2016 Watershed Overview of Wastewater Treatment Plant Performance

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Acronyms and Abbreviations

ADF	Average daily flow
TBOD	5 day biochemical oxygen demand
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
I/I	Inflow/Infiltration
MOECC	Ontario Ministry of the Environment and Climate Change
NDF	Nominal Design Flow (listed in plant's ECA)
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
WMP	Water Management Plan
WWOP	Watershed-wide Wastewater Optimization Program
WWTP	Wastewater treatment plant

Executive Summary

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). A key program activity is monitoring performance and plant loading, which are used to evaluate the success of the program and track WWTP impacts on the Grand River over time. Available performance and loading data for 28 of 30 municipal wastewater treatment plants were voluntarily reported in 2016. These results were summarized and compared to results from 2012 to 2015.

Treatment Performance

Table ES-1 provides a summary of TP and TAN effluent loadings and flow-weighted average concentrations from 2012 to 2016. In 2016 twenty-five plants in the watershed met the interim effluent quality performance target for TP, on an annual basis, as recommended in the Grand River Water Management Plan (WMP). In 2016, 25 plants met the summer TAN interim effluent quality target, based on seasonal average concentrations and 24 plants met the winter TAN target. The total TAN loading decreased by 38% in 2016 compared to 2015. The total TP loading was decreased by 7% in 2016 compared to 2015. The total TP and TAN loadings decreased by 6% and 64% respectively in 2016 compared to 2012.

Table ES-1: Summary of 2012-2016 TP and TAN loading and flow-weighted concentrations to the Grand River

	2012		2013		2014		2015		2016	
	Loading (tonne)	Conc. (mg/L)	Loading (tonne)	Conc. (mg/L)	Loading (tonne)	Conc. (mg/L)	Loading (tonne)	Conc. (mg/L)	Loading (tonne)	Conc. (mg/L)
TAN summer (kg)	417	4.3	346	3.22	343	3.1	206	2.08	124	1.25
TAN winter (kg)	534	5.5	426	3.97	512	4.63	353	3.57	223	2.19
Total	**951**	**4.9**	**773**	**3.6**	**855**	**3.86**	**560**	**2.82**	**347**	**1.75**
TP loading	**35.9**	**0.37**	**37.6**	**0.35**	**36.8**	**0.33**	**36.5**	**0.37**	**33.8**	**0.33**
all the concentrations are flow-weighted average concentrations										

Sludge Accountability and Water Balance

A sludge accountability analysis compares the annual amount of sludge reported by a mechanical plant to the amount of sludge projected based on plant loadings and removal. Conducting this analysis can help to determine if monitoring is truly representative. In 2016, sludge accountabilities were reported for 23 plants in the watershed. For twelve of the plants, the accountability "closed" within ± 15%.

A water balance analysis compares the annual amount of measured net precipitation on surface area of a lagoon system to the annual amount of projected net precipitation using lagoons level measurements, total influent and total effluent of a lagoon system. This analysis can help to determine if the flow measurement devices at a lagoon are accurate. In 2016, water balances were reported for 2 lagoon systems in the watershed. Both of these analyses did not close within ±15%.

Grand River Impacts

Table ES-2 summarizes the impact of wastewater effluent discharges on the Grand River.

Table ES-2: WWTP Effluent flow as a percentage of Grand River total flow

Parameter	2012	2013	2014	2015	2016
% Annual Average Flow	7%	3%	3%	5%	5%
% August Average Flow	14%	5%	9%	12%	9%

The values in Table ES-2 are largely a function of climate. In 2016, precipitation was close to (but lower than) the long-term average. In 2015, precipitation was near the lower end of typical. In 2014, precipitation was close to the long-term average. In 2013, the watershed generally experienced higher than normal precipitation across its central and northern portions. Precipitation in 2012 was near the low end of typical.

Plant Loading

Table ES-3 summarizes key process loading metrics. The results in the table enable municipalities to compare loadings at their facilities to those at other plants in the watershed, which can be used to determine the impact of industrial discharges and may highlight concerns with unrepresentative sampling of raw influent.

Table ES-3: Summary of 2012 to 2016 watershed WWTP performance measures

Performance Measure	Watershed Median 2012	2013	2014	2015	2016	Typical Value
Per capita flow (L/person/day)	313	351	344	294	298	350 - 500
ADF as % of Nominal Design	54%	66%	62%	51%	54%	N/A
Peak day: Annual average flow	2.25	2.53	2.44	2.31	2.75	2.5 - 4
Per capita TBOD[1] loading (g/person/day)	65	72	74	77	69	80
Per capita TSS loading (g/person/day)	82	84	93	73	69	90
Per capita TKN loading (g/person/day)	14	14	14	13	14	13
Per Capita TP loading (g/person/day)	1.8	1.9	2.0	1.8	1.7	2.1
Raw TSS:TBOD ratio	1.14	1.17	1.12	1.01	1.03	0.8 - 1.2
Raw TKN:TBOD ratio	0.22	0.20	0.18	0.17	0.18	0.1 - 0.2

Year-to-year variations in many of the flow metrics in Table ES-3 are largely due to differences in I&I related to climate.

By embracing an optimization approach to reduce the impacts of wastewater effluents on the Grand River, including nutrients, municipalities can help to ensure a healthy and sustainable watershed that supports prosperous and growing communities into the future.

[1] A number of plants do not measure total BOD_5 in the raw influent because their ECAs require measurement of carbonaceous BOD_5. Research indicates that $cBOD_5$ measurements of raw wastewater underestimate organic loading by 20 to 40%. For this summary $TBOD_5$ values were assumed to be 20% higher than $cBOD_5$. This assumption may be impacting the metrics related to TBOD in Table ES-3.

Introduction

The Grand River watershed has a population of about 985,000 that is expected to reach 1.53 million by 2051. There are 30 municipal wastewater treatment plants (WWTPs) that discharge their treated effluent into rivers in the watershed as shown in Figure 1. The organizations listed below are responsible for their operation:

- 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
- Haldimand County
- Six Nations of the Grand River
- Mississaugas of the New Credit First Nation.

Significant population growth will result in more wastewater being discharged into these rivers. Wastewater effluent of high quality will help to ensure that river health continues to improve and watershed communities will continue to prosper.

The following report describes the background and objectives of the Grand River Watershed-wide Wastewater Optimization Program (WWOP) and provides a 5 year summary of 2012-2016 performance data voluntarily reported by the program participants.

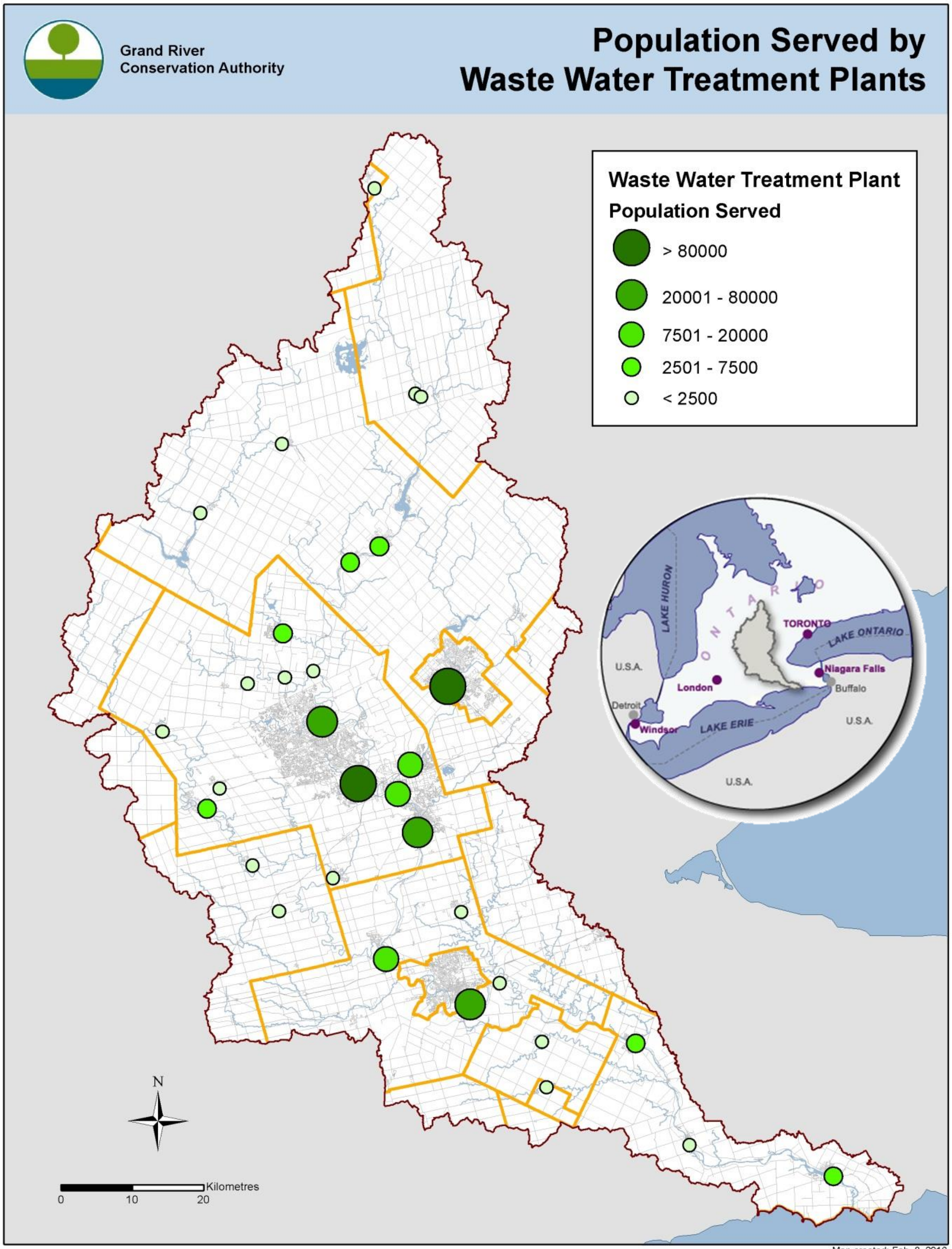

Figure 1: Map of Grand River Watershed showing locations of municipal WWTPs

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 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 existing area-wide optimization programs in the US, and
- Demonstrate strategies that can serve as a model for other areas of Ontario.

The WWOP promotes optimization across the watershed by encouraging the adoption of the Composite Correction Program (CCP). The U.S. Environmental Protection Agency (EPA) developed the CCP as a structured approach to identify and systematically address performance limitations to achieve a desired effluent quality (U.S. EPA, 1989). The CCP was adapted for Ontario and documented in the handbook, “The Ontario Composite Correction Program Manual for Optimization of Sewage Treatment Plants” (WTC and PAI, 1996).

Additionally, the Grand River Water Management Plan (WMP) recommends adopting the CCP 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 and re-rated capacity.

The CCP is based on the model shown in Figure 2. Good administration, design, and maintenance establish a “capable plant” and, by applying good process control, operators achieve a “good, economical” effluent.

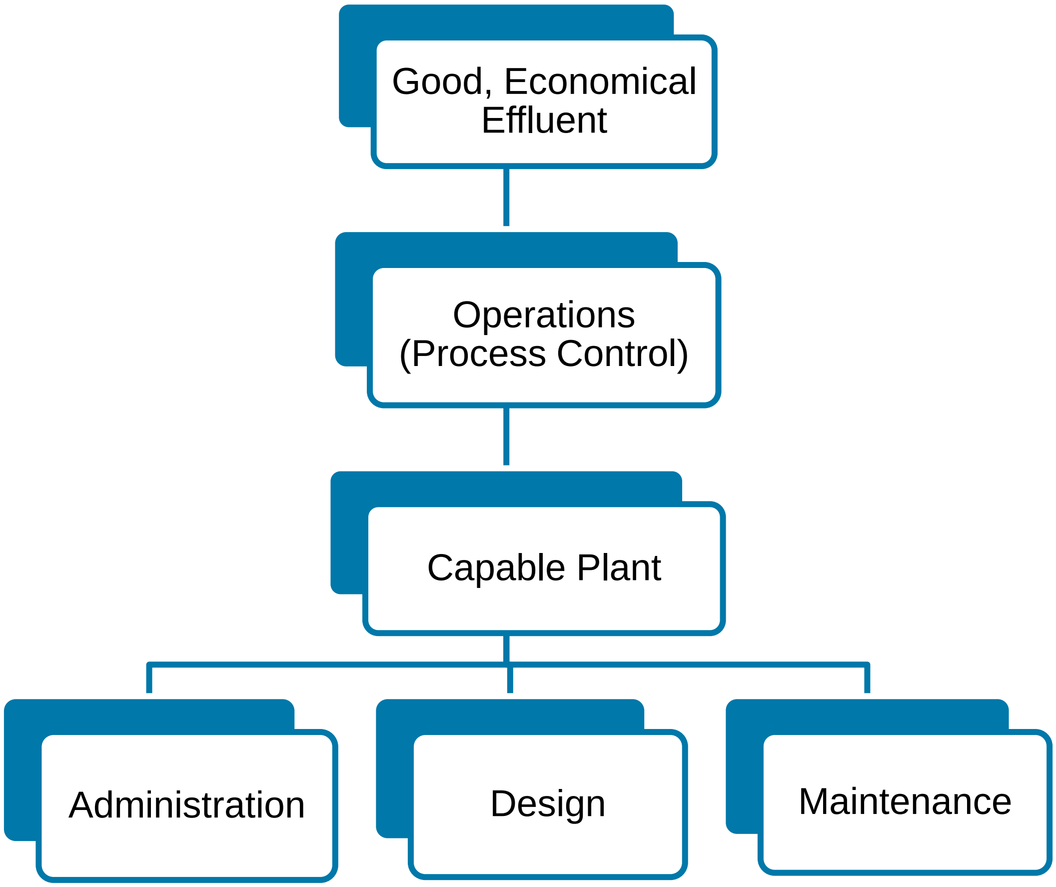

Figure 2: Composite Correction Program Performance Pyramid

The CCP is a two-step approach. The first step, a Comprehensive Performance Evaluation, evaluates and identifies performance limiting factors in the areas of administration, design, maintenance and operations. If applicable, in Step 2 (Comprehensive Technical Assistance) a facilitator works with plant operators and managers to address and resolve any factors identified in Step 1. This approach has proven to be successful but is also very resource intensive, as it used on a plant-by-plant basis. To address this challenge, an area-wide approach (as shown in Figure 3) was adopted based on the successful strategy for optimizing drinking water treatment systems in the US. Major components include: Status, Targeted Performance Improvement, and Maintenance. The model utilizes a proactive, continuous improvement approach to improved effluent quality.

