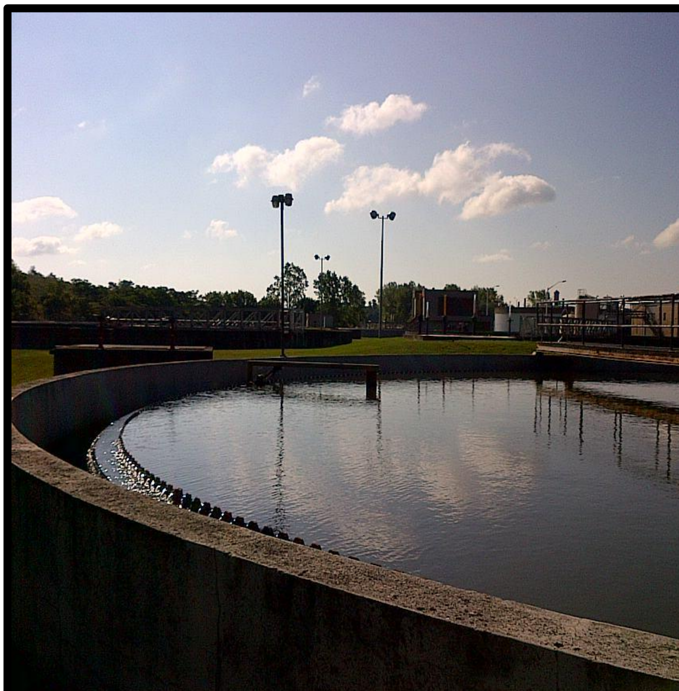
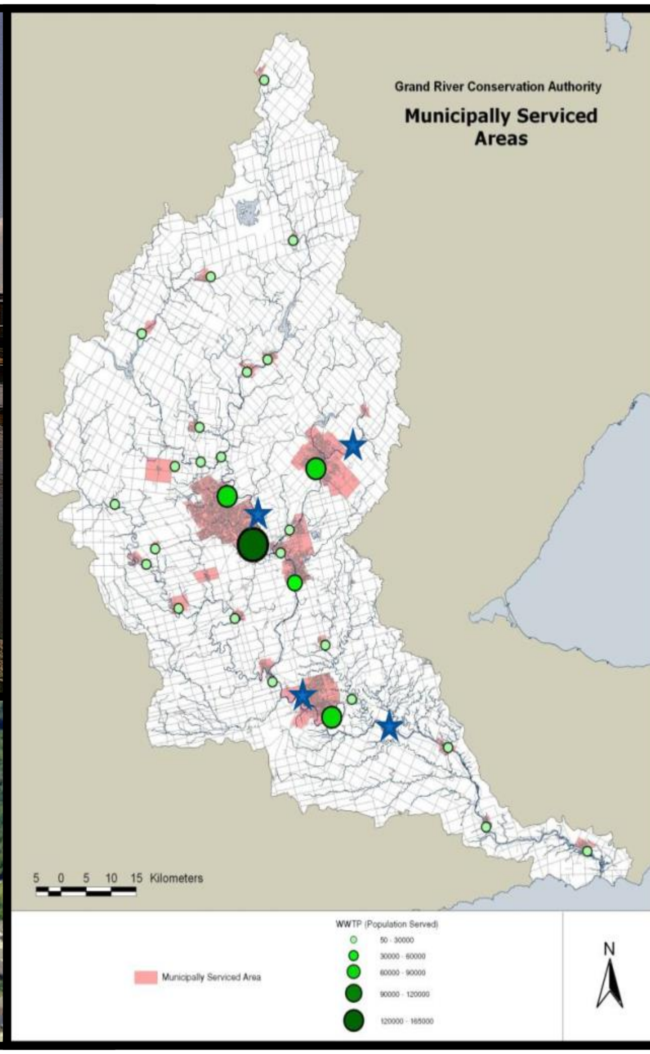
2013
Watershed Overview of Wastewater Treatment Plant Performance





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Acronyms and Abbreviations

ADF	Average daily flow
cBOD	Carbonaceous 5 day biochemical oxygen demand
CCP	Composite Correction Program
ECA	Environmental Compliance Approval (formerly called Certificate of Approval)
EPA	US Environmental Protection Agency
GRCA	Grand River Conservation Authority
MOECC	Ontario Ministry of the Environment and Climate Change
OCWA	Ontario Clean Water Agency
TAN	Total ammonia nitrogen
TBOD	Total 5 day biochemical oxygen demand
TKN	Total Kjeldahl nitrogen
TP	Total phosphorus
TSS	Total suspended solids
WWOP	Watershed-wide Wastewater Optimization Program
WWTP	Wastewater treatment plant

Introduction

Background

Since 2010, the Grand River Conservation Authority (GRCA) has been working collaboratively with municipal partners and the Ministry of the Environment and Climate Change (MOECC) to develop a Watershed-wide Wastewater Optimization Program (WWOP). The WWOP promotes optimization across the watershed by encouraging the adoption of the Composite Correction Program (CCP). The US Environmental Protection Agency (EPA) developed the CCP as a structured approach to identify and correct performance limitations with the goal of producing high quality, economical effluent. The CCP is based on the model shown in Figure 1, where good administration, design, and maintenance establish a “capable plant”, which, by applying good process control, can achieve a “good, economical” effluent.

The Grand River Water Management Plan recommends adopting the CCP as a potential means to reduce overall loading of total phosphorus to the Grand River and, ultimately, to Lake Erie. The watershed municipalities of Guelph, Haldimand County and Brantford have applied the CCP approach and have demonstrated its benefits, including improved effluent quality.

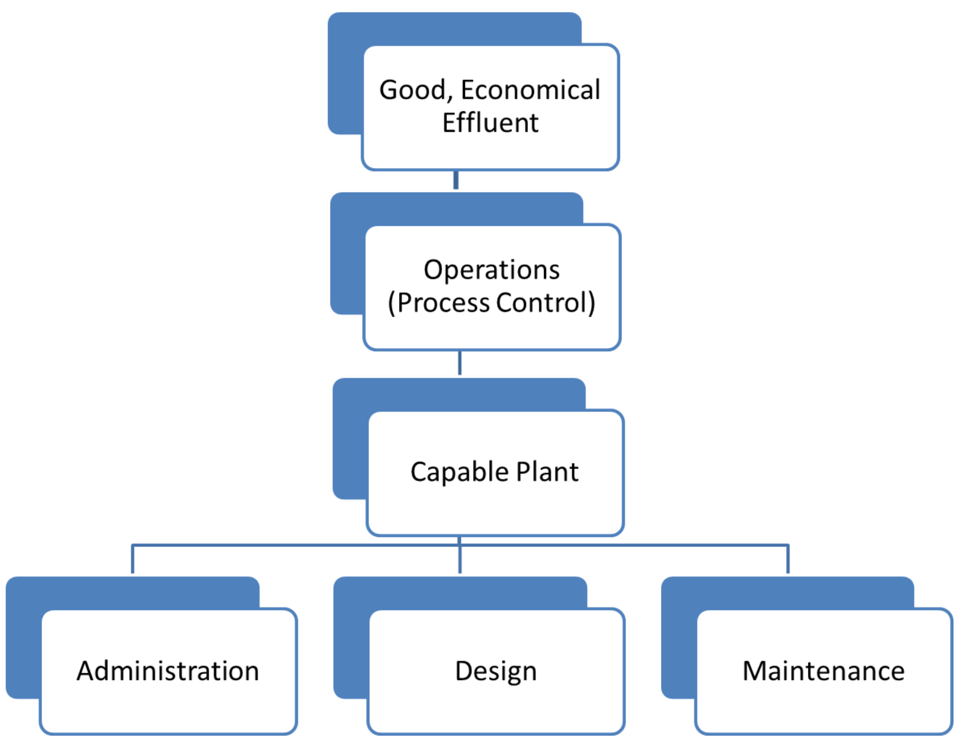


Figure 1: Composite Correction Program Performance Pyramid

The Grand River WWOP is a voluntary program focused on skills development, knowledge transfer and capacity building within the watershed. The objectives of the program are to:

- Improve water quality in the Grand River and its tributaries as a direct result of improving wastewater treatment plant performance;
- Improve the quality of Lake Erie;
- Tap the full potential of existing wastewater infrastructure and promote excellence in infrastructure management;
- Build and strengthen partnerships for wastewater optimization;
- Enhance partner capability and motivation;
- Leverage and learn from EPA experience with area-wide optimization programs in the US; and
- Demonstrate an area-wide optimization program that can serve as a model for other areas of Ontario.

One component of the WWOP is to assess the status of wastewater treatment plants (WWTPs) across the watershed by tracking performance over time, which will help to identify plants in most need of assistance and most likely to achieve improved performance. This component was initiated through several workshops that were held in 2010/2011 that brought wastewater operators, supervisors and managers together from communities within the watershed. These workshops provided information on optimization using the CCP and training on some of the tools used to evaluate WWTP performance. Workshop participants, with the assistance of peer facilitators, were encouraged to carry out the performance calculations using their own plant data.

Additional workshops held throughout 2012 and 2013 to review the metrics that were introduced during the initial phase of the WWOP. Some of the metrics taught include:

- ADF as a percentage of nominal design capacity;
- Per capita influent flow;
- Ratio of peak day flow to annual average flow;
- Per capita TBOD, TSS and TKN loading to the plant; and
- The ratios of TSS to TBOD and TKN to TBOD in the raw influent

Participants across the watershed were encouraged to calculate these metrics for their own facilities using data from Jan-Dec 2012, and report the information back to the GRCA using a standard data summary spreadsheet. The participants were also encouraged to start including these simple metrics in their annual performance reports to the MOECC. Additionally, these metrics were reviewed in a December 2013 workshop and documented in a report entitled "Watershed Overview of WWTP Performance", released May 2014. This report is a follow-up to the 2014 report and summarizes available watershed WWTP performance for both the 2012 and 2013 calendar year.

