APPENDIX B

GREAT LAKES WASTEWATER TREATMENT PLANT OPERATIONAL DATA SURVEY

GREAT LAKES WASTEWATER TREATMENT PLANT (WWTP) OPERATIONAL DATA SURVEY

Prepared for:

International Joint Commission

Great Lakes Regional Office

Windsor, Ontario

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1.1 Purpose of Study

The International Joint Commission (IJC) was created by the 1909 Boundary Waters Treaty between the United States and Canada for the purpose of assisting the governments in addressing boundary water issues. The IJC is currently studying the impacts of chemicals of emerging concern (CECs) on water quality in the Great Lakes. As part of this effort, Brown and Caldwell was engaged by the IJC to compile operational data for a cross-section of municipal wastewater treatment plants (WWTP) in the Great Lakes Basin. These data will then be used to assess the potential for Great Lakes WWTPs to remove CECs from their waste streams.

1.2 WWTP Selection Process

The selection of plants for this survey was based on the goal of covering a range of key characteristics to represent the variety of WWTPs in the Great Lakes Basin. These key characteristics are geography, size, main type of treatment employed, and disinfection technology used. A matrix showing the selected plants and the detailed distribution of these key characteristics is included as Exhibit A.

The first key characteristic is geographical distribution. Plants on all five of the Great Lakes are included. The next characteristic is plant size. Average flow and/or capacity values for all plants were not available prior to the study, but available information from previous IJC reports was used to select plants that cover a large range of flow rates. For the purpose of this study a small plant is defined as one with an average flow of 10 MGD (37,850 m^3/day) or less. A medium plant is defined as one with an average flow of 10 to 50 MGD (37,850 to 189,250 m^3/day). Lastly, a large plant is defined as one with a flow of greater than 50 MGD (189,250 m^3/day).

The selection process also identified a wide range of main treatment technologies employed on the Great Lakes. Plants were selected that include the following:

- Primary Treatment (no secondary treatment)
- Lagoons
- Fixed Film Systems (various, e.g. trickling filter, biological aerated filter)
- Activated Sludge (and variations including phosphorus precipitation or nitrification)
- Biological Nutrient Removal (nitrification, denitrification, and biological phosphorus removal)
- Tertiary Filtration

Lastly, a goal of the survey was to include multiple disinfection technologies. Plants included in the study use chlorine disinfection, ultraviolet (UV) disinfection, seasonal chlorine or UV disinfection, or have no disinfection.