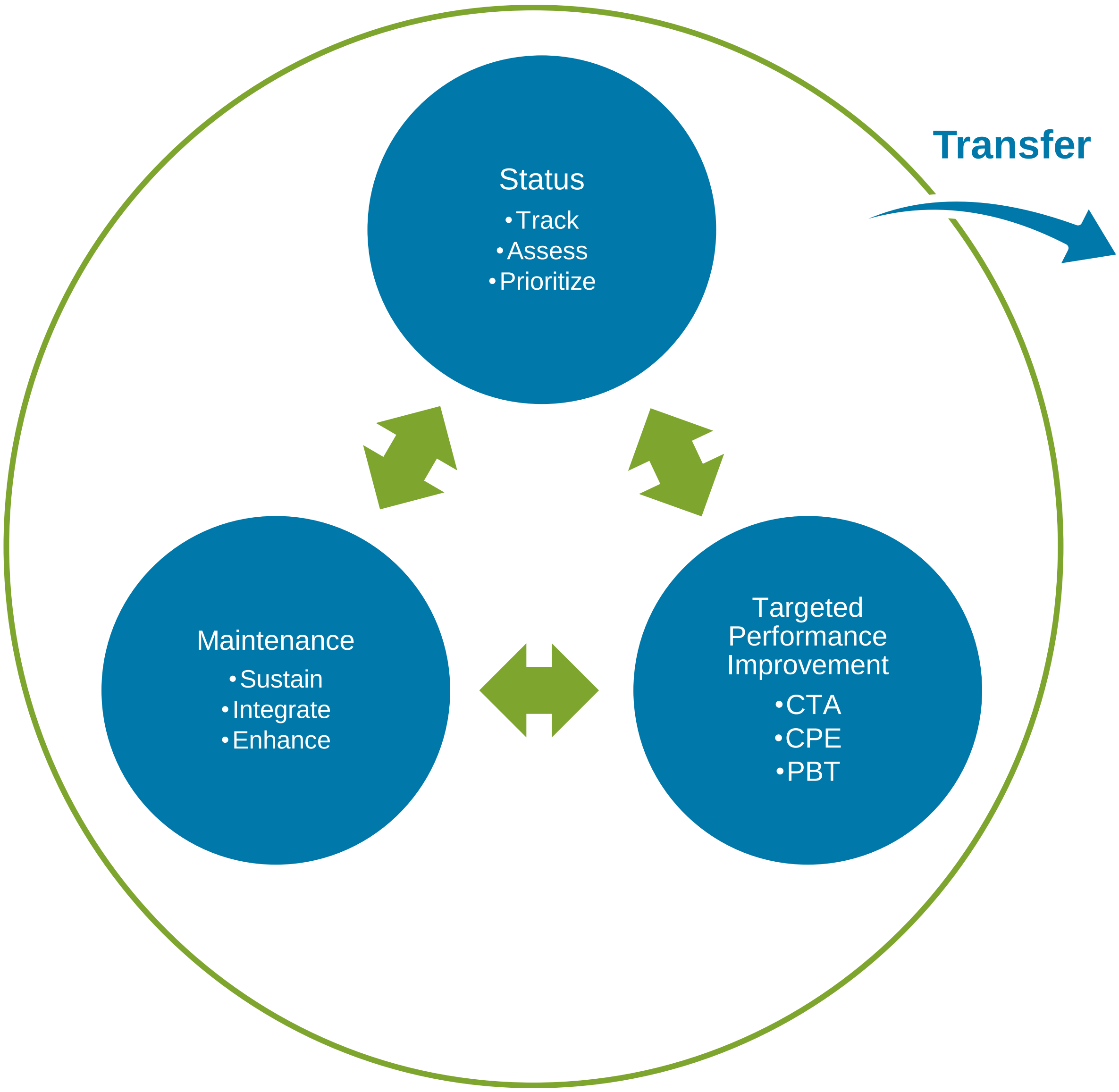

Figure 3: Area-Wide Optimization Model

A key activity under the Status Component is plant performance monitoring, which can be used to demonstrate the success of the program, track changes over time and identify plants for further optimization work. Targeted Performance Improvement establishes voluntary performance targets and applies tools for achieving them. This component can include performance-based training, technical assistance, and other activities to develop and transfer skills. The purpose of the Maintenance component is to sustain and grow the program and includes a recognition program to encourage participation. Once these components have been successfully demonstrated within the Grand River watershed, they can be adapted and applied to other jurisdictions.

Recognition Program

As part of the Maintenance Component a recognition program has been developed to encourage participation and to acknowledge plants that:

- Participate in the WWOP,
- Apply CCP concepts,
- Meet all of the effluent compliance limits stated in their ECA,
- Adopt and achieve voluntary effluent quality performance targets,
- Participate in enhanced annual reporting (per capita loading, sludge accountability, etc.) and,
- Conduct annual sludge accountability analysis (or water balance for lagoon systems).

The recognition awards based on 2016 plant data will be presented at a future WWOP workshop.

Data Collection Methodology

Voluntary performance reporting across the watershed was initiated through several workshops that were held in 2010 and 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 following performance calculations using their own plant data for 2012:

- Annual Average Daily Flow (ADF) as a percentage of Nominal Design Flow (NDF),
- Per capita influent flow,
- Ratio of peak day flow to ADF,
- 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.

Additional workshops were held throughout 2012-2016 to review these performance metrics. Participants across the watershed were encouraged to calculate these metrics on an annual basis, report the information back to the GRCA as well as include them in performance reports to the MOECC.

In addition to the metrics listed above, plant staff voluntarily submitted plant performance data including effluent total phosphorous (TP) and Total Ammonia Nitrogen (TAN) concentrations. An Excel data spreadsheet was provided to plant owners and operators for data submission.

This report summarizes 2016 plant data and compares it to 2012-2015 data.

Wastewater Treatment Plant Reporting and Performance

Data Reporting

For 2016, 28 of the 30 municipal WWTPs voluntarily reported their performance to the GRCA. 8 of these treatment plants reported their data using an Excel spreadsheet and 20 treatment plants provided their annual report to GRCA. Data was not available for two facilities.

In presenting summaries of the data in the following sections, the plants are ranked from largest to smallest in terms of flow treated.

Final Effluent Quality

Total Phosphorus (TP)

A body of water requires a proper amount of nutrients to stay healthy, however excessive quantities of these elements can have negative impacts on aquatic ecosystem. An excessive amount of phosphorous in water leads to algal growth which ultimately consumes DO in the water. TP is being targeted for improvement under WWOP since "a high concentration of phosphorus in most rivers and streams in the Grand River watershed has long been recognized as an issue as it is the primary nutrient that promotes nuisance growth of aquatic plants and algae in the rivers" (GRCA, 2014). Over the past decade, zones of low oxygen, as a result of excessive algal growth, have been increasing in Lake Erie causing significant impact on the lakes environment and Canadian economy (Canada-Ontario Agreement Partners, 2017). In early 2017, the Canada-Ontario action plan on achieving phosphorus reduction in Lake Erie from Canadian sources was drafted. According to 2003-2013 data, "Canadian sources contribute 54 percent of the total phosphorus load to the eastern basin, with the majority of this coming from one tributary, the Grand River" (Canada-Ontario Agreement Partners, 2017). This shows another important reason to improve phosphorous reduction in the Grand River and its tributaries.

For reporting purposes, data for effluent TP was separated by treatment type (secondary and tertiary). Tertiary treatment plants provide filtration in addition to secondary treatment. Lagoons reporting in 2016 equipped with filters have been categorized under tertiary treatment and those without are categorized under secondary treatment.

Figure 4 and Figure 5 show reported annual final effluent TP concentrations and each plant's corresponding ECA limit (orange dashes) for secondary and tertiary treatment, respectively. The figures also show a plant's ECA objective (or other voluntary performance objectives if they have one) by a blue dash. The voluntary effluent quality performance target, as outlined in the Water Management Plan, is shown by a solid dark blue line.

The interim effluent quality performance targets, shown in Table 4, were established based on demonstrated performance across the province and within the watershed for various levels of treatment (e.g. separate targets for secondary and tertiary treatment).

Table 4: Proposed voluntary effluent quality performance targets for TP

Treatment level	Interim Target	Final Target
Secondary effluent	0.4 mg/L	0.3 mg/L
Tertiary effluent	0.2 mg/L	0.15 mg/L

The graphs in Figure 4 and Figure 5 show that annual average TP concentrations met ECA limits over the five year period. Twenty-five out of 28 plants in the watershed met the interim effluent quality performance targets on an annual average basis in 2016. This number was twenty-three out of 28 plants in 2012.

Voluntary Targets

"A study modelling future river water quality conditions suggests that water quality will incrementally improve with the adoption of **effluent quality performance targets** achieved through enhanced process control techniques as set out in the CCP." (GRCA, 2014)

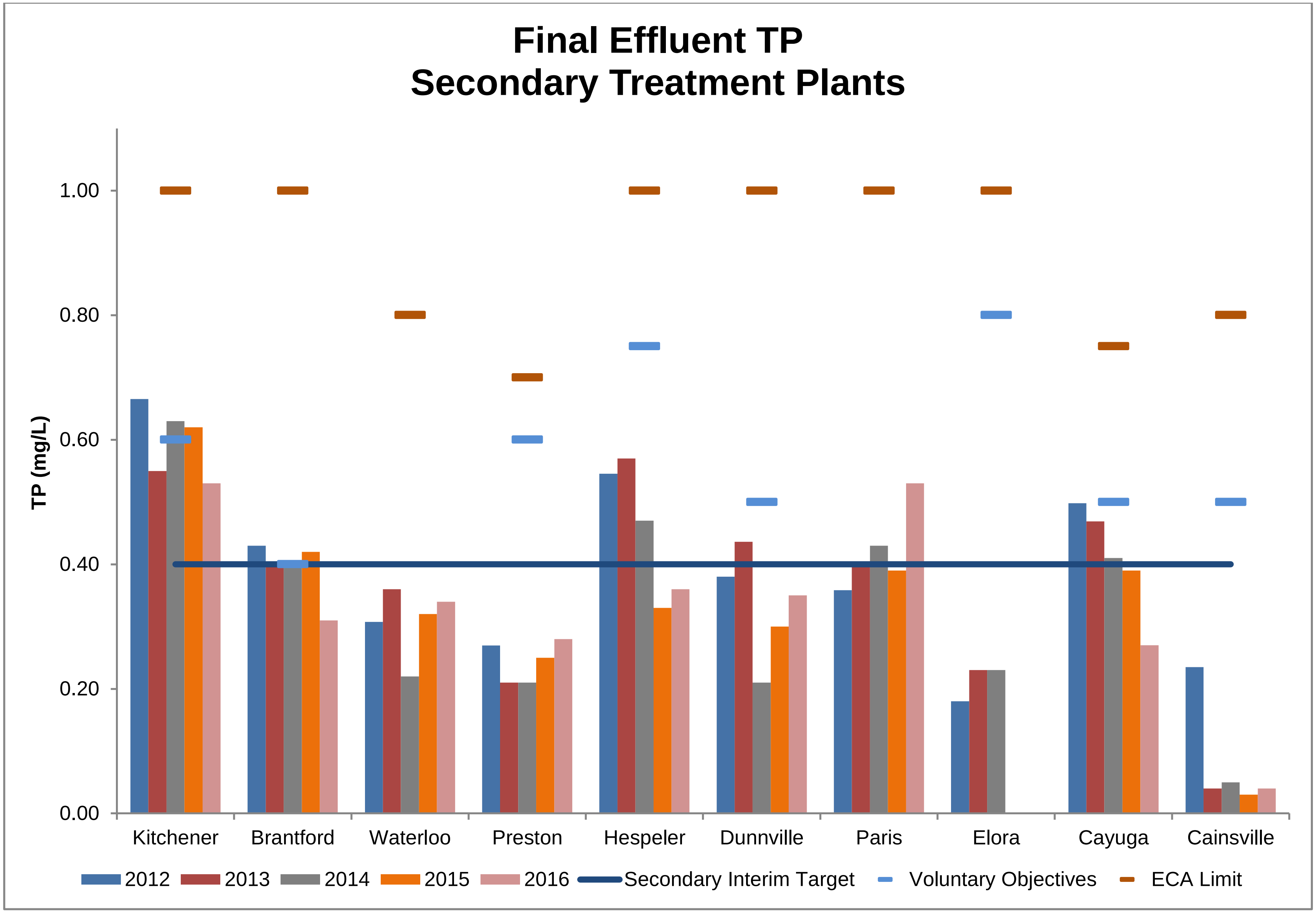

Figure 4: Annual Average Effluent Total Phosphorus with limits and objectives for Secondary WWTPs