Data Collection Methodology

Plant performance data from 2013 were collected from wastewater plants within the watershed via information compiled from either a facility's annual report or a completed data summary spreadsheet. The data summary spreadsheet was provided to partners, including plant owners and operators, at previous workshops and meetings. The municipalities listed below are responsible for the 28 municipally-owned WWTPs discharging directly to the Grand River or one of its tributaries:

- Township of Southgate;
- Town of Grand Valley
- Township of Mapleton
- Township of Wellington North;
- Township of Centre Wellington;
- Region of Waterloo;
- City of Guelph;
- Oxford County;
- County of Brant;
- City of Brantford; and
- Haldimand County.

It is desirable for each municipality or the contract operator to compile WWTP performance data and enter it into the spreadsheet template and submit to GRCA on an annual basis. The template can then be used to calculate a number of metrics based on the data. Compiling this information for all plants allows WWTP performance to be compared on a watershed basis, which can be tracked over time. It also enables an assessment of the status of plants to determine suitability for follow-up optimization activities. All available 2012 and 2013 performance data is summarized in graphical form in the following sections. The report also compares 2013 overall WWTP performance to 2012 overall WWTP performance in Table 2.

Wastewater Treatment Plant Performance Summary

Influent flow

Figure 2 shows a summary of the ADF to each plant (shown in red) compared to the Rated Capacity of the plant as stated in the plant's ECA (shown in green). Plants A to E are plotted on a separate vertical scale as these facilities are considerably larger than the rest of the WWTPs in the watershed. In most cases ADF is less than the rated capacity and this is demonstrated in

Figure 3, which shows the ADF as a percentage of the rated capacity. There are, however, some exceptions. Plant Q, for instance, received more flow than the plant's nominal design in 2013, likely due to excessive inflow and infiltration and/or possible inaccuracies with the flow measurement data. Plant Y also received flows exceeding the nominal design for this plant. Plant P experienced issues with their flow meter in 2013, which is thought to be the cause of higher flow and loading values for this plant.

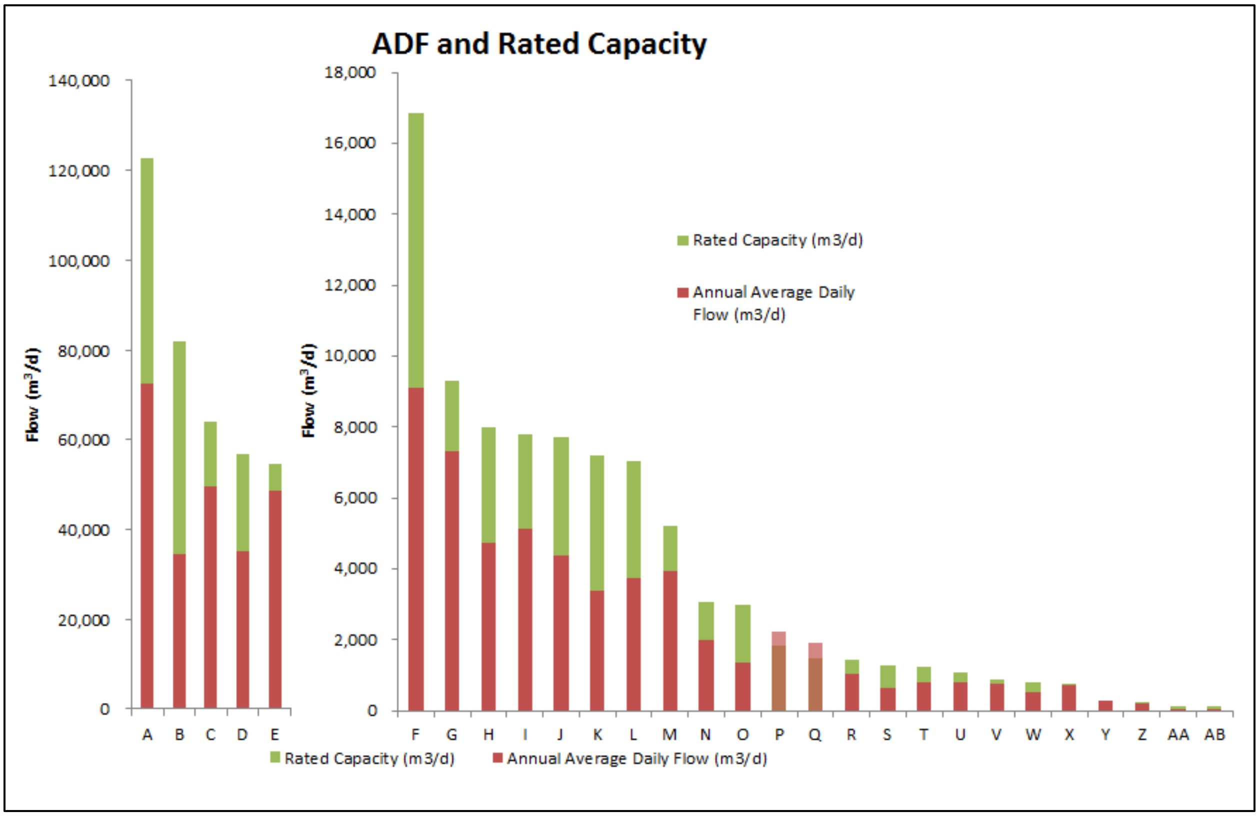


Figure 2: ADF and Rated Capacity of 28 WWTPs in the watershed

Another way to look at influent flow is to normalize it based on the serviced population and express it as per capita flow. Per capita wastewater flows vary from location to location but typical values used in the CCP are from 350 to 500 L/person/d. Figure 4 shows per capita flows for WWTPs in the watershed for both 2012 and 2013. From this figure, it appears that plants in the Grand River watershed were generally at or below the low end of the typical range. The watershed median for 2013 is 351 L/person/day, which is slightly higher than 2012 (317 L/person/day).

There are some notable plants with higher than typical per capita flows. Per capita flows at Plant P increased dramatically in 2013 and this is thought to be due to influent flow metering issues, which were identified and addressed in 2014. Plant Z services primarily industrial users, which may explain why the per capita flows are high. Plants J and Q are believed to be subject to quite a bit of I/I, and these municipalities are moving forward with I/I reduction strategies. Several communities in the watershed experience I/I that results in high per capita flows and most of these communities have active control programs with measures to limit extraneous flows.

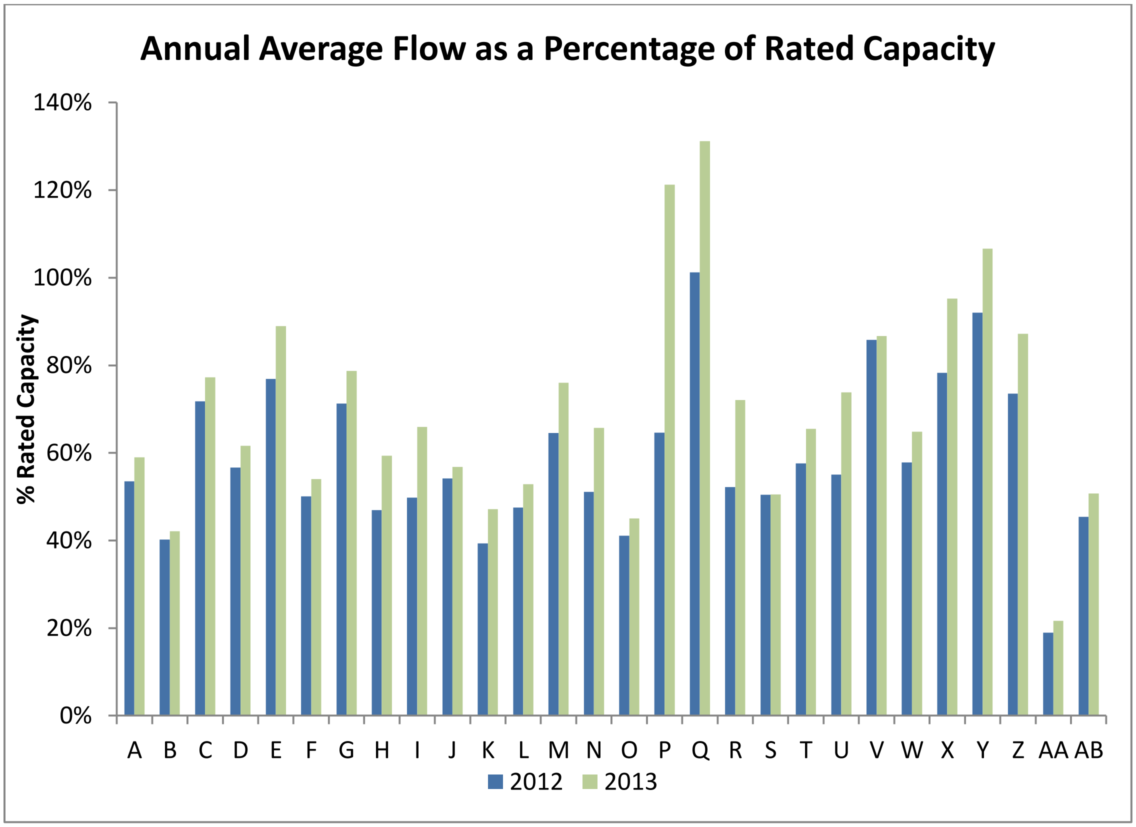


Figure 3: Annual average flow as a percentage of rated plant capacity

Alternatively, there are some plants that show very low per capita flows and the data used to derive these numbers may be questionable. Plant AA, for example, is a small communal system with a per capita flow of 126 L/person/d. This seems unrealistically low and it is possible that the population and/or influent flow data for this system are incorrect.