Exhibit A. Selected Plants Distribution Matrix

	Size			Geography					Treatment								Disinfection			
Canadian Plants	**Small <10 MGD**	**Medium 10-50 MGD**	**Large >50 MGD**	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**	**Primary**	**Lagoon**	**Fixed Film**	**Activated Sludge**	**Chemical P Removal**	**Nitrification**	**BNR**	**Tertiary Filtration**	**UV**	**Chlorine**	**Type Unspecifed**	**None/ Unknown**
City of Cornwall WPCP		1						1	X				X					1		
Region of Halton - Burlington Skyway WPCP		1						1				X	X	X			1			
City of Hamilton - Woodward Avenue WPCP			1					1				X	X					1		
Kincardine Lagoons (Township of Bruce-Tiverton, Ontario)	1					1				X			X					1		
City of Kingston - Ravensview WPCP		1						1			X				X			1		
Napanee WPCP	1							1				X	X					1		
Niagara Falls WPCP		1						1			X		X					1		
Township of Nipigon WPCP	1			1					X									1		
City of Sarnia WPCP	1					1						X	X				1			
City of Sault Ste. Marie - East End WPCP	1					1									X		1			
City of Thunder Bay WPCP		1		1							X			X			1			
City of Toronto - Ashbridges Bay WPCP			1					1				X	X					1		
Trenton WPCP	1							1				X				X	1			
City of Windsor - Lou Romano WPCP		1					1				X						1			
American Plants																				
Bay City WWTP		1				1					X					X	1			
Buffalo, NY Sewer Authority WWTP			1				1					X	X					1		
Detroit WWTP			1				1					X	X					1		
Erie, PA Sewer Authority WWTP		1					1					X	X					1		
Green Bay Metropolitan Sewage District WWTP		1			1							X			X			1		
Michigan City (IN) Sanitary District WWTP	1				1							X	X	X		X		1		
Milwaukee Metro Sewerage District-Jones Island WWTP			1		1							X	X	X				1		
Milwaukee Metro Sewerage District-South Shore WWTP			1		1							X	X	X				1		
Muskegon Co. WWMS Metro WWTP		1			1					X										1
Niagara Falls WWTP		1						1								(Activated Carbon Beds) X		1		
NEORSD, Cleveland, OH-Westerly WWTP		1					1				X	X	X					1		
NEORSD, Cleveland, OH-Easterly WWTP			1				1					X	X					1		
City of Oswego WWTP	1							1				X	X							1
Rochester Pure Waters District-VanLare Plant			1					1				X	X					1		
Rochester Pure Waters District-NW Quadrant Plant		1						1				X	X					1		
City of Superior (WI) WWTP	1			1								X	X					1		
Traverse City Regional WWTP	1				1							X	X		X	X	1			
City of Toledo - Bay View WWTP			1				1					X	X	X				1		
Western Lake Superior Sanitary District (Duluth, MN)		1		1								X				X		1		
TOTALS	10	14	9	4	6	4	7	12									8	23	0	2

Denotes plants that did not provide data (grey shading)

Denotes seasonal disinfection (yellow shading)

1.3 Wastewater Parameters of Interest

Wastewater parameters were identified that would be important to the IJC team tasked with assessing potential CEC removal in municipal WWTPs. Several types of data were solicited from the candidate WWTPs. The most readily accessible data are those that are required to be reported to state or provincial governments such as flow rate, temperature, and effluent biochemical oxygen demand (BOD_5), total suspended solids (TSS), and ammonia and phosphorus concentrations. The IJC team is interested not only in permit data, but also in those parameters that are used to control plant operation. These include parameters such as mixed liquor suspended solids (MLSS), solids retention time (SRT), hydraulic retention time (HRT) and organic loading. Other parameters that were solicited are deemed less critical to the project but also of value. These secondary priority parameters include chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), waste activated sludge (WAS) production rate and return activated sludge (RAS) rate.

A blank data template that summarizes the wastewater parameters of interest is included as Exhibit B. This template was forwarded to the operators of the selected wastewater treatment plants to facilitate their compilation of the requested data. For most parameters data were requested on a monthly basis (average, maximum, and minimum) for the past three years. For some parameters this level of detail is not required and only monthly average data were requested for the same three-year period.

Finally, basic information about the plant was solicited such as its location, flow and loading capacity, the specific treatment processes used and whether chemicals were being used for phosphorus control. Some of this information was already available to the team from previous reports, but this study presented an opportunity to obtain updated information. A blank plant information sheet is included as Exhibit C.

1.4 Data Collection

Once the process of selecting plants and parameters of interest was complete, plants were contacted via telephone to discuss the project. Formal requests, as well as templates for providing information (Exhibits B and C), were sent via e-mail and the U.S. Postal Service.

Of the 33 plants solicited, 25 plants participated in the study. Figure 1 is a map of the locations of the 25 plants. Their detailed responses are attached as Appendix A. For each of the plants in Appendix A, a plant information sheet is provided with a companion data sheet containing the plant operational data provided.