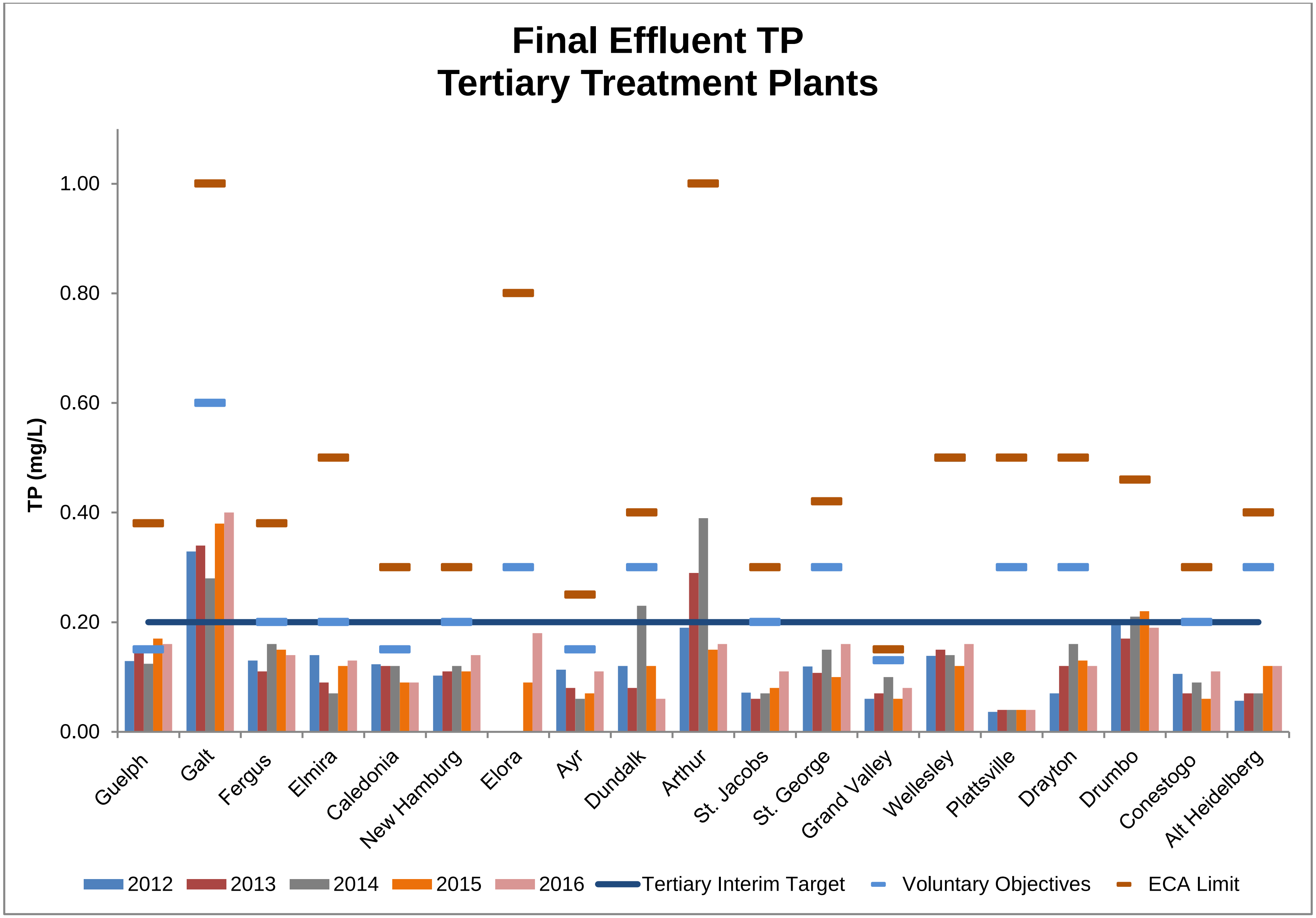

Figure 5: Annual Average Effluent Total Phosphorous with limits and objectives for Tertiary WWTPs

Total Ammonia Nitrogen (TAN)

Nitrate and ammonia can have direct toxic effects on aquatic life at high concentrations and TAN acts as an oxygen scavenger that reduces the DO concentration in water. TAN is being targeted under WWOP since "high levels of un-ionized ammonia occur in the Grand River watershed in reaches downstream of wastewater treatment plants" (GRCA, 2014).

Data for TAN in final effluent was separated by season. Figure 6 shows the data for the "summer" period which was defined as May to October. Figure 7 shows the data for the "winter" period which was defined as November to April. 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.

Improving water quality in the watershed

The Water Management Plan Project Team recommends "watershed municipalities who own WWTPs adopt voluntary effluent quality performance targets that go beyond the compliance objectives as stated in ECAs."

Both graphs show the seasonal average TAN concentration and the ECA limit (if there is one) for each plant. Nine of the 28 plants do not have summer TAN limits in their ECA, and 8 of 28 plants do not have limits for the winter period. Generally, TAN effluent concentrations are higher in winter as nitrifying bacteria which remove TAN are less effective under cold conditions.

Additionally, Figure 6 and Figure 7 show voluntary TAN objectives, which can be a plant's ECA objective or other objective (blue dash). The voluntary effluent quality performance target, as outlined in the Water Management Plan, is shown by a dark blue line. The Water Management Plan project team recommended that plants adopt the voluntary interim targets (or plant specific targets), as shown in Table 5, to achieve the goal of improved water quality in the watershed. In 2016, 25 of the 28 plants met the interim target for the summer period, and 24 plants met the winter interim target, based on seasonal average concentrations. In 2012, 23 and 22 plants met the TAN interim targets for summer and winter period, respectively.

Table 5: Proposed voluntary effluent quality performance targets for TAN

Season	Interim Target	Final Target
Summer	2 mg/L	1 mg/L
Winter	4 mg/L	2 mg/L

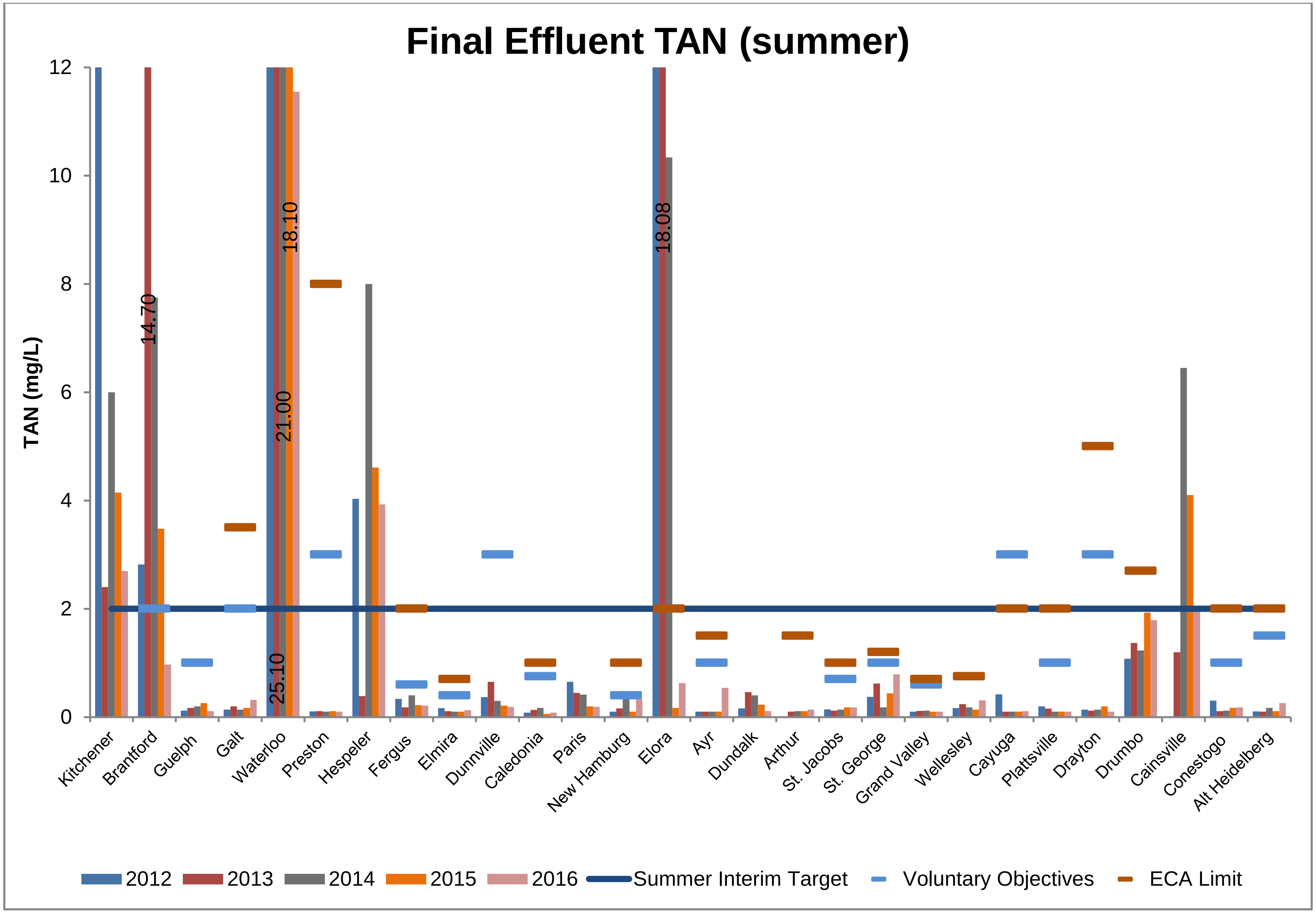

Figure 6: Average Effluent Total Ammonia Nitrogen (summer)

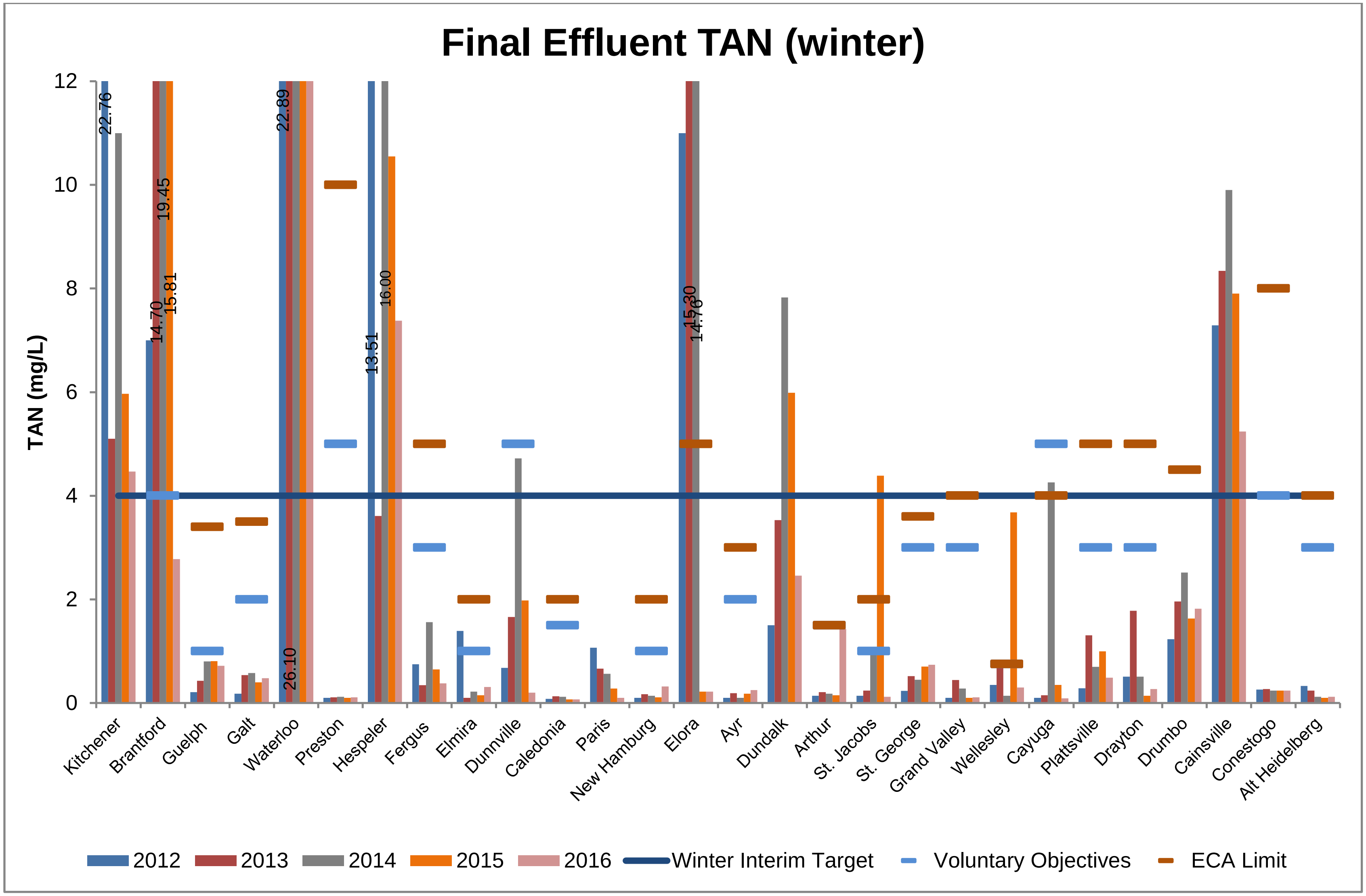

Figure 7: Average Effluent Total Ammonia Nitrogen (winter)