Figure 5 shows the ratio of peak day flow to ADF, which is another indicator of I/I or periodic industrial flows. The 2013 median is 2.53, which is in the low range of typical (2.5 to 4.0). Most plants were within typical range or less. Several plants are known to experience I/I (such as Plants K, Q and V) and this is reflected in Figure 5.

Year to year variability in per capita flow is assumed to be largely due to differences in I&I related to climate. 2013 generally experienced higher than normal precipitation across the central and northern portions of the watershed (Shifflett, 2013), whereas precipitation in 2012 was lower than normal (Shifflett, 2012). These general trends are shown in Figure 6, which shows total precipitation (i.e. snow and rain) at selected sites in the watershed. Precipitation in 2012 was below average in the central and northern parts of the Grand River watershed, whereas 2013 had precipitation that was at or above the 95th percentile. The southern area of the watershed experienced typical levels of precipitation in 2012 and 2013.

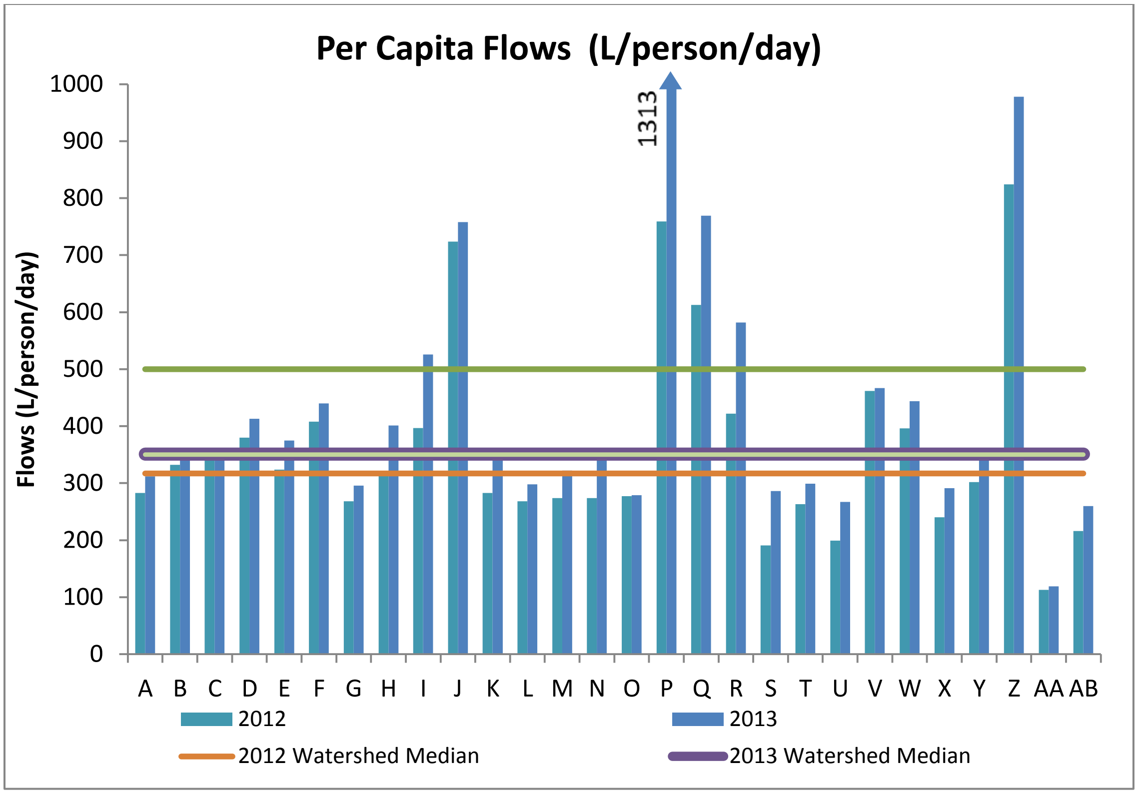


Figure 4: Per capita influent flow

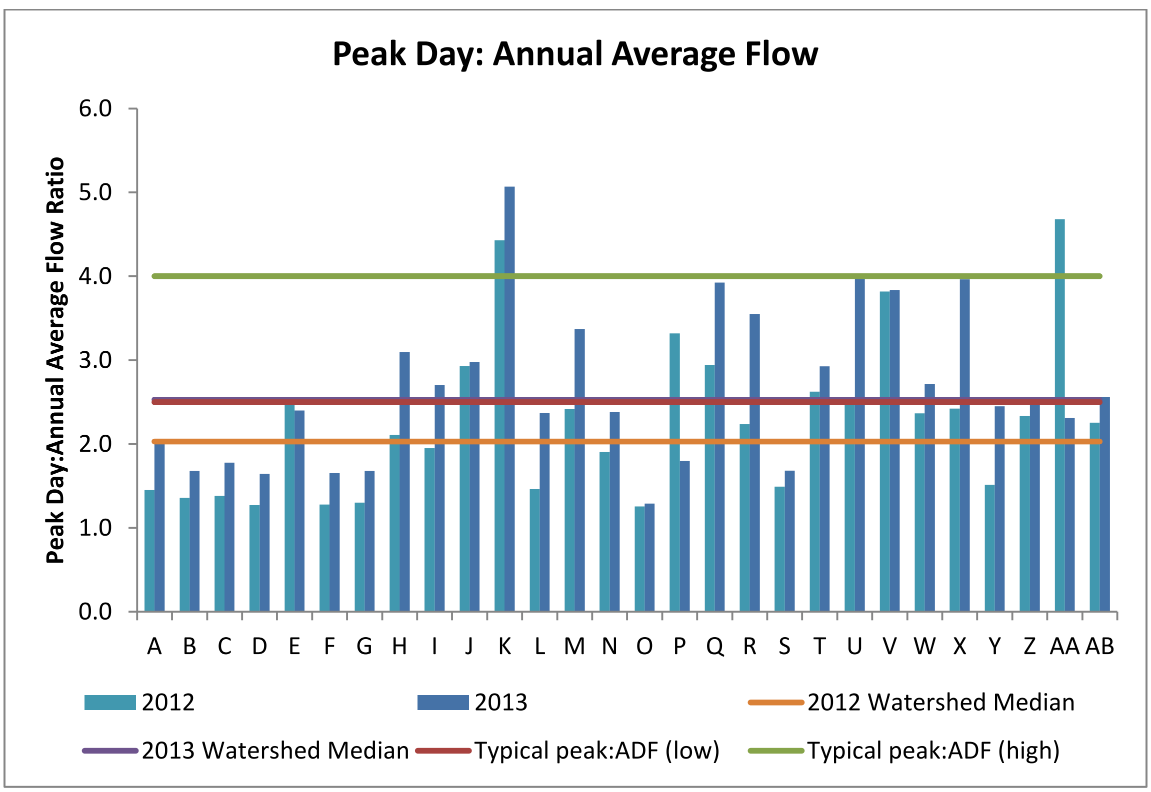
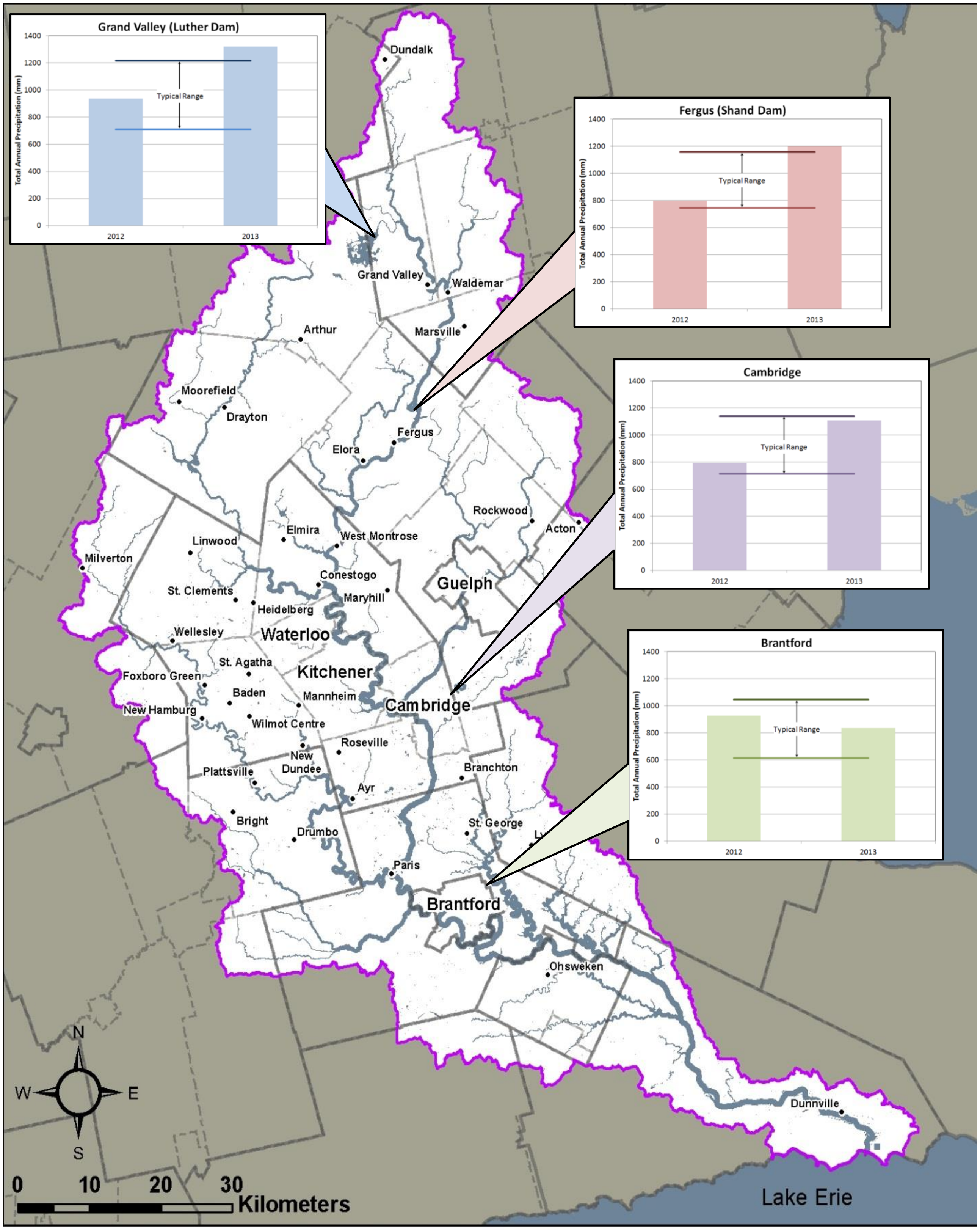