Exhibit B.1. Priority 1 Data Template (Page 1 of 2)

Data Template

Plant Name:

Primary Priority

	Flow m3/day or MGD	Temperature* deg C or deg F	Biochemical Oxygen Demand, BOD_5, mg/L *(specify carbonaceous or total)*						Total Suspended Solids, TSS mg/L						Ammonia, NH3-N mg/L					
			Influent			Effluent			Influent			Effluent			Influent			Effluent		
Month and Year			Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max

*If you don't have daily temperature measurements, please provide a general operating range

Exhibit B.1. Priority 1 Data Template (Page 2 of 2)

Data Template

Plant Name:

Primary Priority

	Total Phosphorus, TP mg/L						Solids Retention Time, SRT days *(For Activated Sludge)*	Organic Loading lb BOD/ft3-day *(For Fixed Film Systems)*	Food to Microorg. Ratio, F:M mass BOD/ mass of MLSS or MLVSS (*specify which*)	Mixed Liquor Suspended Solids, MLSS mg/L *Please provide if F:M or SRT not available*
	Influent			Effluent						
Month and Year	Avg	Min	Max	Avg	Min	Max				

Exhibit B.2. Priority 2 Data Template

Data Template

Plant Name:

Secondary Priority

	Chemical Oxygen Demand, COD mg/L						Total Kjeldahl Nitrogen, TKN mg/L						Hydraulic Retention Time, HRT hours	Nitrate, NO3-N mg/L	Sludge Recycle Rate m3/day or MGD	Waste Activated Sludge (WAS) Mass Mass/day	WAS Concentration mg/L	MLSS mg/L
	Influent			Effluent			Influent			Effluent								
Month and Year	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max						

Exhibit C. Plant Information Sheet

IJC WWTP Survey - Plant Information Sheet

1. Plant Name & Location:

2. Approximate Population Served:

3. Peak Hour Hydraulic Capacity (mgd):

4. Peak Day Process Capacity (lb BOD/day):

5. Treatment Technologies Employed at Plant (please check appropriate box):
   a. Preliminary
      ☐Screening
      ☐ Grit removal
      ☐ Other – please specify ___________________________

   b. Primary:
      ☐ Primary clarifiers
      ☐ Chemically assisted primary clarifiers (CEPT)
      ☐ High rate clarifiers (e.g., Actiflo, Densadeg)
      ☐ Other – please specify ___________________________

   c. Secondary:
      ☐ Activated sludge
         ☐ Carbonaceous oxidation (BOD removal) only
         ☐ Nitrifying
         ☐ Nitrifying and denitrifying
         ☐ Biological phosphorus removal
         ☐ Chemical phosphorus precipitation
      ☐ Trickling filter
      ☐ Trickling filter/solids contact process (TF/SC)
      ☐ Biological aerated filter (BAF)
      ☐ Membrane bioreactor (MBR)
      ☐ Other – please specify ___________________________

   d. Tertiary (e.g. filtration. Please specify type.):
      ☐ Dual or multi media filtration
      ☐ Membrane filtration
      ☐ Chemical phosphorus precipitation
      ☐ Other – please specify ___________________________

6. Disinfection (Please specify if **seasonal** or **year-round**):
   ☐ Chlorination
   ☐ UV radiation
   ☐ Other – please specify ___________________________

7. Polymer usage (where in the plant and what type):

Figure 1 Plant Locations.

1.5 Data Summary and Analysis

A summary table (Exhibit D) has been compiled to show selected data from all the plants. Annual averages of the monthly data for each of 2007, 2008 and 2009 have been compiled for flow, BOD, TSS, NH_3, and SRT for each plant.

Several observations may be made from Exhibit D. The most common secondary treatment technology used in these Great Lakes WWTPs is the activated sludge process (17 plants) although this group includes different modes of operating the activated sludge process: nitrification only, biological nutrient removal (BNR) (combination of nitrification, denitrification and biological phosphorus removal) and membrane bioreactor. Chemical precipitation of phosphorus is practiced at all these plants except where biological phosphorus removal is implemented.