Sludge Accountability and Water Balance

A sludge accountability analysis is a key component of the CCP evaluation and is used to determine if monitoring is truly representative of plant performance. A sludge accountability analysis for mechanical activated sludge plants compares the amount of sludge reported to the amount of sludge projected based on plant loadings and removals, on an annual basis. The reported sludge includes sludge intentionally wasted by the operator to control the biological process and unintentional wasting (i.e. effluent TSS). Projected sludge can include an estimate of primary sludge, biological sludge generated by the conversion of organics to biomass, and chemical sludge (solids produced as a result of coagulant addition). The formula to calculate sludge accountability is as follows:

$$\frac{projected\ sludge - reported\ sludge}{projected\ sludge} * 100\%$$

If the result is within a range of ± 15% the sludge accountability is considered to "close". If the value is outside of this range, then the monitoring may not be truly representative of plant loading or performance. Further investigation is warranted to review sample frequency, sampling techniques, analytical methods, flow measurement accuracy, etc.

Common sources of sludge accountability analysis discrepancy include:

- Non-representative sampling (poor sampling techniques or analytical procedures, inadequate sampling frequency, a sampling location which is not representative, etc.),
- Lack of flow measurement on some streams or inaccurate flow measurement, and
- Neglecting to take into account all inputs and outputs (e.g. no measurements on return streams such as filter backwash or digester decant, etc.).

Table 6 shows the results for 23 plants in the watershed that conducted sludge accountability for 2016. Number of plants that conducted the analysis increased from 9 in 2015 to 23 in 2016. Kitchener, Brantford, Guelph, Galt, Preston, Fergus, Elmira, Caledonia, Paris, Ayr, St. Jacobs and Alt Heidelberg WWTPs have a sludge accountability analysis that closed (i.e. within ±15%). Data from Fergus, Paris, Elora and St. George WWTPs were collected through the MOECC's Performance Based Training pilot program and sludge accountability analysis was implemented for Arthur and Grand Valley WWTPs as a training workshop.

Table 6: Summary of 2014 - 2016 Sludge Accountability analyses of plants that report on it

Plant	Projected Sludge (kg)			Reported Sludge (kg)			Sludge Accountability (%)		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Kitchener			12,672			14,303			**-13**
Brantford	8,056	10,491	10,202	7,024	9,427	9,387	**+13**	**+9**	**+8**
Guelph	14,079	15,952	13,655	12,855	14,320	12,624	**+8**	**+10**	**+8**
Galt			8,052			9,045			**-12**
Waterloo			10,645			14,970			**-41**
Preston			1,642			1,587			**+3**
Hespeler		1,021	968		1,640	1,541		**-61**	**-59**
Fergus		350	554		458	520		**-31**	**+6**
Elmira			1,173			1,152			**+2**
Dunnville	646	682	798	619	550	531	**+4**	**+19**	**+34**
Caledonia	1,044	1,232	844	807	1,131	727	**+23**	**+8**	**+14**
Paris		438	661		330	762		**+25**	**-15**
New Hamburg			471			265			**+44**
Elora		263	374		928	1,118		**-253**	**-199**
Ayr			162			172			**-6**
Arthur			193			130			**+33**
St. Jacobs			216			199			**+8**
St. George			149			232			**-56**
Grand Valley			50			100			**-68**
Wellesley			122			192			**-57**
Cayuga	96	101	99.4	113	122	118	**-18**	**-20**	**-19**
Conestogo			13			21			**-65**
Alt Heidelberg			12			13			**-9**

Under the Grand River program, a water balance analysis was developed for lagoon systems as performance check as sludge accountability cannot be performed. A water balance analysis compares the amount of net precipitation on the surface area of a lagoon system to the total amount of net precipitation estimated using lagoon level measurements, total influent sewage and effluent on annual basis (projected net precipitation). The formula to calculate water balance is as follows:

$$\frac{projected\ net\ precipitation - reported\ net\ precipitation}{projected\ net\ precipitation} * 100\%$$

If the result is within a range of ± 15%, the water balance is considered to "close". If the value is outside of this range, then the flow measuring devices or lagoon level measurements may not be accurate. Further investigation is warranted to review all flow measuring devices and confirm their accuracy.

Table 7 shows the results for 2 lagoons in the watershed that conducted water balance analysis for 2016. Both of the water balance analyses did not close. Sources of discrepancy may include the following; inaccurate flow measurement, inaccurate surface area information, uncertainties in precipitation data and error in storage lagoon measurements. Water balance analysis for these two lagoons was implemented as a training workshop.

Table 7 - Summary of 2016 Water Balance analyses of plants that report on it

Plant	Projected Net Precipitation (m^3)	Reported Net Precipitation (m^3)	Water Balance (%)
Dundalk	-17,969	28,101	**+256**
Drayton	-9,672	48,910	**+606**

Work is continuing as part of the WWOP to develop the methodology for a lagoon water balance as part of voluntary reporting in the Grand River watershed.

Influence of WWTPs on the Grand River

Figure 8 shows total precipitation (i.e. snow and rain) at selected sites in the watershed. 2016 observed precipitation was close to the long-term average (Shifflett, 2017). Although the annual total was close to the long-term average, much of the precipitation fell in winter and spring (January to April) with an extended dry period from May to November.

2015 experienced precipitation near the low end of typical (Shifflett, 2016). 2014 saw precipitation close to the long term average (Shifflett, 2014), whereas 2013 generally experienced higher than normal precipitation across the central and northern portions of the watershed (Shifflett, 2013). Precipitation in 2012 was at the low end of typical (Shifflett, 2012). Table 8 shows characterization of precipitation in the Grand River watershed according to GRCA precipitation data over the period 2012-2016.

Table 8 - Characterization of precipitation in Grand River watershed over 2012-2016 period

Year	Precipitation Characterization
2012	Low end of typical
2013	Higher than typical in some areas
2014	Long-term average
2015	Low end of typical
2016	Long-term average

Figure 9 shows the relative influence of wastewater effluent on the Grand River by comparing the total volume of treated effluent in each of the years 2012 to 2016 to the annual average river flow at York for the same years. York, in Haldimand County, is the location of GRCA's southern-most flow monitoring station on the Grand River. Figure 9 shows that the volume of treated effluent ranges from 3% to 7% of the total river flow.

Figure 10 shows a similar comparison based on low flow conditions observed in the month of August. Under summer low flow, the proportion of treated effluent ranges from 5% to 15% of the river flow. The influence of WWTP flow on the river varies from year to year depending on climate.

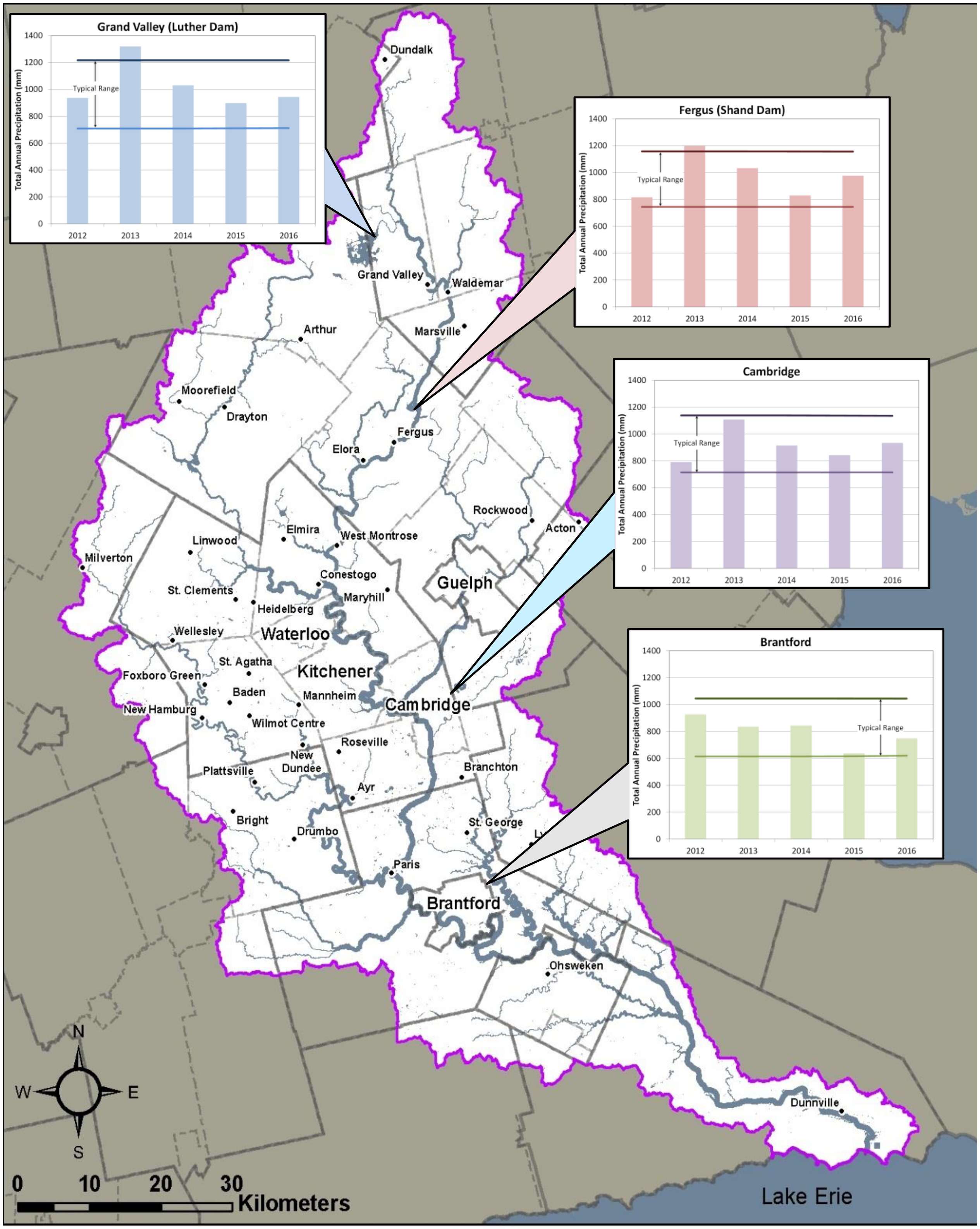

Figure 8: Total annual precipitation (in mm) at selected locations across the watershed. Typical range is based on 5th and 95th percentile of historical observations over the past 50 years.