Figure 5: Ratio of peak day flow to annual average flow



Map created: 6 May 2015

Figure 6: Total annual precipitation (in mm) at selected locations across the watershed. Typical range is based on 5th and 95th percentile of historical observations over the past 50 years

Raw Influent Loads

Characterization of raw wastewater is important to ensure effective wastewater treatment as well as to assist with future planning, and can provide indications of any issues occurring in the collection system. Loading of raw influent TBOD, TSS and TKN can be calculated by multiplying raw influent concentrations by flow. These loads can be expressed on a per capita basis and compared to values that are typical of systems that are primarily treating domestic sewage.

TBOD Loading

Figure 7 shows estimated per capita TBOD loads for plants in the Grand River watershed in 2013. A typical value for domestic wastewater is 80 g/person/d. The reported 2013 median is 72 g/person/d, which is slightly higher than 2012 (64 g/person/d) and slightly lower than the typical value. The reason for this is unknown but could be partly related to the fact that most of the plants in the watershed do not measure TBOD in the raw influent on a routine basis. This stems from the fact that most of the ECAs have a requirement to measure cBOD in the raw influent. A paper by Albertson (1995) stated that the cBOD test underestimates the strength of raw wastewater by 20 to 40%. In the absence of measured TBOD data, TBOD loads were estimated based on cBOD concentrations multiplied by a factor of 1.2. The scaling factor of 1.2 is an assumption based on the data presented by Albertson (1995) and it introduces significant uncertainty in the estimate of TBOD loads. In Figure 7, plants where an estimated TBOD value was used are represented by hatched bars and plants with actual TBOD data are represented by solid bars. There are a couple of WWTPs that have TBOD loads that are much higher than typical and this is attributed to industrial discharges. For example, Plant Z serves primarily industrial users and therefore it is not expected to have BOD, TSS or TKN loadings that are typical for domestic wastewater.

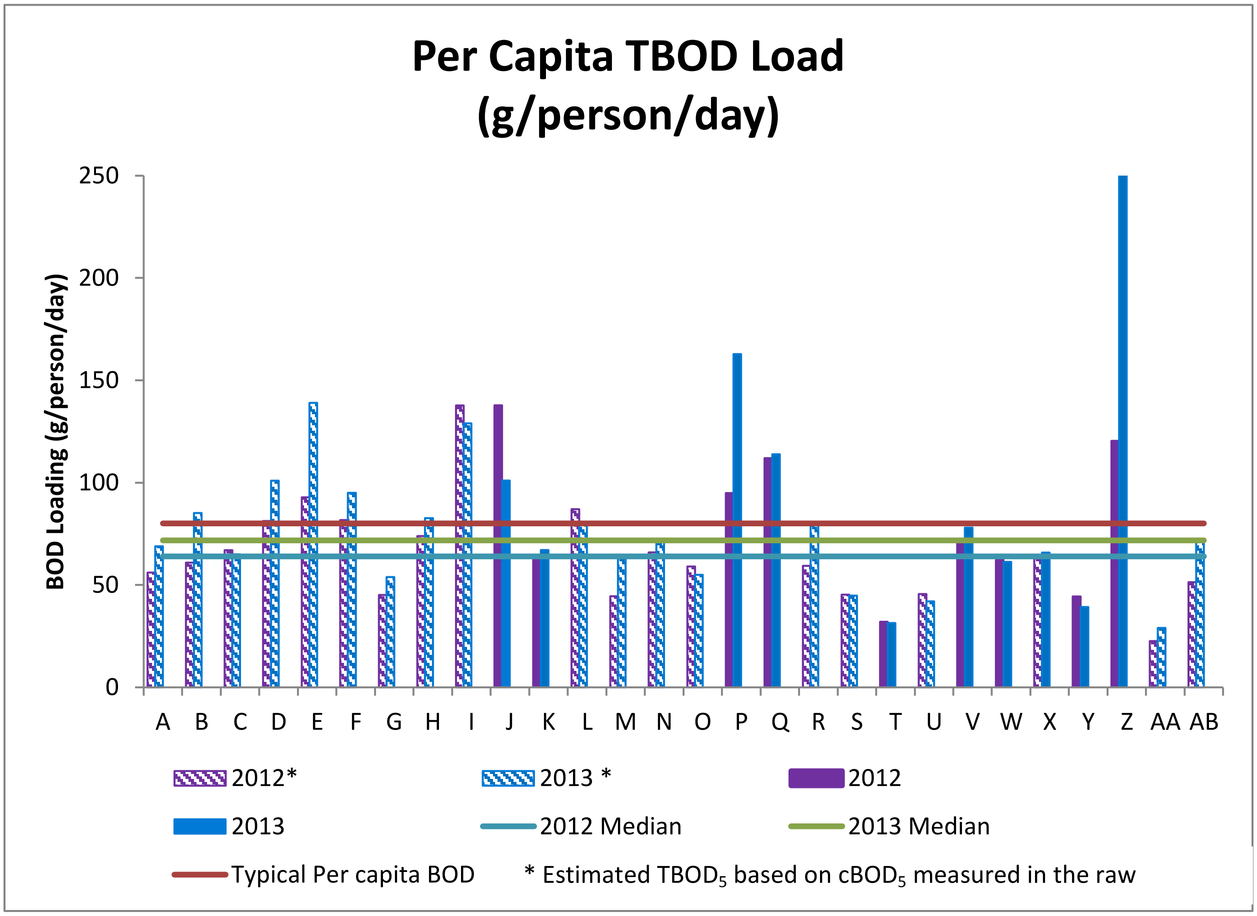


Figure 7: Per Capita TBOD Load

TSS Loading

TSS loads in raw influent for 2012 and 2013 are summarized in Figure 8. Several plants have reported per capita TSS loads that are lower than typical (90 g/person/d) and some are higher. Where the loads are less than expected based on the typical value, it brings into question the adequacy of raw influent sampling to accurately characterize the influent. Higher than expected loads may be attributed to industrial inputs and/or internal recycle streams that may be influencing the raw influent sample (e.g. this has been observed at some local WWTPs).

TKN Loading

Figure 9 shows per capita TKN loads to plants in the watershed. Several plants were reported to have TKN loads that are higher than expected and in most cases the per capita TSS and/or TBOD loads are also high. This suggests industrial loads to the plant or internal recycle streams may be influencing raw influent samples.

A small number of plants had TKN, TSS and TBOD loads that were less than the typical values and this may be indicative of insufficient sampling to characterize the raw influent. Other sources of inaccuracies in the calculation of these metrics are the population estimates and raw influent flows. For example, there are some questions about the accuracy of influent flows and/or population estimates, e.g. Plants U, Y and AA.