The second most common secondary treatment technology used by these plants is based on biological fixed films (4), three of which use biological aerated filtration technology; the remaining plant deploys the trickling filter/solids contact process. These fixed film processes are more advanced than the historically more common trickling filter process and it will be interesting to see if future research shows that these advancements improve the removal efficiency of CECs over that observed for the conventional trickling filter technology. Trickling filters have not been able to achieve as high removal efficiencies of some CECs when compared to the activated sludge process because of the limited hydraulic residence time in the filters.

Of the remaining plants, two are lagoon-based systems and two have no secondary treatment process, employing only primary treatment (Nipigon) or activated carbon and chemical oxidation (Niagara Falls).

One critical parameter that has been identified with high CEC removals (at least for those CECs that are biodegradable) is an SRT that is relatively high (Drewes *et al.*, 2005, 2006; Clara *et al.*, 2005a, b). Some CECs are difficult to degrade and the microorganisms that have adapted to degrade them are slow growing. The SRT is related to the microorganism growth rate and so serves as a surrogate measure of the ability of the activated sludge to retain the slower growing organisms. It is fortunately coincidental that BNR systems are operated at higher SRTs than those that are designed to remove BOD only and so are able to retain the slower growing organisms that can degrade some CECs. As a result, it has been observed that BNR systems remove some CECs more efficiently than activated sludge systems operated at lower SRTs (Melcer *et al.*, 2006). This parameter applies only to those plants deploying activated sludge systems because only these systems lend themselves to SRT control, unlike fixed film or lagoon systems.

In the absence of CEC data, it is useful to compare the efficiency of the candidate plants for their ability to nitrify, that is, to remove ammonia, because in operating as BNR facilities, the supposition is that they should be able to remove CECs efficiently, too. The plants in Exhibit D that reported SRT data can be divided into two groups, those operating with an SRT of 5 days or less and those with an SRT greater than 5 days. The former category includes Hamilton, Napanee and Detroit. Detroit operates with the lowest SRT with the clear objective of not nitrifying to save the operational cost associated with aeration; there is almost no change in ammonia from influent to effluent, indicating the absence of nitrification. This plant may show a poorer CEC removal efficiency. Hamilton and Napanee operate at approximately 5 days SRT and show partial nitrification, that is, effluent ammonia concentrations are in the 4-10 mg/L range. These plants most likely are required to nitrify on a seasonal basis because of the large range of effluent ammonia concentrations; data in Appendix A for Hamilton and Napanee show that high ammonia concentrations occur during the winter months. Therefore, if these plants were selected as candidates for CEC removal measurement, sampling in the winter will likely show a poorer performance than in the summer.

The group of activated sludge plants that are reported to operate with SRTs greater than 5 days include Buffalo, Green Bay, Michigan City, both the Milwaukee plants, and Toledo; typically, they operate with SRTs in excess of 10 days. The effluent ammonia concentrations are typically less than 1.0 mg/L (except for Buffalo) indicating almost complete nitrification, a high level of performance. The lowest of these (effluent ammonia concentration of 0.2 mg/L or less) occur at Michigan City and the two Milwaukee plants. Common to these plants is the high level of HRT indicating that all three plants were conservatively designed with a year-round capability of nitrification. CEC removal efficiencies are likely to be the highest at these three plants. It is not clear why the Buffalo plant does not nitrify as well as the Toledo plant despite similar SRTs and HRTs and receiving similar BOD, TSS and ammonia loads. Perhaps this is due to the types of industry that the Buffalo plant serves; nitrification is impeded by some industrial discharges.

The Traverse City plant produces a very high quality effluent with <0.2 mg/L ammonia as well as very low BOD and TSS concentrations. The latter are attributed to the membrane used in this type of activated sludge system. The high degree of nitrification is attributed to the higher level of control over sludge inventory that can be achieved with a membrane bioreactor as is shown with this plant operating at an average SRT just in excess of 4 days. This plant, too, will likely achieve a high level of CEC removal during summer and winter. That said, it is not necessary to invoke membrane bioreactor technology in order to achieve high quality effluent. For example, the lagoon system at Muskegon achieved the lowest effluent ammonia concentrations of all 25 plants (<0.1 mg/L). The effluent BOD and TSS concentrations were similarly very low (2 and 6 mg/L, respectively). This is remarkable performance and illustrates that the plant has been designed conservatively and is operated very well. It would be interesting to compare CEC removal at plants such as these versus the highly mechanized and more expensive activated sludge plants. Of course, lagoon technology cannot be deployed in large population centers, such as Detroit, due to the large area required, but the Muskegon plant does illustrate what can be achieved in small to medium-sized communities (the Muskegon flow rate is 20 MGD) with lagoon technology.