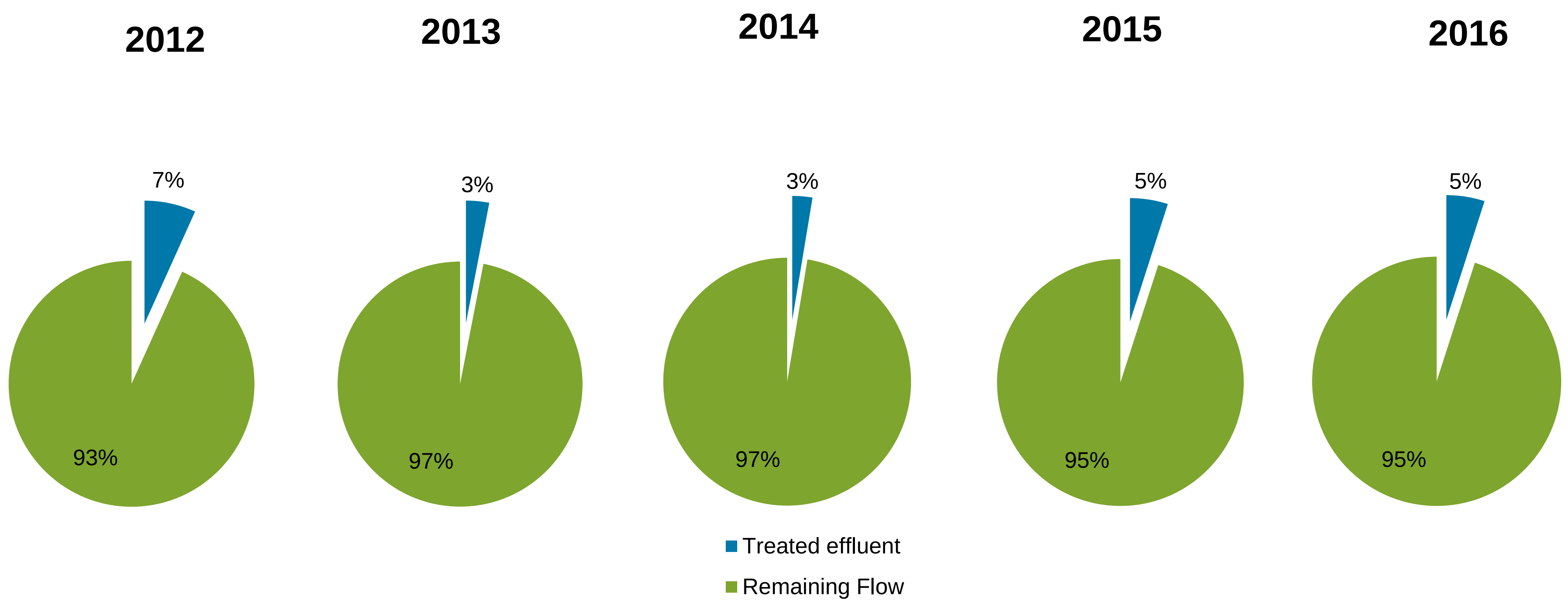

Figure 9: Annual Average Effluent Flow compared to Grand River Flow at York from 2012 to 2016

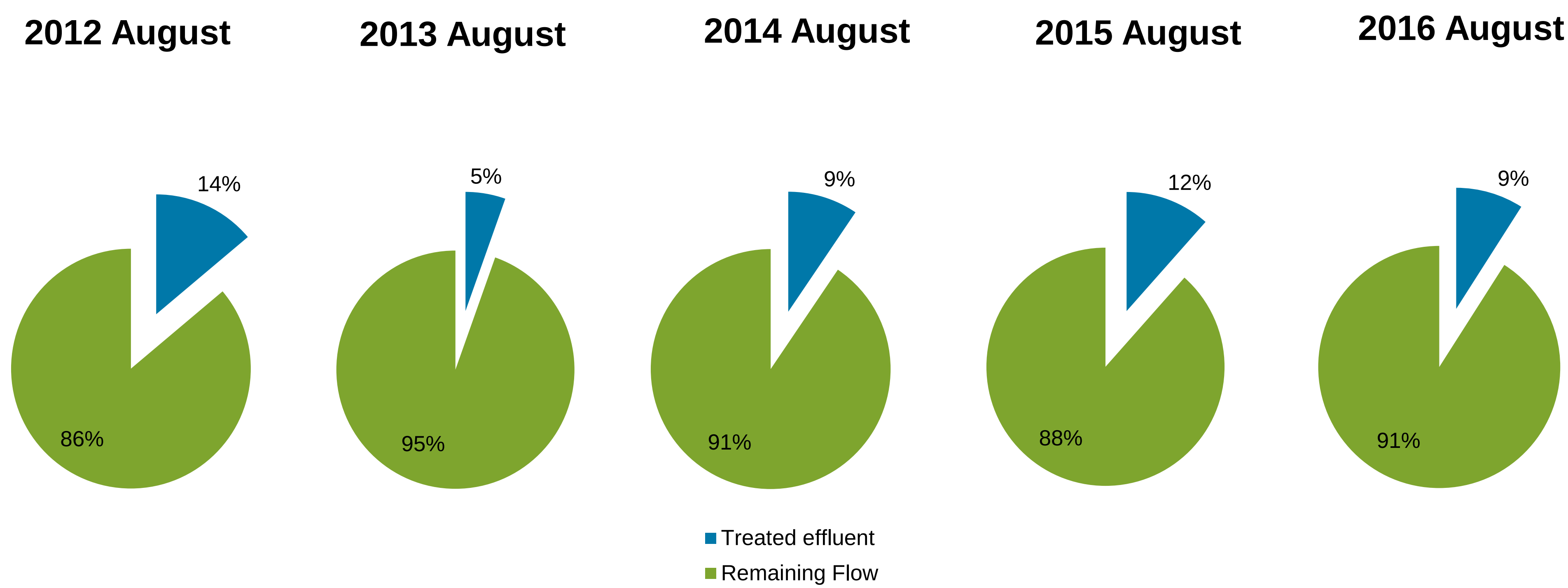

Figure 10: Average Effluent Flow compared to Grand River Flow at York in August from 2012 to 2016

Table 9 shows the annual average effluent TP loadings from WWTPs for the years 2012 to 2016, as well as flow-weighted TP concentrations. The TP loading was calculated based on the product of each plant's monthly average flow and its corresponding effluent TP concentration. The flow-weighted concentrations were calculated by dividing the loading by the total average flow. There was a 7% decrease in TP loading in 2016 from 2015, and an 11% decrease in the flow-weighted concentrations from 2015 to 2016. Five year TP loading and flow-weighted concentration from 2012 to 2016 have dropped by 6 and 11%, respectively.

Table 9 - Wastewater effluent TP loading and flow-weighted concentration to the Grand River

	Loading (tonne)	Flow-Weighted Concentration (mg/L)
2012	35.9	0.37
2013	37.6	0.35
2014	36.8	0.33
2015	36.5	0.37
2016	33.8	0.33

The total annual loading of wastewater effluent TAN discharged to surface water and corresponding flow-weighted concentrations are documented in Table 10 which shows the TAN loadings separated into summer and winter periods. There was a 40% decrease in summer TAN loadings from 2015 to 2016, which can be attributed to large loading decreases from Kitchener, Brantford and Waterloo WWTPs. There was a 37% decrease in winter TAN loadings from 2015 to 2016, which can be attributed to large loading decreases from the same plants as well as from Hespeler, Dunnville and St. Jacobs WWTPs. Overall, there was a 38% decrease in wastewater effluent TAN loading from 2015 to 2016. Five year Total TAN loading and flow-weighted concentrations both decreased by 63% in compare to 2012 data.

Table 10 - Wastewater effluent TAN loading and flow-weighted concentration to the Grand River

		Loading (tonne)	Flow-Weighted Concentration (mg/L)
2012	Summer	417	4.3
	Winter	534	5.5
	Total	**951**	**4.8**
2013	Summer	346	3.2
	Winter	426	4.0
	Total	**773**	**3.6**
2014	Summer	343	3.1
	Winter	512	4.6
	Total	**855**	**3.9**
2015	Summer	206	2.1
	Winter	354	3.6
	Total	**560**	**2.8**
2016	Summer	124	1.25
	Winter	223	2.19
	Total	**347**	**1.75**

Wastewater Treatment Plant Loading Summary

Influent flow

Figure 11 shows a summary of the average daily flow (ADF) to each plant for 2012 to 2016 compared to the Nominal Design Flow of the plant as stated in the plant's ECA (shown in light blue). Kitchener, Brantford, Guelph, Galt and Waterloo WWTPs are plotted on a separate vertical scale as these facilities are considerably larger than the rest of the WWTPs. Figure 12 shows the ADF as a percentage of the nominal design flow. In 2016, all plants experienced an ADF that was less than the nominal design flow. Since 2012 three plants experienced ADFs higher than their nominal design flow: Arthur (2012 to 2014), Drumbo (2013 and 2014) and Cainsville (2014).

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 13 shows per capita flows for WWTPs in the watershed for 2012-2016. From this figure, plants in the Grand River watershed were generally at or below the low end of the typical range, shown in violet. The watershed median for 2016 was 298 L/person/day, a 1% increase from the 2015 median of 294 L/person/day and 5% decrease from 2012 median of 313 L/person/day.

Some plants experience higher than typical per capita flows and this may be attributed to a variety of reasons. For example, the Cainsville WWTP services primarily industrial users and is therefore expected to have higher per capita flow than a typical domestic sewage system. Others WWTPs, such as Arthur and Dundalk, appear to be subject to inflow/infiltration (I/I).

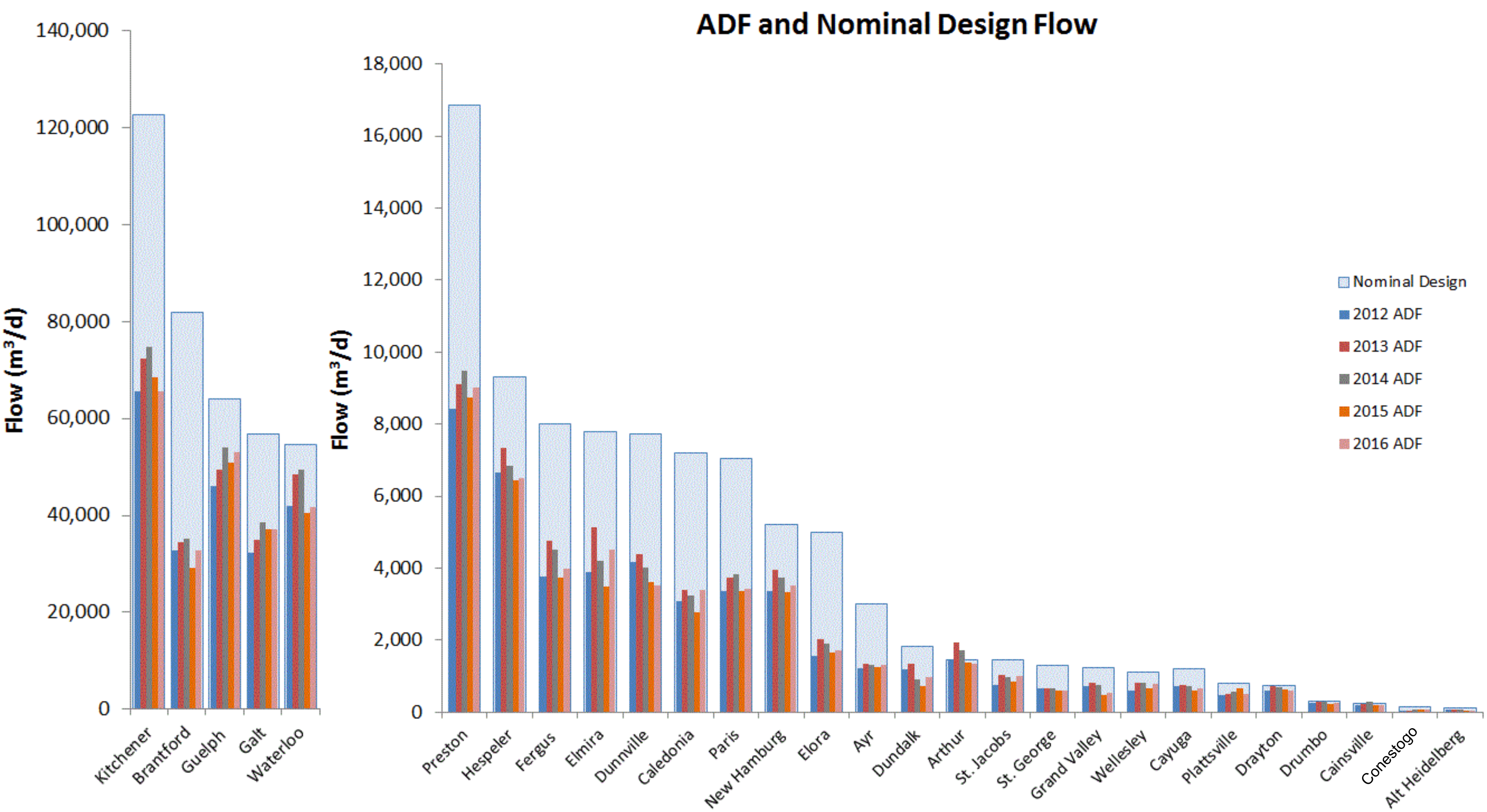

Figure 11: ADF and Nominal Design Flow of 28 WWTPs in the watershed

***NDF of Elora WWTP was increased from 3,066 to 5,000 m^3/d in 2015 and NDF of Drumbo WWTP was increased from 272 to 300 m^3/d in 2015 and NDF of Cayuga WWTP was increased from 873 to 1,200 m^3/d in 2015**