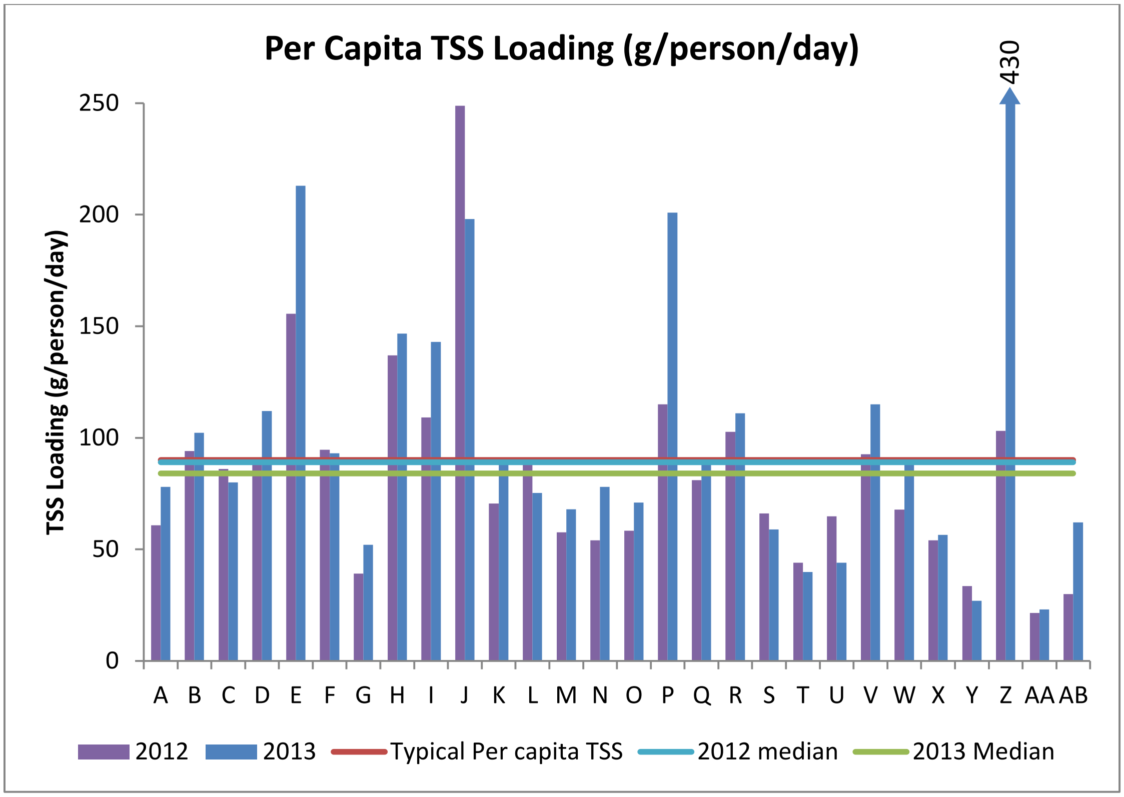


Figure 8: Per Capita TSS Load

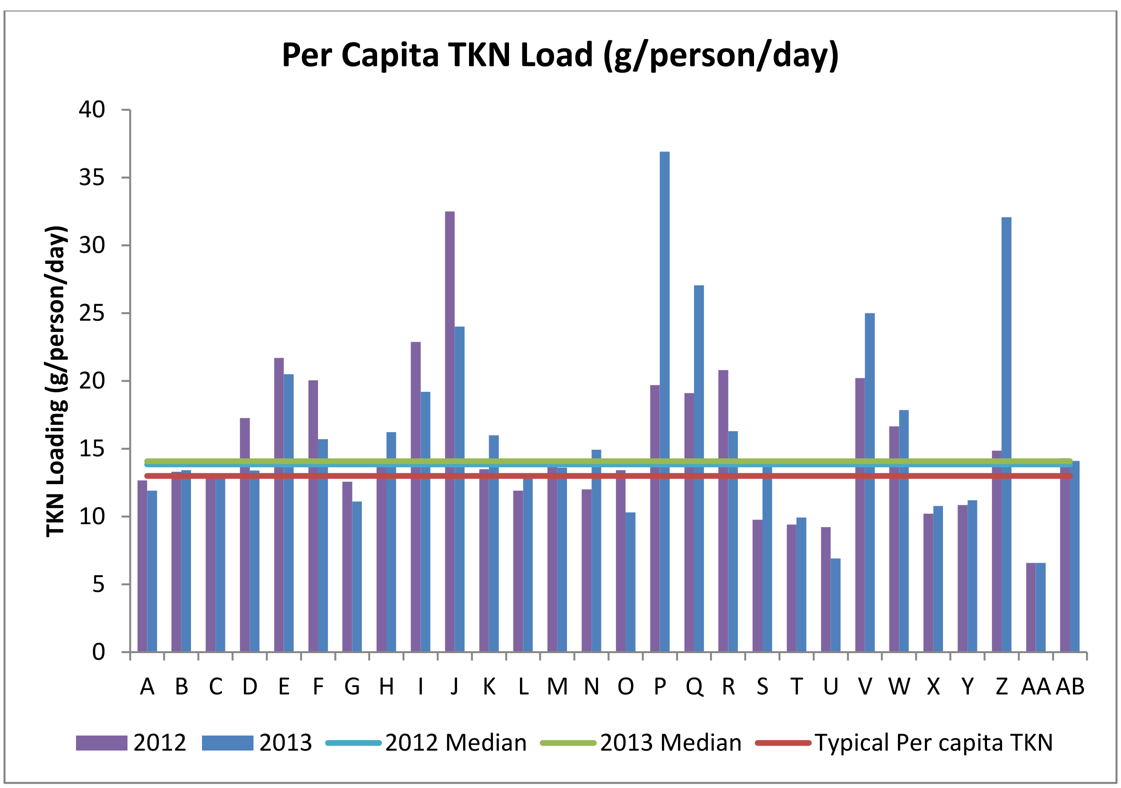


Figure 9: Per Capita TKN Load

Ratios

Calculating raw influent ratios for TSS:TBOD and TKN:TBOD can be used to provide insight on what is coming to the plant from the collection system as well as any potential inaccuracies of the data used.

Figure 10 shows the ratio of raw influent TSS to TBOD concentrations. For a typical domestic sewage system, this value would typically be between 0.8 and 1.2. The median for watershed plants in 2013 is 1.17. Figure 11 shows a graph for the ratio of raw TKN to TBOD, with a range of 0.1 to 0.2 considered typical. The 2013 watershed median is 0.2, which is the high end of typical. Higher ratios could be attributed to recycle streams or an industrial influence in the collection system.