Four of the plants were selected for more detailed evaluation using log probability distribution plots. This type of analysis is a useful way of displaying large amounts of data in a graphical format. It readily facilitates comparison of the influent and effluent performance data within a plant and in comparison with other plants. Flow, BOD and TSS concentration data are plotted in log form on the y-axis and the log probability of the occurrence of these parameters occurring at a given value is plotted on the x-axis. Each line represents the logarithmic probability distribution of that parameter. The shape and slope of each line reveal specific characteristics of the data set. A straight line indicates that the data are log-normal. The greater the slope of a line, the more variability in the data set. Typically, it is expected that the slope of effluent values is lower than the corresponding influent parameter because of the attenuation achieved in a treatment plant.

The four plants that were selected for this analysis were Detroit, Green Bay, Traverse City, and Muskegon. The first three are activated sludge plants with Detroit operating at the lowest SRT of the three at 2.7 days, Traverse City at 4.3 days and Green Bay at 7-10 days. These three plants were selected for comparison because they deployed the same technology and operated over a range of SRTs. Performance comparisons are more relevant when comparing like technologies. Muskegon uses lagoon technology and has an indeterminate SRT.

The distribution plot for Detroit is given in Figure 2. As discussed above, it is a very large plant, operated with the objective of BOD removal only. No nitrification was reported. The influent parameter plots display relatively shallow slopes indicating limited variability in the data sets. However, it must be noted that these are monthly average data that are plotted from three years. Daily data would possess more variability and display a steeper slope. Despite the lack of nitrification, the effluent plots show that the plant achieves effluent BOD and TSS concentrations of ≤7 and ≤10 mg/L, respectively, at least 50 percent of the time. However, the effluent TSS plot departs from a linear slope at values greater than 50 percent probability displaying a variable performance in the secondary clarifiers such that the plant exceeds 30 mg/L TSS approximately 10 percent of the time.

Green Bay (Figure 3) is a medium-sized activated sludge plant that operates with an SRT that is almost three times greater than Detroit. Comparison of Figures 2 and 3 shows that the slopes of the influent BOD and TSS concentrations are relatively similar for both plants, but they are displaced higher for Green Bay indicating greater influent concentrations for Green Bay than Detroit. The 50th percentile values for effluent BOD and TSS concentrations are lower for Green Bay (4 and 5 mg/L, respectively) than for Detroit, indicating a more stable operation at the higher SRT. The slopes of the BOD and TSS concentration lines are almost linear with no elevated values at the higher percentile values compared to the curvilinear shape of the corresponding Detroit data.

It can be said that 99 percent of the time, the effluent TSS concentration is <10 mg/L and the effluent BOD concentration is <7 mg/L.

Traverse City (Figure 4) is a small-sized membrane bioreactor plant that produces a very high quality effluent. Comparison of Figures 3 and 4 shows shallower slopes for influent BOD and TSS concentrations albeit displaced higher than Green Bay, indicating that the Traverse City plant was receiving higher strength wastewater than Green Bay or Detroit. Despite this, the Traverse City MBR was able to achieve the lowest effluent BOD and TSS concentration of all three plants evaluated. The slopes of effluent cBOD and TSS concentrations are approximately zero with 50th percentile values equal to 95th percentile values. Clearly, the membrane confers a high level of removal capability on this process by screening most of the effluent solids and the BOD associated with those solids. The 50th percentile BOD and TSS concentrations were 2 and 1 mg/L, respectively.