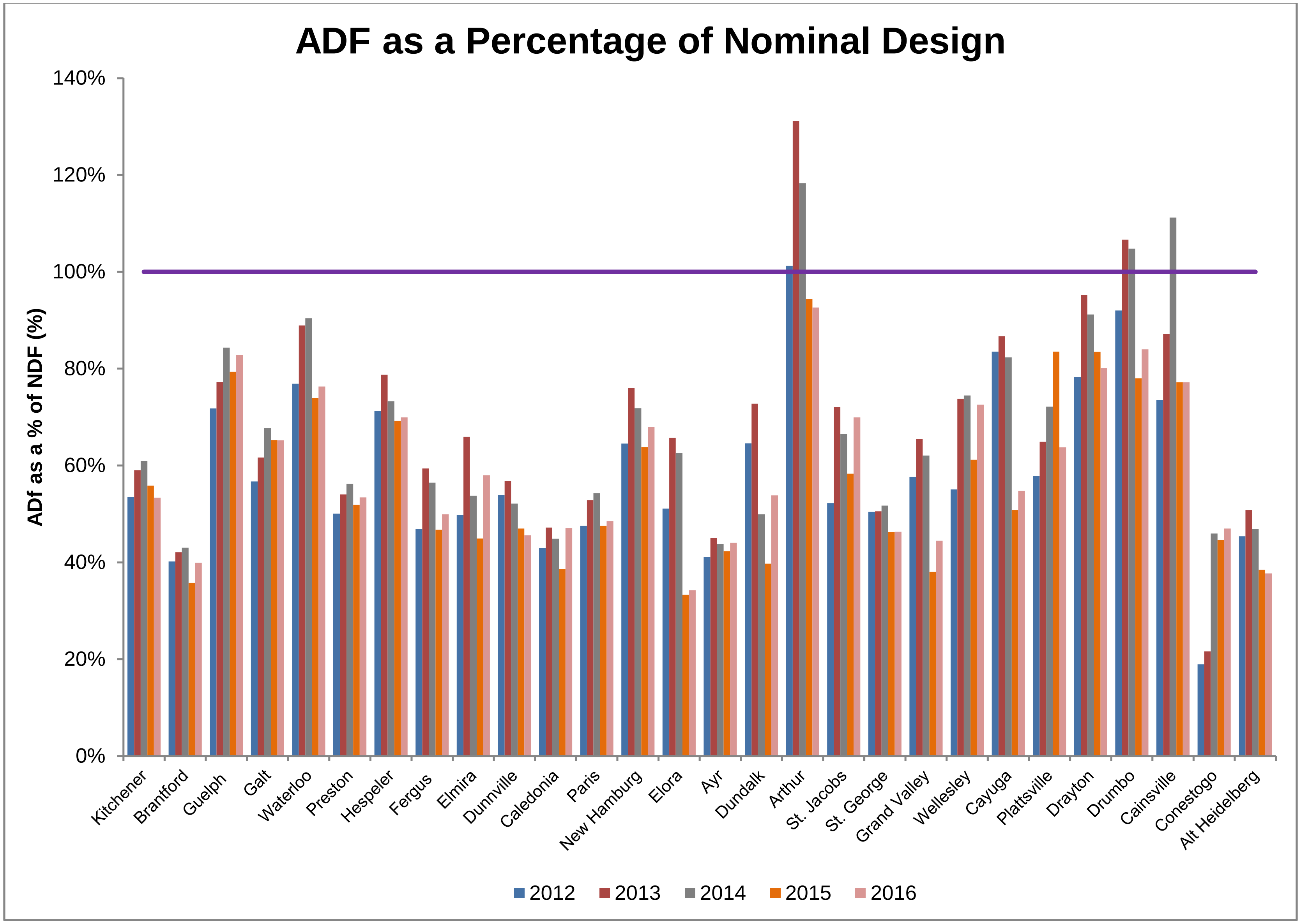

Figure 12: Annual average flow as a percentage of rated plant capacity

Figure 14 shows the ratio of peak day flow to ADF, which is another indicator of I/I or periodic industrial flows. The 2012 median was 2.25 and it increased to 2.75 in 2016, which is at lower end of the typical range (2.5 to 4.0). Most plants were within the typical range or less. Several plants are known to experience I/I (such as Arthur WWTP) and this is reflected in Figure 14.

Year-to-year variability in per capita flow is assumed to be largely due to differences in inflow and infiltration related to climate. The highest per capita flows were 351 L/d per person in 2013 which was a “wet” year. The smallest per capita flows were 294 L/d per person in 2014 which was a “dry” year (Shifflett, 2017).

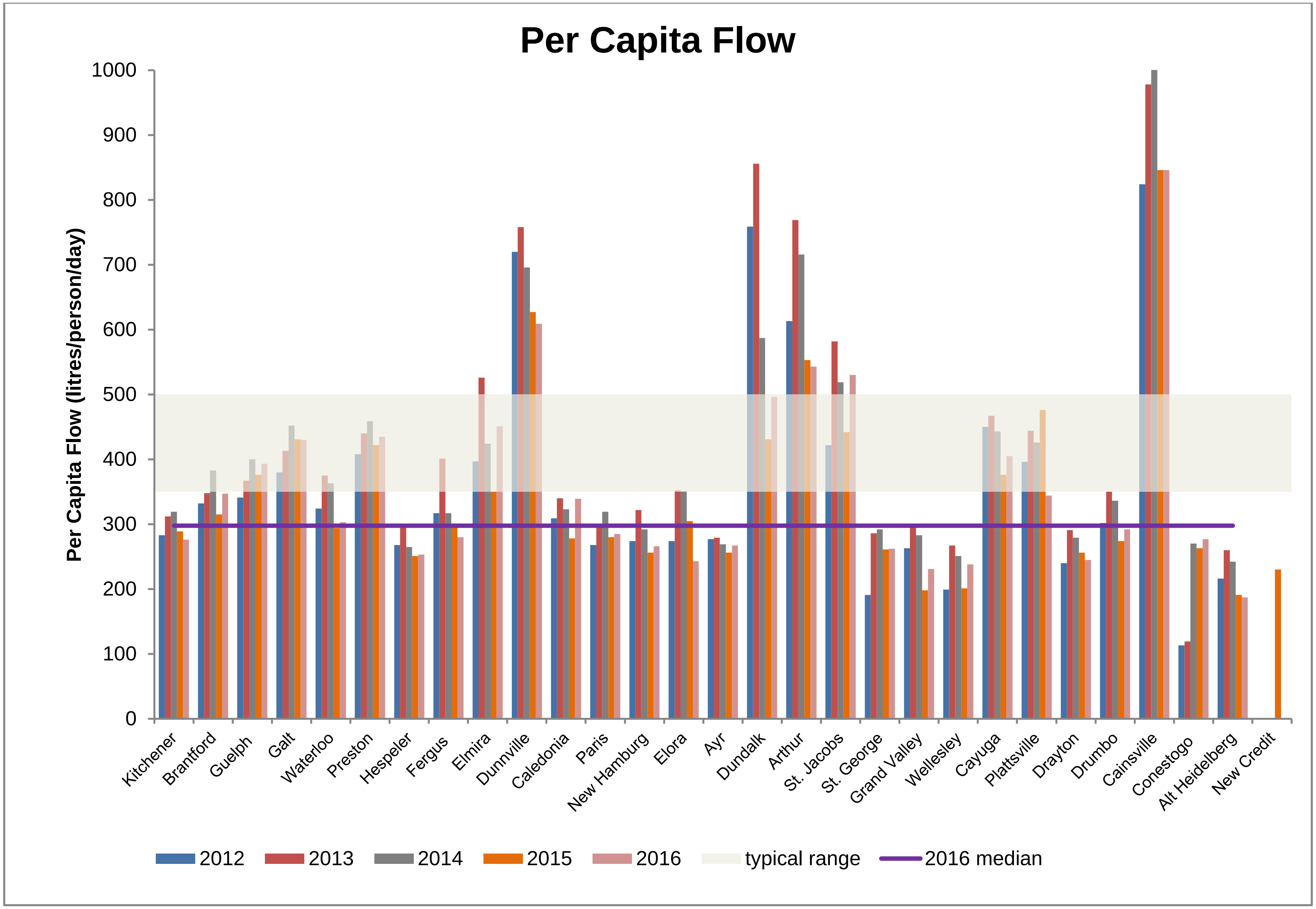

Figure 13: Per capita influent flow

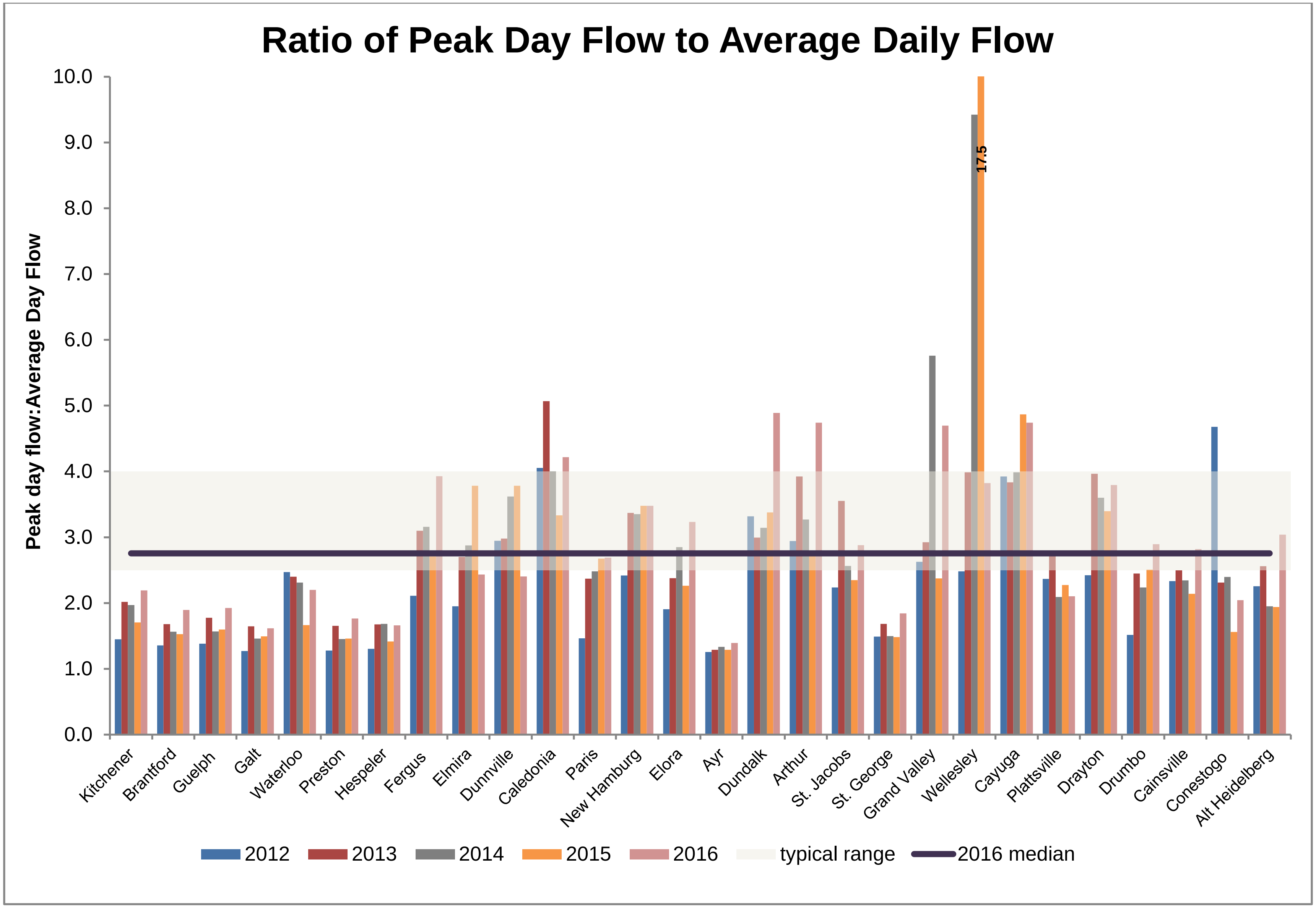

Figure 14: Ratio of peak day flow to annual average flow

Raw Influent Loads

Characterization of raw wastewater is important to ensure effective wastewater treatment, assist with future planning, and identify 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 typical of domestic sewage.

TBOD Loading

In 2015, 16 of 28 plants in the watershed did not measure TBOD in the raw influent on a routine basis because their ECAs required cBOD measurements of the raw influent. This number decreased to 7 since new ECAs were adopted for Fergus and Elora WWTPs requiring measurement of TBOD in raw sewage and Region of Waterloo measured both cBOD and TBOD under the Region's enhanced monitoring program in Kitchener, Galt, Waterloo, Preston, Hespeler, Wellesley and Alt Heidelberg plants for potential expansion purposes. Table 11 summarizes the results of both cBOD and TBOD as reported by plants in the Grand River watershed in 2016:

Table 11 - Annual average raw influent BOD concentrations reported by Grand River watershed plants in 2016

Measurement	No. of plants reporting	Median (mg BOD/L)	Range (mg BOD/L)
cBOD	18	195	127-389
TBOD	21	208	142-411

Albertson (1995) has documented that the cBOD test underestimates the strength of raw wastewater by 20-40%. In the absence of measured TBOD data, TBOD loads were estimated based on cBOD concentrations multiplied by a factor of 1.2. The assumed scaling factor of 1.2 introduces significant uncertainty in the estimate of TBOD loads. In 2016, 11 of 28 plants in the watershed measured both cBOD and TBOD. The average TBOD:cBOD ratio among these plants is 1.16 which is slightly lower than the 1.2 factor used in estimations.

Measuring $cBOD_5$ in the raw?

"Use of raw wastewater $cBOD_5$ possibly underestimates the organic load for some facilities and might result in inadequate designs." (Muirhead et al., 2006)

Figure 15 shows estimated per capita TBOD loads for plants in the Grand River watershed; plants with estimated TBOD values are represented by hatched bars and plants with actual TBOD data are represented by solid bars. A typical value for domestic wastewater is 80 g/person/d. The reported 2016 median is 69 g/person/d, which is lower than the 2015 median value of 77 g/person/d and slightly higher than 2012 value of 65 g/person/d.

Per capita TBOD loads that are much higher or much lower than the typical value should be further investigated to see if there is a reasonable explanation for the discrepancy. In some cases, industrial contributions may result in very high per capita TBOD loads, e.g. Cainsville. However, atypical TBOD loads may also be related to inadequate sampling frequency, non-representative sampling, errors in flow metering or population estimates, etc.