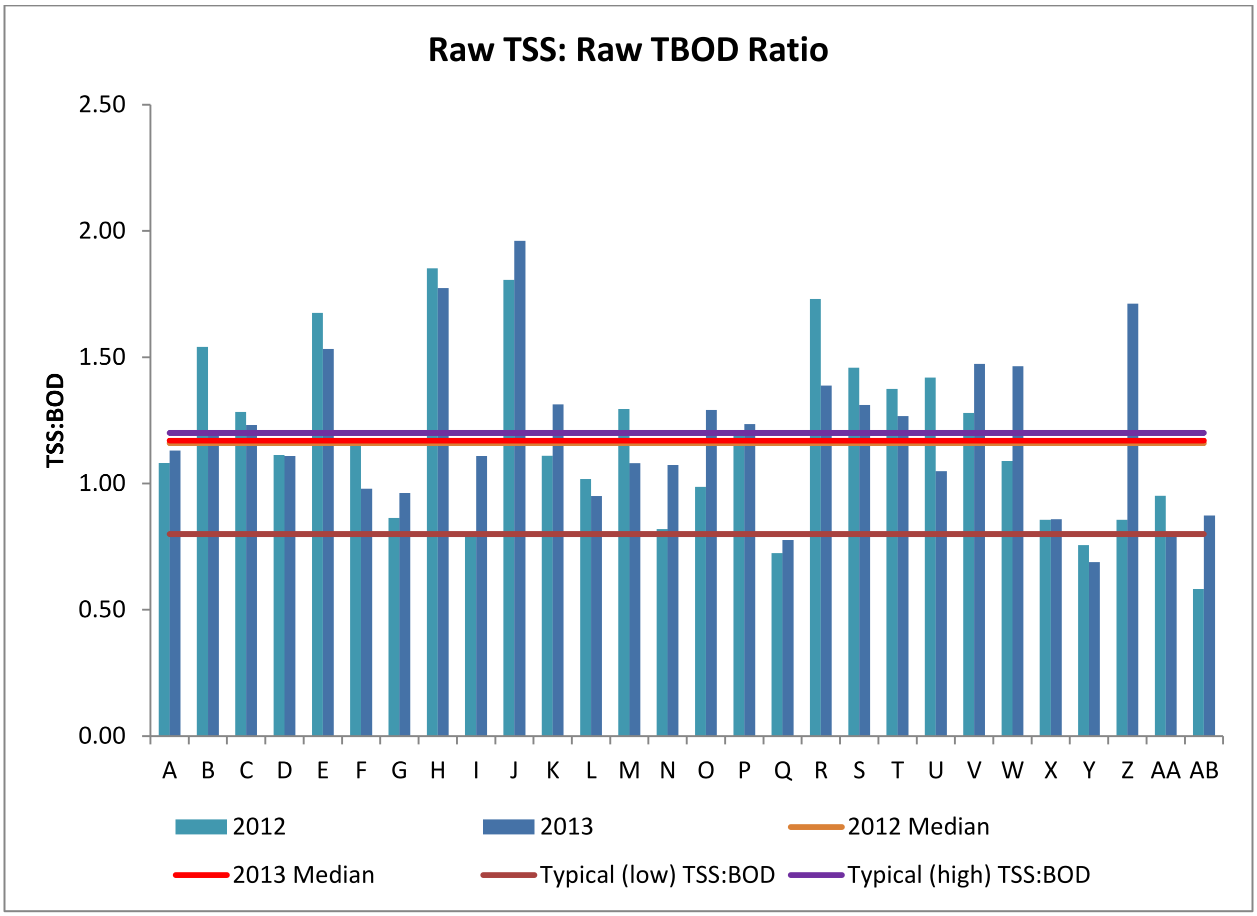


Figure 10: Ratio of Raw TSS to Raw TBOD

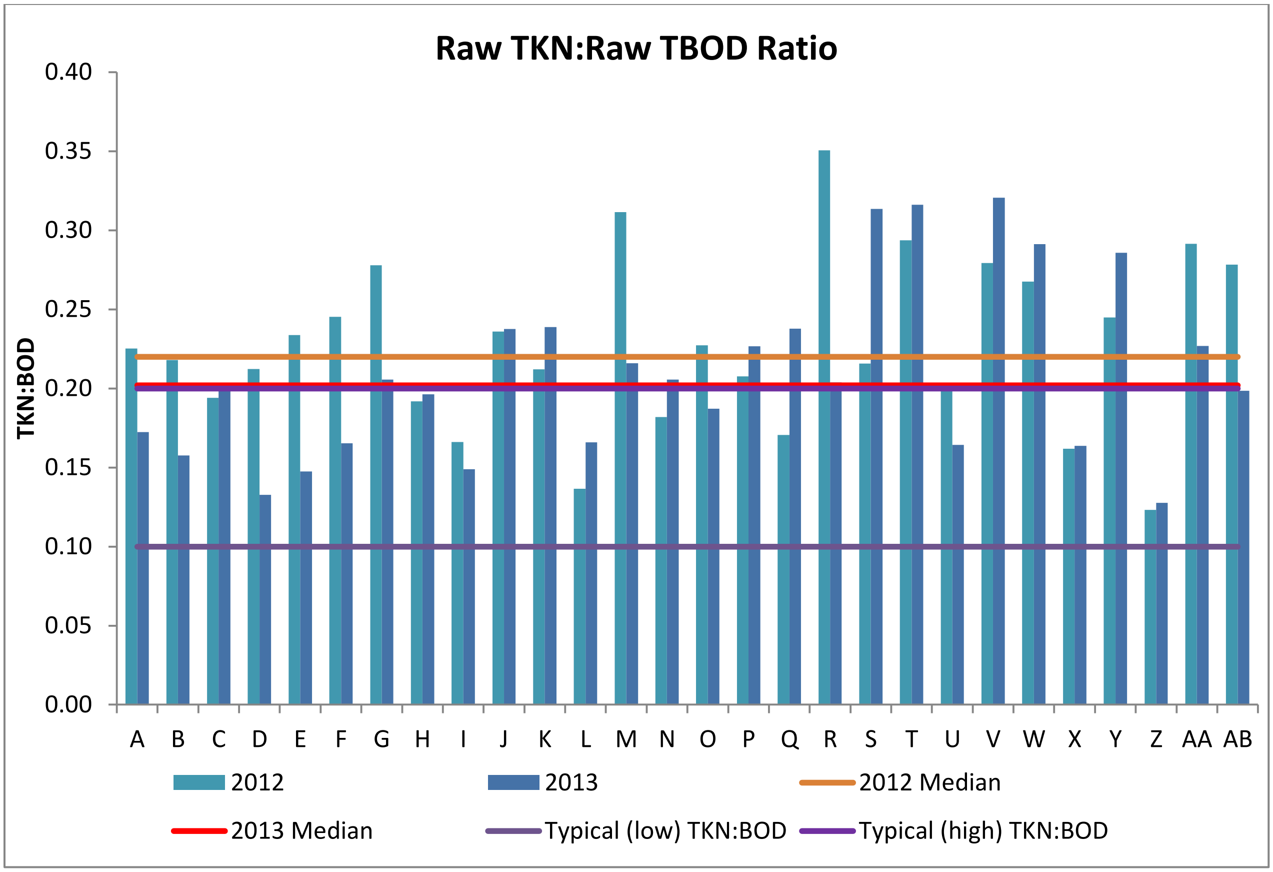


Figure 11: Ratio of Raw TKN to Raw TBOD

Final Effluent Quality

Total Phosphorus (TP)

Figure 12 shows 2012 and 2013 reported final effluent TP with the ECA limit shown in red. Additionally, the graph shows proposed voluntary interim effluent TP target for secondary and tertiary treatment plants, represented by green and dark green dashes, respectively. These interim quality performance "targets", outlined in the Grand River Management Plan (GRCA, 2014), could be achieved through enhanced process control techniques as set out in the CCP. The interim performance targets were established based on demonstrated performance across the province and within the watershed and have been established for various levels of treatment (e.g. separate targets for secondary plants, tertiary plants and lagoons).

The graph in Figure 12 shows that plants generally perform well and consistently meet their ECA criteria. Based on annual average TP concentrations, 22 out of 28 plants in the watershed are meeting the interim performance targets recommended in the Grand River Water Management Plan.

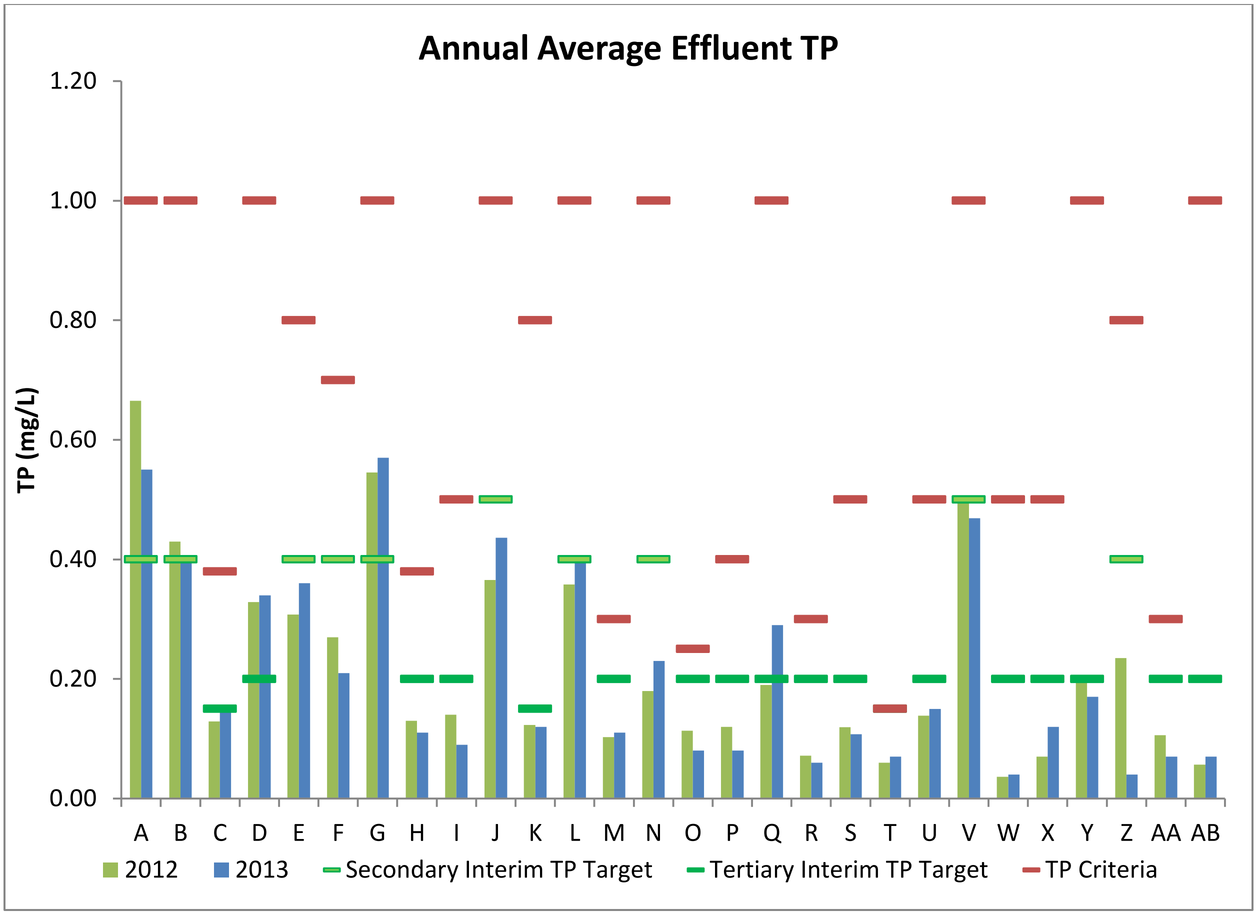


Figure 12: Annual Average Effluent Total Phosphorus

Total Ammonia Nitrogen

Data for TAN in final effluent has been separated by season. Figure 13 shows the data for the "summer" period which is defined as May through October, inclusive. The "winter" period is considered to be November to April and this data is shown in Figure 14. Each graph shows the annual average TAN concentration with a green bar for 2012 and a blue bar for 2013 data and the ECA limit, where there is one, in red. It is common to have different ECA criteria for TAN in "summer" and "winter". For some plants, the definition of "summer" and "winter" in their ECA is slightly different from the definition used in this report. These graphs show that plants in the watershed are meeting their ECA criteria for TAN in summer and winter. Generally, effluent concentrations are somewhat higher in winter due to the fact that nitrification is less effective under cold conditions.

The proposed voluntary interim effluent quality performance targets for TAN are included in Figures 13 and 14, shown by green dashes. The Water Management Plan project team recommended these voluntary targets (or plant specific targets) be adopted to achieve the goal of improved water quality in the watershed. Many of the plants in the watershed met these targets based on seasonal average concentrations.

