometric mean	counts/100ml	360	523	643	215	309	348	111	158	178	145	205	189	113	160	179	146	206	190	154	214	187
Mean	#/100ml	4241	4645	4361	2816	3025	2518	1430	1536	1279	1947	2236	1391	1491	1582	1293	2005	2284	1404	1716	1965	1327
Median	#/100ml	115	209	394	64	113	191	33	58	97	36	58	100	33	58	97	36	58	100	44	58	110
Geometric mean standard	Days/yr met (200 per 100ml)	110	41	41	198	122	109	277	257	224	243	201	215	276	255	224	242	200	215	236	190	216
Not to exceed standard	Days met/yr (400 per 100 ml)	208	208	163	209	207	186	216	214	204	208	205	200	216	214	204	208	205	200	199	195	198
Long term geometric mean (swimming season)	#/100ml	212	340	337	126	200	191	65	103	98	89	142	106	66	105	98	89	143	106	98	154	106
Mean (swimming season)	#/100ml	1791	1960	2169	1206	1294	1318	613	657	672	1204	1602	793	650	702	681	1236	1653	801	987	1443	744
Median (swimming season)	#/100ml	308	442	546	185	260	300	95	134	154	131	181	165	97	135	155	132	182	166	140	192	165
Geometric mean std (swimming season)	Days/yr met (200 per 100ml)	49	21	23	93	63	51	133	127	109	114	93	104	133	126	109	114	92	103	110	88	104
Not to exceed std (swimming season)	Days met/yr (400 per 100ml)	109	109	91	108	108	97	109	108	104	105	105	102	109	108	104	105	105	102	98	97	100
Dissolved Oxygen																						
Median	mg/L	9.82	6.58	11.20	9.81	6.68	11.19	9.82	6.67	11.19	9.85	6.67	10.93	9.82	7.00	10.94	9.85	6.68	10.93	9.90	7.03	10.92
Mean	mg/L	9.86	7.38	10.94	9.87	7.43	10.93	9.87	7.43	10.93	9.87	7.43	10.82	9.91	7.67	10.82	9.87	7.44	10.82	9.95	7.66	10.82

Measure	Units/ Criteria	SCN 1			SCN 2			SCN 3			SCN 4			SCN 5			SCN 6			SCN 7		
		KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8	KK-5	KK-6	KK-8
Dissolved oxygen standard	Days/yr met (5 mg/l)	264	226	357	264	228	357	264	228	358	268	229	363	262	228	363	267	229	363	265	233	363
Total Suspended Solids																						
Median	mg/L	3.81	4.99	5.38	3.07	3.73	3.76	3.07	3.73	3.76	3.16	3.73	3.82	3.08	3.73	3.76	3.16	3.73	3.82	3.21	3.73	3.79
Mean	mg/L	8.25	7.90	14.96	7.91	7.37	11.31	7.91	7.37	11.31	15.00	17.09	12.64	8.23	7.90	11.40	15.16	17.34	12.72	12.71	15.28	12.08
TSS Guideline	Days/yr met (100 mg/L)	365	365	360	365	365	361	365	365	361	353	352	359	364	365	361	353	352	359	357	357	360
Total Nitrogen																						
Median	mg/L	0.894	0.706	0.660	0.854	0.644	0.617	0.849	0.641	0.576	0.867	0.663	0.583	0.852	0.644	0.576	0.868	0.665	0.584	0.850	0.636	0.577
Mean	mg/L	1.192	0.682	0.915	1.150	0.619	0.873	1.142	0.618	0.834	1.158	0.646	0.840	1.145	0.619	0.835	1.160	0.648	0.841	1.138	0.625	0.835
Total Phosphorus																						
Median	mg/L	0.070	0.034	0.039	0.068	0.032	0.052	0.065	0.032	0.044	0.069	0.032	0.045	0.066	0.032	0.044	0.069	0.032	0.045	0.068	0.033	0.045
Mean	mg/L	0.121	0.056	0.134	0.119	0.053	0.105	0.117	0.052	0.098	0.126	0.065	0.101	0.118	0.053	0.099	0.127	0.067	0.101	0.121	0.060	0.099
TP Planning Guideline	Days/yr met (0.1 mg/L)	263	305	299	265	310	278	270	314	288	250	287	283	269	311	288	249	287	282	257	297	287
TP Planning Guideline	% of time standard met	72.0%	83.4%	81.9%	72.5%	84.8%	76.0%	74.0%	85.9%	78.9%	68.4%	78.7%	77.4%	73.6%	85.2%	78.8%	68.2%	78.5%	77.3%	70.4%	81.3%	78.5%
Total Copper																						
Median	mg/L	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002
Mean	mg/L	0.003	0.004	0.004	0.003	0.003	0.004	0.003	0.003	0.004	0.004	0.005	0.004	0.003	0.003	0.004	0.004	0.005	0.004	0.004	0.004	0.004

7.0 REFERENCES

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