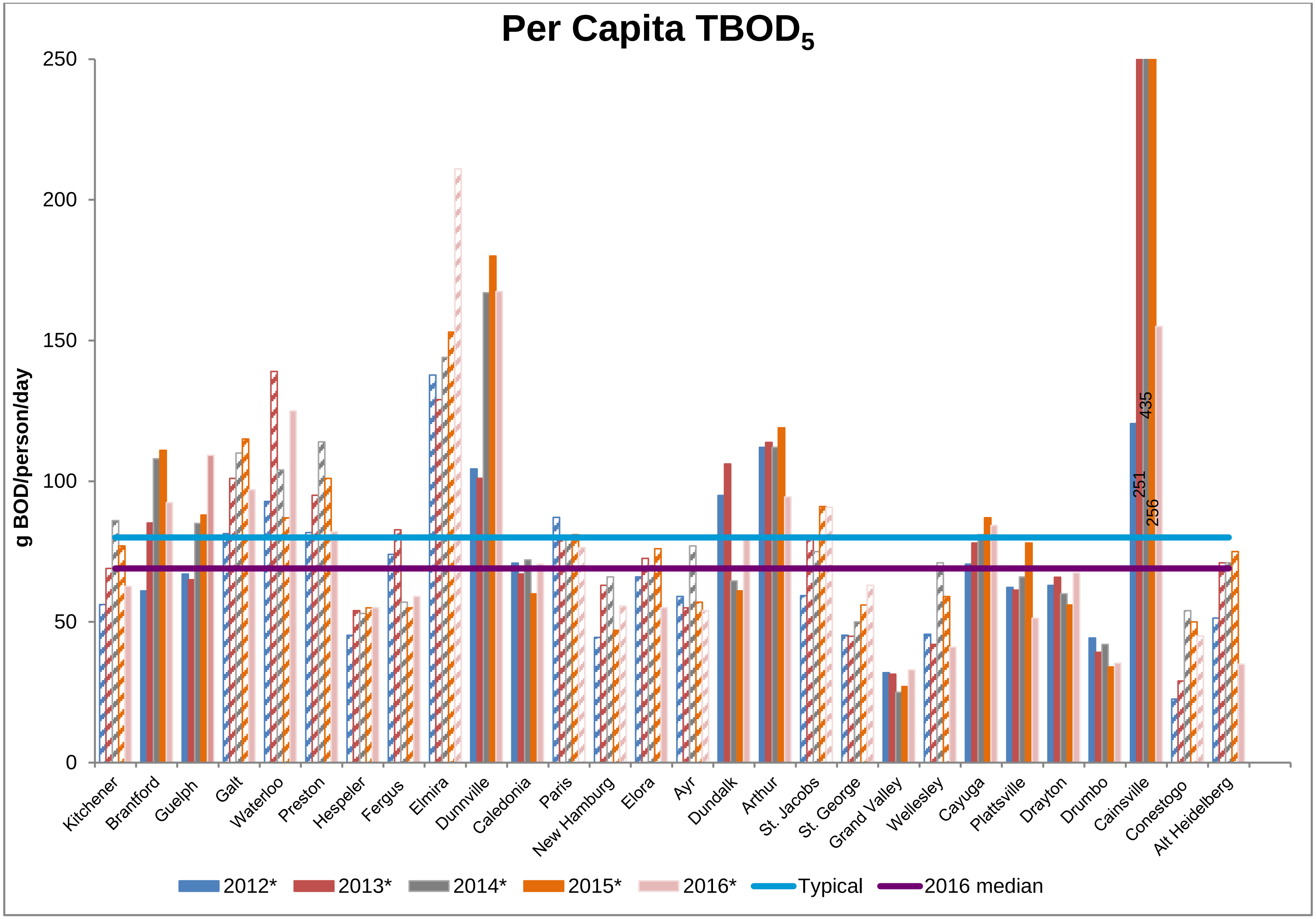

Figure 15: Per Capita TBOD Load

TSS Loading

TSS loads in raw influent for 2012 to 2016 are summarized in Figure 16. The 2016 watershed median was 69 g/person/d, which is less than the typical value of 90 g/person/d. This value was 82 g/person/d in 2012. Where the loads are significantly less than typical, 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.

TKN Loading

Figure 17 shows per capita TKN loads to plants in the watershed. The watershed median was 14 g/person/d for 2016 which is slightly higher than the typical value of 13 g/person/d and the same as 2012 per capita TKN load. Several plants (such as Waterloo, Preston, Fergus, Elmira, Dunnville, Caledonia, Dundalk, Arthur, Cayuga, Plattsville, and Cainsville) reported TKN loads that are higher than expected and in most cases the per capita TSS and/or estimated TBOD loads were also high. A small number of plants had TKN, TSS and TBOD loads that were less than typical. Further investigation, such as characterization of raw influent and recycle streams and review of population estimates, may be helpful when per capita loadings are outside the typical range.

TP Loading

Figure 18 shows the TP loads in the raw influent for 2012 to 2016. The watershed median for 2016 was 1.7 g/person/d. This is slightly less than the typical value of 2.1 g/person/d. TP per capita has not changed significantly since 2012 (1.8 g/person/d).