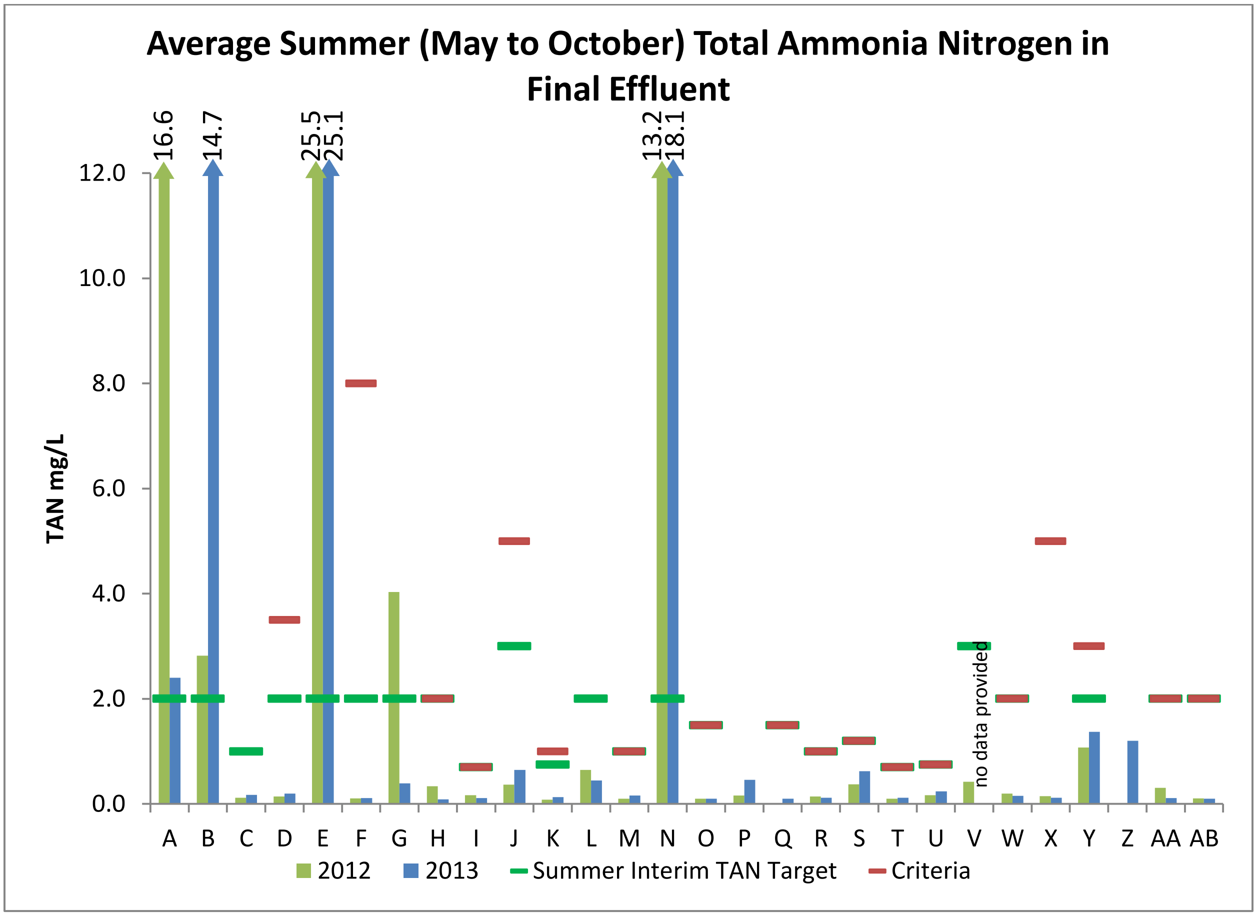


Figure 13: Average Effluent Total Ammonia Nitrogen (Summer)

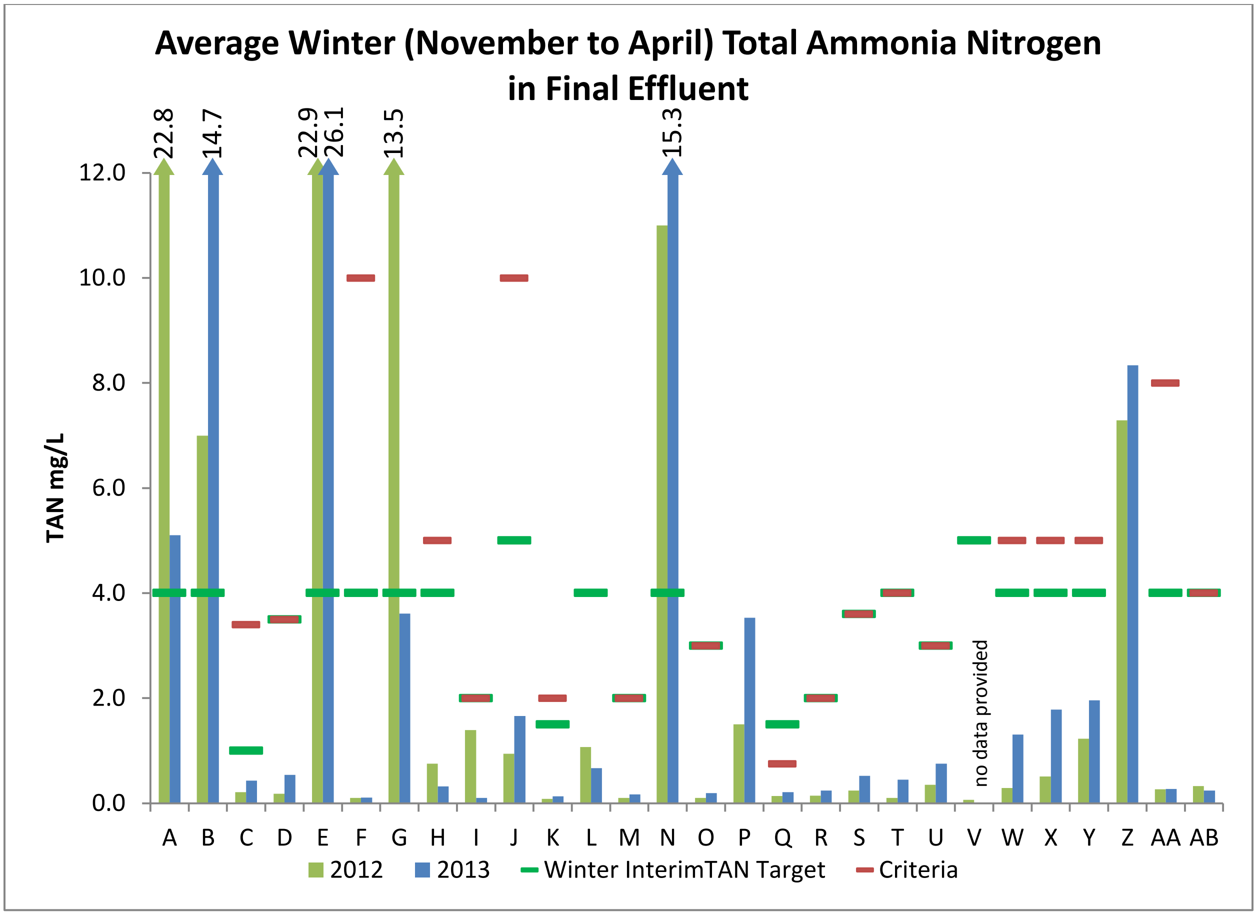


Figure 14: Average Effluent Total Ammonia Nitrogen (Winter)

Influence of WWTPs on the Grand River

Figure 15 shows the relative influence of wastewater effluent on the Grand River by comparing the total volume of treated effluent in 2013 to the annual average river flow at York in Haldimand County. Figure 15 shows that treated effluent made up approximately 3% of the river flow on an annual average basis in 2013. Figure 16 shows a similar comparison based on low flow conditions observed in the month of August 2013. During summer low flow, the proportion of treated effluent increased to 5%. As a result of higher precipitation in 2013 (see Figure 5), flow in the Grand River in August 2013 was much higher than usual. In a more typical year, wastewater flow makes up a much higher proportion of the river flow and therefore it is important to maintain the best possible effluent quality to minimize environmental impacts.

Figures 17 and 18 show the annual loading of TP from watershed WWTPs as a percentage of the TP loading in the Grand River at York for 2012 and 2013, respectively. Annual loading of TP in the Grand River at York has been estimated based on regular monitoring of river water quality and flow reported by Environment Canada (Dove, 2014). Figure 17 shows the TP loading to the river from wastewater effluent was approximately 40% in 2012. Conversely, the TP loading contribution from WWTPs in 2013 was approximately 9%. As mentioned above, in years where there is lower than typical precipitation (i.e. 2012) the impact of wastewater effluent to the river is greater. In a year with higher than typical precipitation (2013), wastewater effluent TP loading makes up a smaller fraction of the loading in the river, likely due to other sources of TP (i.e. agricultural non-point sources, urban runoff, etc.).

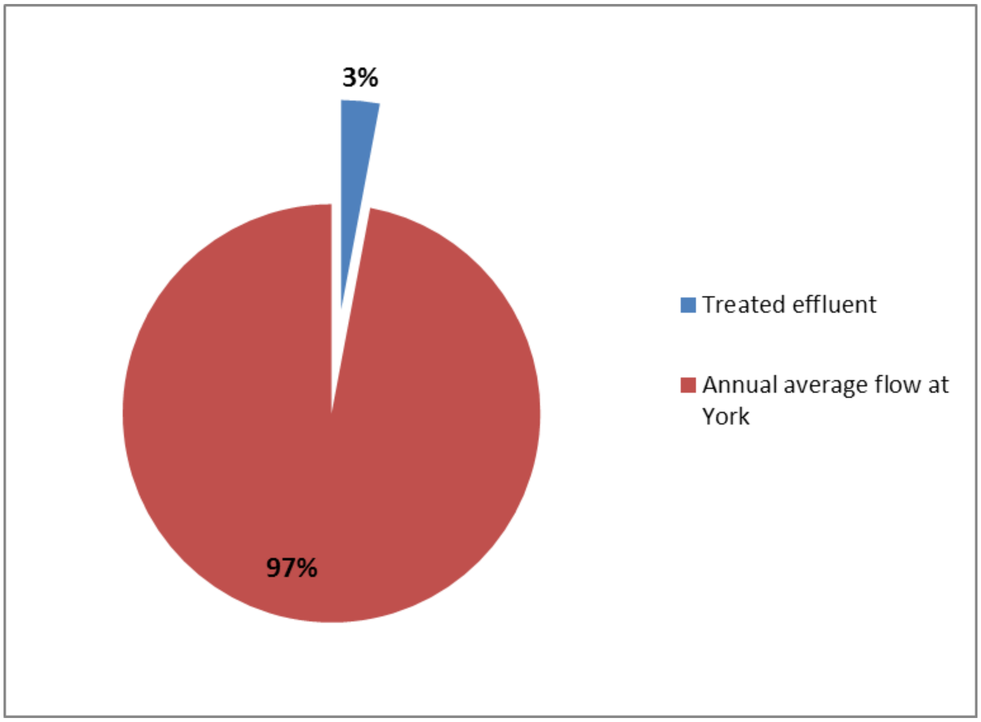


Figure 15: Annual Average Effluent Flow in 2013 compared to Grand River Flow at York