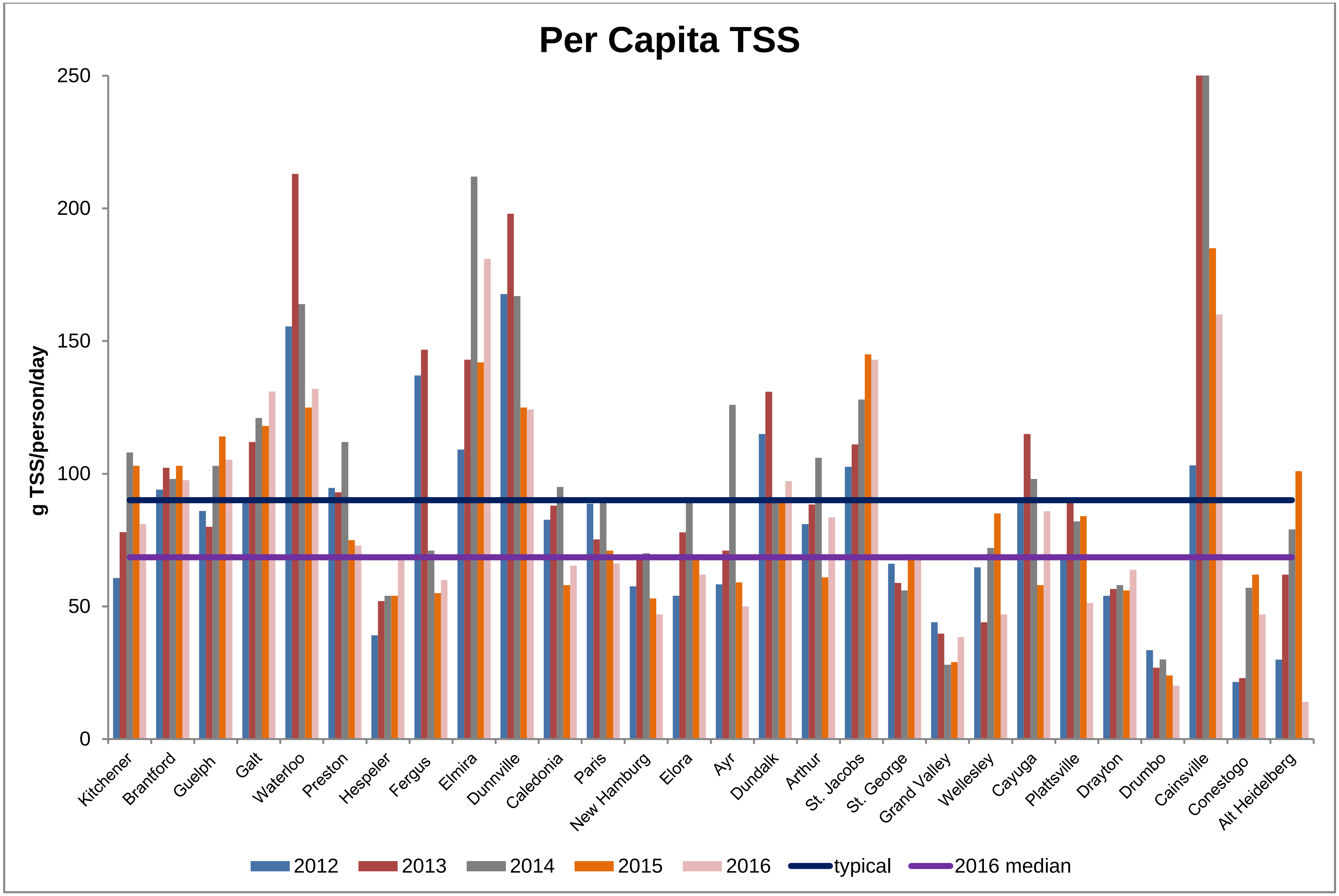

Figure 16: Per Capita TSS Load

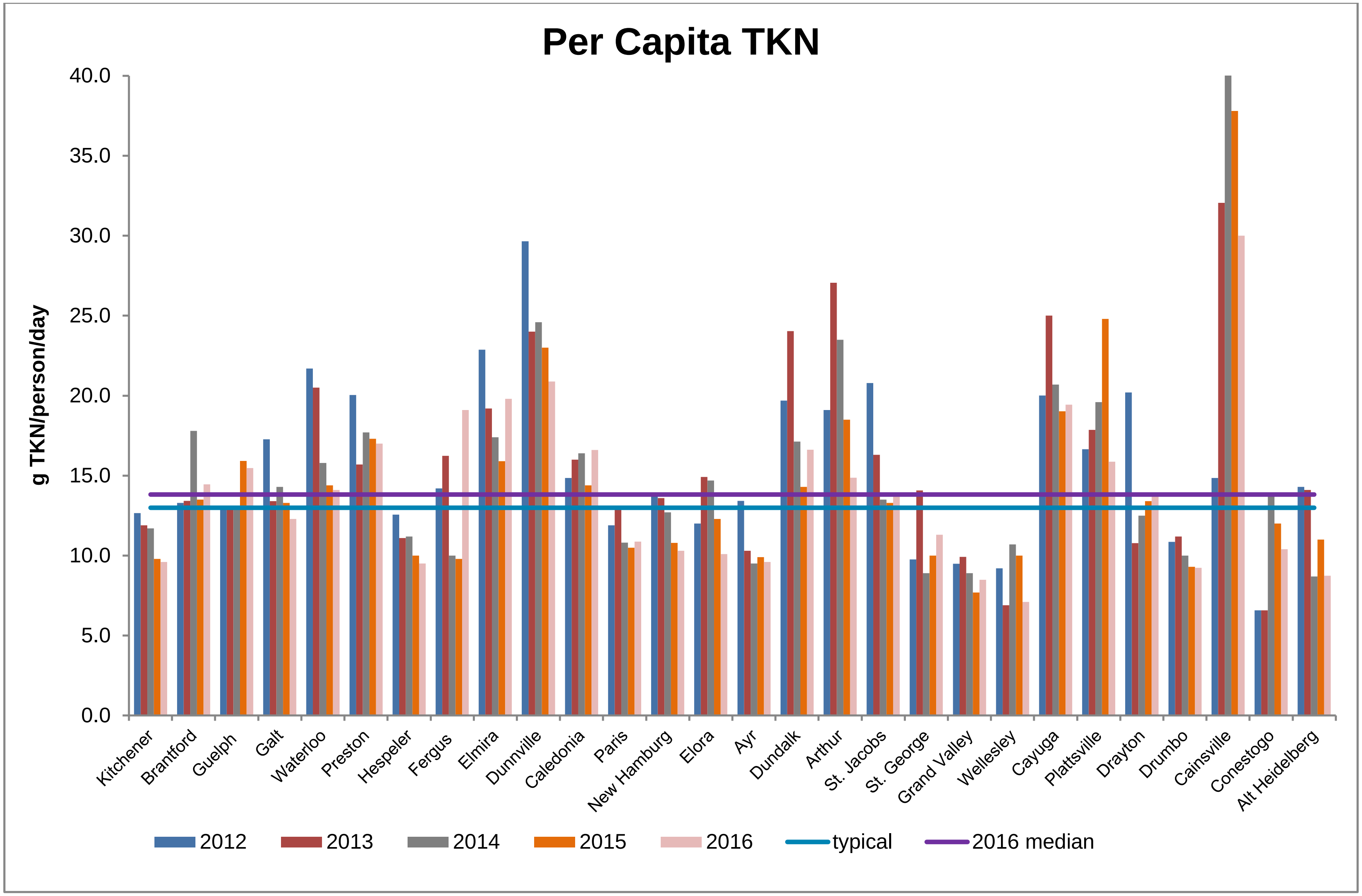

Figure 17: Per Capita TKN Load

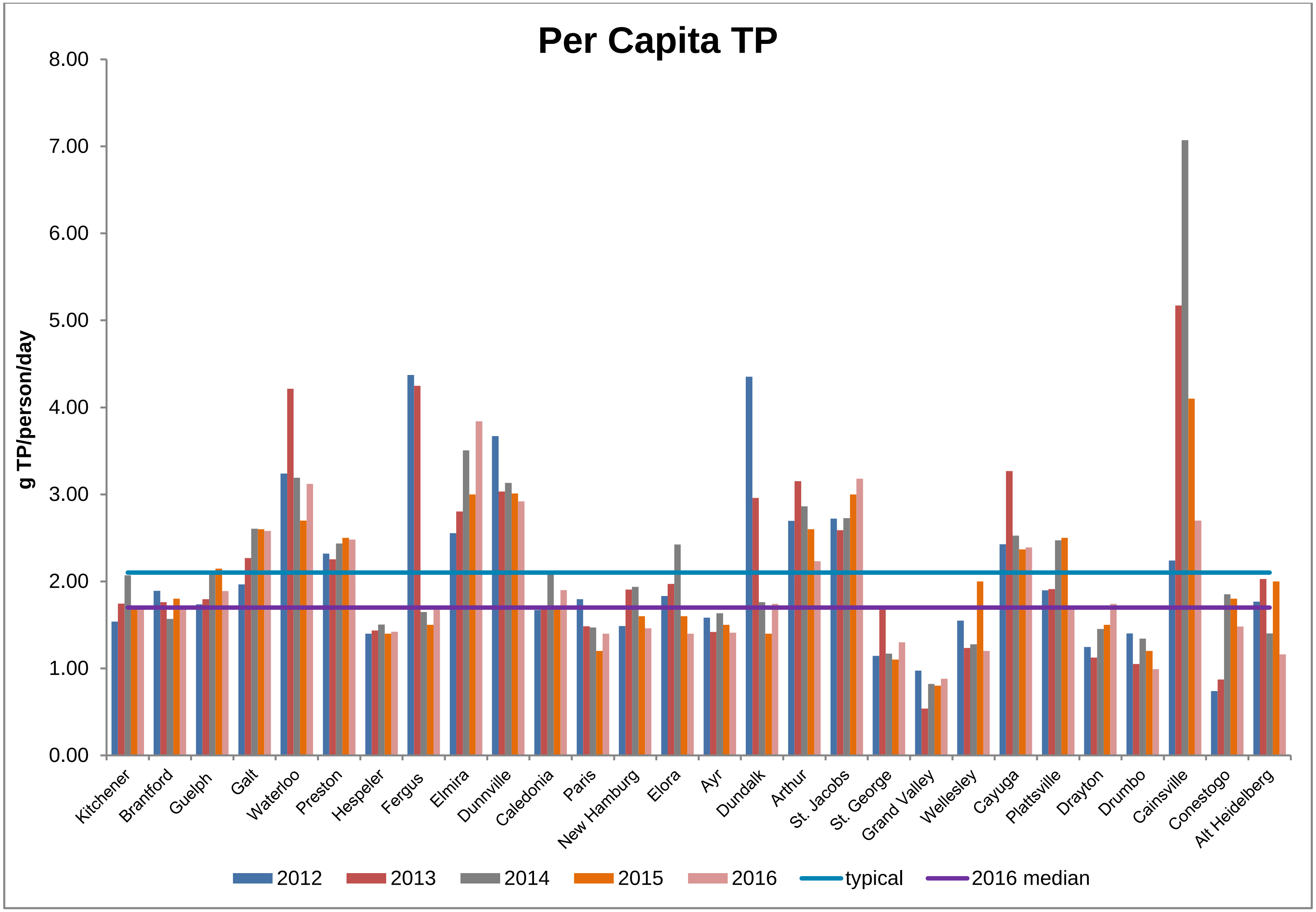

Figure 18: Per Capita TP Load

Ratios

Calculating raw influent ratios for TSS:TBOD and TKN:TBOD can be used to provide insight on what is entering the plant from the collection system as well as any potential sampling problems. Figure 19 shows the ratio of raw influent TSS to TBOD concentrations. For a typical domestic sewage system, this value ranges between 0.8 and 1.2. The median for watershed plants in 2016 was 1.03. The 2016 median was lower than 2012 value of 1.14.

Figure 20 shows a graph for the ratio of raw TKN to TBOD, with a range of 0.1 to 0.2 considered typical. The 2016 watershed median was 0.18, which is the high end of typical. 2012 data showed slightly higher median of 0.23. Higher ratios could be attributed to recycle streams, an industrial influence in the collection system, or estimated TBOD values that are lower than actual.

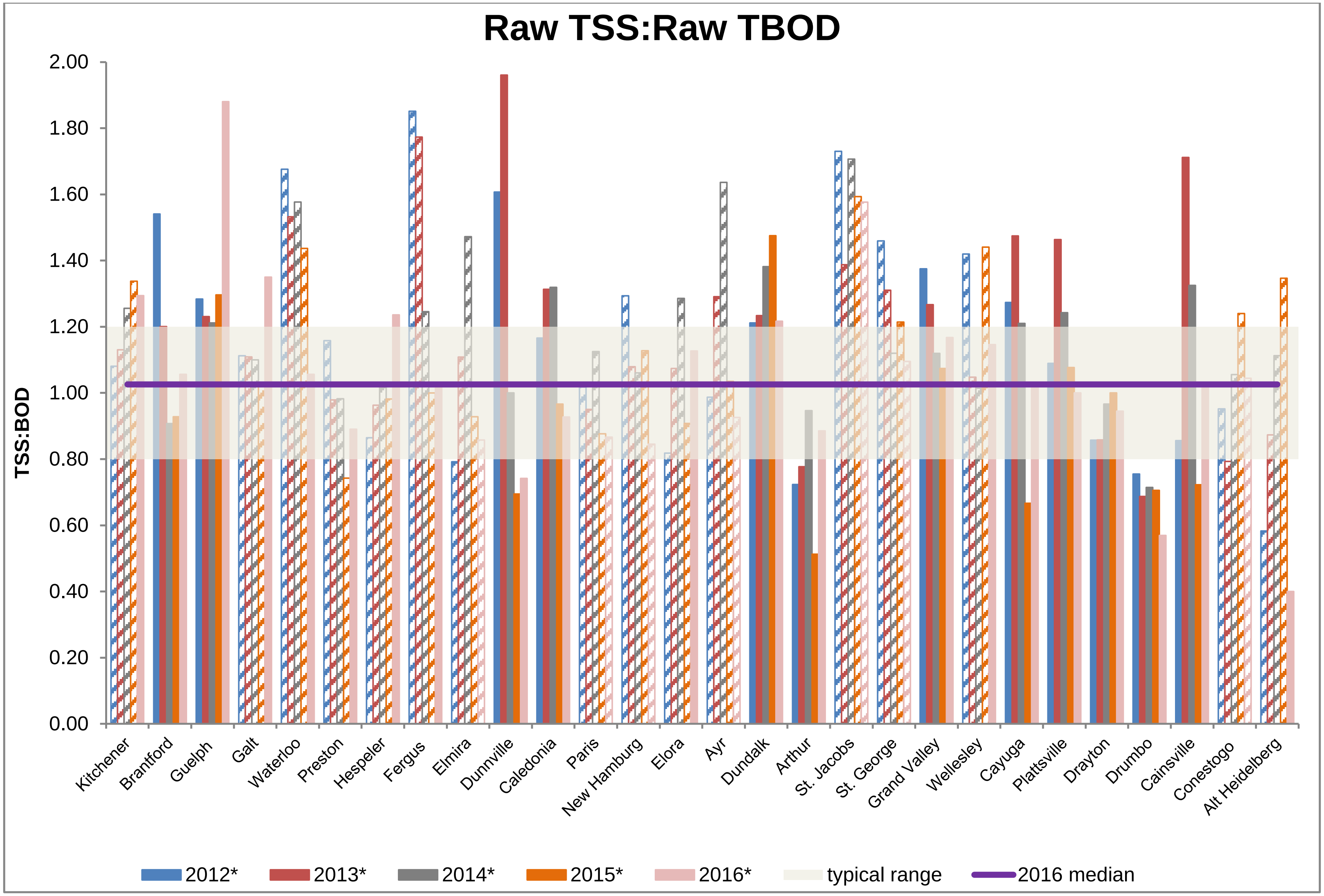

Figure 19: Ratio of Raw TSS to Raw TBOD

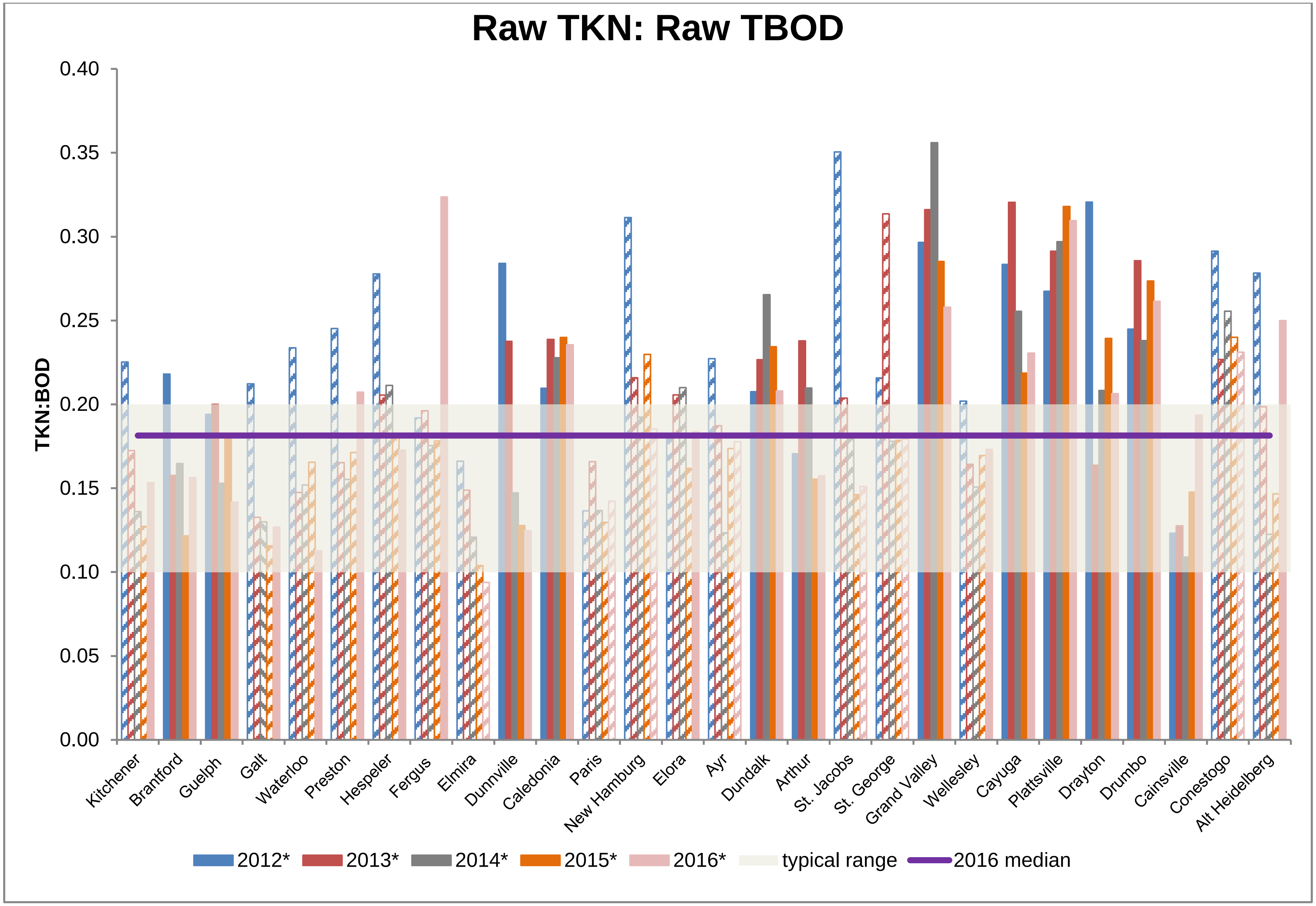

Figure 20: Ratio of Raw TKN to Raw TBOD

Final Comments

The number of plants meeting the TP WMP interim target increased from 23 in 2012 to 25 in 2016. TP flow-weighted concentration for all of the 28 WWTPs across the watershed dropped from 0.37 in 2012 to 0.33 mg/L in 2016. In 2012, 19 plants met the TP WMP final target while 17 plants met these targets in 2016.

In 2012, 23 WWTPs met the TAN WMP interim targets in the summer and 23 WWTPs met the TAN targets for the winter season. In 2016, the number of plants increased to 25 for the summer targets and 25 for the winter targets. TAN flow-weighted concentration for all of the 28 WWTPs in the watershed decreased from 4.8 mg/L in 2012 to 1.75 mg/L in 2016. In 2012, 22 of the plants met summer WMP final target and 23 of the plants met winter WMP final target while in 2016, 24 plants met summer WMP final target and 24 plants met winter WMP final target.

As part of the ongoing watershed-wide optimization program, the GRCA will continue to encourage and support municipalities to report on these performance and loading metrics on an annual basis. Tracking these metrics over time will document the effectiveness of the program and help to identify candidates that may benefit from further optimization.

The authors thank WWOP participants for their efforts at voluntary reporting and encourage them to consider adopting and reporting against the Water Management Plan voluntary effluent quality performance 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.

Further information on the Grand River Watershed-wide Optimization Program can be obtained from the Grand River optimization web page, or by contacting Kelly Hagan, the Optimization Extension Specialist at 519-621-2761 Ext. 2295 or Mark Anderson at 519-621-2761 Ext. 2226.

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