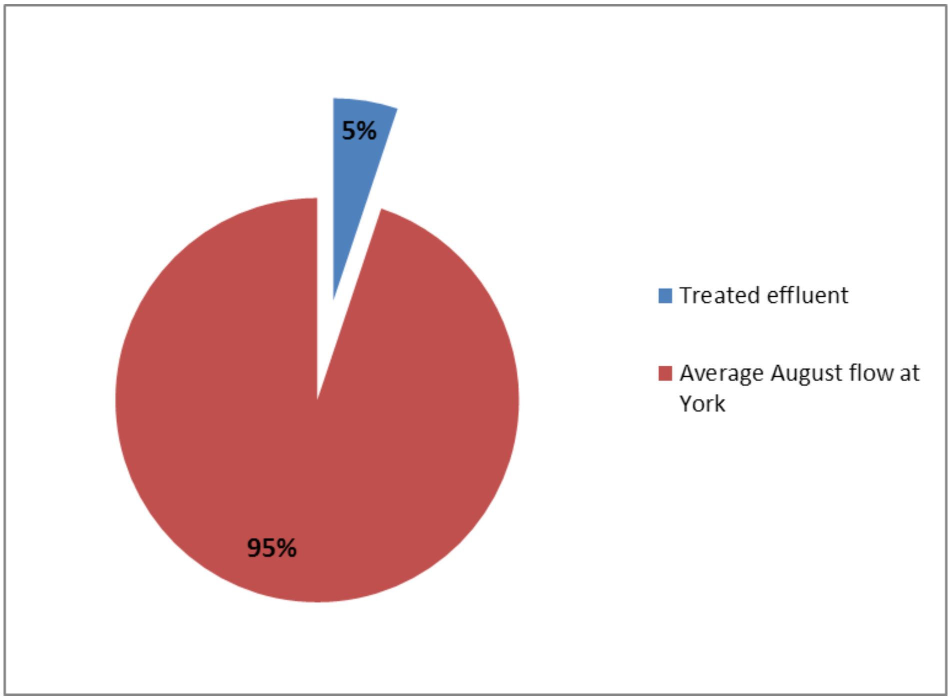


Figure 16: Average Effluent Flow compared to Grand River Flow at York in August 2013 only

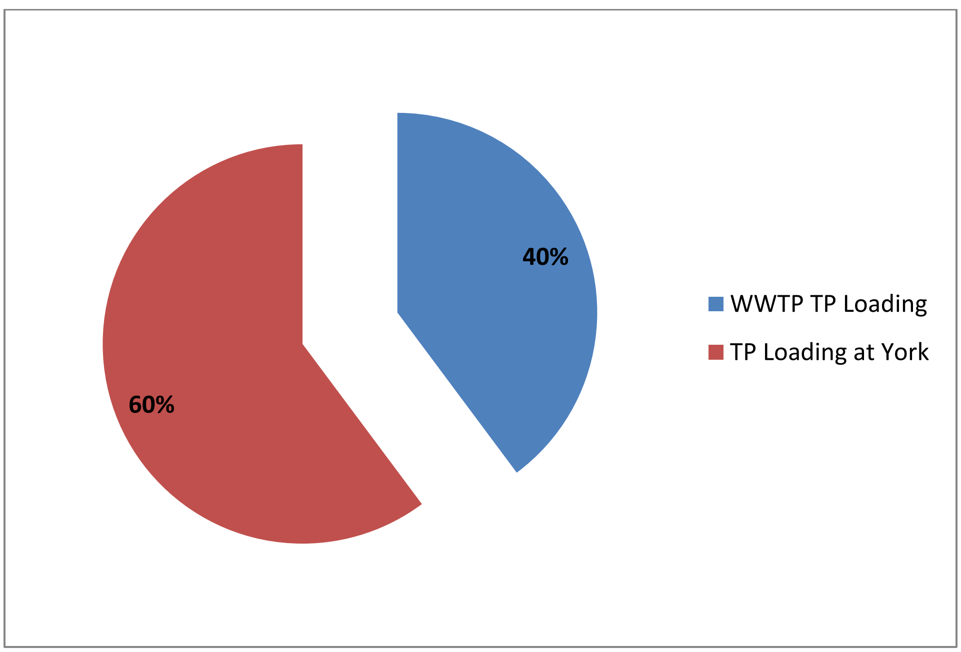


Figure 17: Annual average effluent TP loading in 2012 compared to Grand River TP loading at York

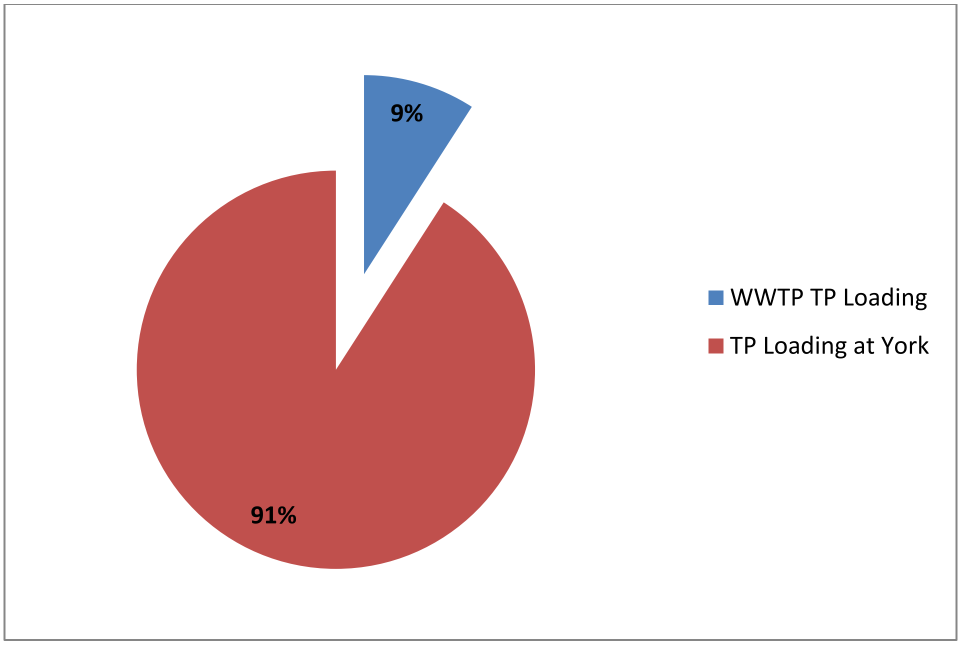


Figure 18: Annual average effluent TP loading in 2013 compared to Grand River TP loading at York

The total annual loading of wastewater effluent TAN discharged to surface water was also calculated based on each plant's annual average flow and its average concentration of TAN in both the summer and the winter. These results are documented in the following table. From Table 1, there was a 17% decrease in wastewater effluent TAN loading from 2012 to 2013, which was attributed to a large reduction in TAN loading from Plant A.

Table 1: Wastewater effluent TAN loading to the Grand River

TAN Loading	2012	2013
TAN summer (kg)	426,657	361,417
TAN winter (kg)	512,237	410,651
Total	**938,894**	**772,068**

Conclusion

Per capita wastewater flows to plants in the Grand River watershed in 2013 were generally at the low end of the typical range. The general low per capita flows has been attributed to water conservation efforts in recent years. Year to year variability in per capita flows may be attributed to changes in climate, for example 2013 was very wet and per capita flows were somewhat higher than in 2012.

TBOD, TSS and TKN loads were generally not within the typical range, which suggests that there may be some opportunities to improve the characterization of raw influent at many plants. This could include considerations such as sampling frequency, composite or grab, cBOD vs. TBOD, sampling location, etc.

Most plants in the watershed are required by their ECA to measure cBOD in raw influent. This may be resulting in significant underestimation of the TBOD loadings. Other challenges include raw influent sampling locations that may not be representative of raw sewage entering the plant due to internal recycle streams.

Table 2 provides a summary of performance measures based on data from 28 municipally-owned plants across the Grand River watershed. WWOP participants have successfully reported on two years of plant performance data and the GRCA will continue to encourage local municipalities to report on these performance measures on an annual basis. Tracking these measures over time can be used to demonstrate improved performance and help to identify candidates that may benefit from further optimization. In addition, WWOP participants are encouraged to consider adopting and reporting against the Water Management Plan voluntary interim targets for TP and TAN. By embracing an optimization approach to reduce these nutrients in wastewater effluent, municipalities can help to ensure a healthy and sustainable watershed that supports prosperous and growing communities into the future.

Table 2: Summary of 2012 and 2013 watershed WWTP performance measures

Performance Measure	2012 Watershed Median	2013 Watershed Median	Typical Value
Per capita flow (L/person/day)	317	351	350 - 500
% rated capacity	54%	66%	N/A
Peak day: Annual average flow	2.1	2.47	2.5 - 4
Per capita TBOD loading (g/person/day)	64	72	80
Per capita TSS loading (g/person/day)	89	84	90
Per capita TKN loading (g/person/day)	14	14	13
Raw TSS:TBOD ratio	1.11	1.17	0.8 - 1.2
Raw TKN:TBOD ratio	0.23	0.20	0.1 - 0.2

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