Muskegon (Figure 5) stands out from other plants because it is a low rate lagoon-based system but it produces an effluent that is low in BOD and ammonia. As with the Green Bay plant (Figure 3), the influent lines show that this plant received higher strength BOD and TSS concentrations than Detroit. However, the influent TSS concentration plot is curvilinear indicating a much higher variability in influent TSS than the other three plants. Despite the higher influent BOD loading, effluent BOD concentrations were <2 mg/L 90 percent of the time. This is probably because of the extended SRT typically found in low rate lagoon systems. The effluent TSS plot, however, is not completely linear reflecting the high variability of the influent TSS and probably the limitation in settling capability of lagoon systems.

Exhibit D. Summary Table (Page 1 of 4)

	Monthly Flow	BOD				TSS		Ammonia		SRT	HRT	Plant Size			General Treatment Type
		Total		Carbonaceous											
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent						
	MGD	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	days	hours	Small	Medium	Large	
Canadian Plants															
Region of Halton - Burlington Skyway WPCP[1]													X		Activated Sludge
2007	28	172		123	2	170	4	16.4	0.2						
Average 2008	32	106			2	152	3	13.5	0.3						
2009	31	118			2	178	3	15.8	0.3						
Range	24-41	66-213		103-152	<1 - 3	62-330	2-7	10.3-21.3	0.1-1.0						
City of Hamilton - Woodward Avenue WPCP[2]														X	Activated Sludge
2007	89			145	12	208	10	18.7	4.8	4.3					
Average 2008	92			124	13	176	14	16.2	5.0	5.5					
2009	84			132	10	177	11	16.9	3.4	6.6					
Range	65-128			94-183	6-22	143-262	6-22	12.2-23.4	0.5-12.8	2.6-9.2					
Kincardine Lagoons (Township of Bruce-Tiverton, Ontario)												X			Lagoon
2007	1.0	146	14			159	22		9.1						
Average 2008	1.1	123	13			139	21		8.9						
2009	1.2	111	11			135	23		9.6						
Range	0.7-2.5	39-195	5-29			54-230	3-45		0.5-16.6						
City of Kingston - Ravensview WPCP													X		Biological Aerated Filter
2007	17			38	19	103	17	7.7	10.7						
Average 2008	19			34	12	77	10	8.1	6.4						
2009	18			49	10	89	3	7.5	0.8						
Range	12-25			13-82	4-27	57-154	2-31	4.8-11.7	0.1-16.5						
Napanee WPCP[3]												X			Activated Sludge
2007	2.0			131	3	245	11		5.5	5.9	4.6				
Average 2008	2.5			96	2	214	9	44.5	7.7	4.9	3.5				
2009	2.3			84	2	184	8	30.6	8.4	6.3	3.8				
Range	1.3-3.7			44-219	2-5	85-428	5-20	7.0-83.5	0.1-26.4	3.7-9.0	2.3-6.4				
Township of Nipigon WPCP[4]												X			Primary
2007															
Average 2008	1.1			120	55	154	55								
2009	1.5			96	48	161	51								
Range	0.9-2.0			40-184	24-76	77-315	26-84								
City of Thunder Bay WPCP													X		Biological Aerated Filter
2007	16			157	12	146	9		2.2						
Average 2008	18			120	11	149	12		1.5						
2009	18			107	6	166	12		1.6						
Range	11-27			63-270	4-24	102-255	5-17		0.2-5.5						

Note: All blank spaces indicate that data were not provided for those parameters.

[1] The 2007 Total BOD average is based on the last 4 months of the year. Carbonaceous BOD was measured in the influent for the first 8 months of 2007. That average and range are also included above.

[2] SRT was reported for 2 Aeration areas. The North Aeration results are above. The South Aeration results are: 5.4 (2007), 3.5 (2008), 5.5 (2009) and range 2.5-10.9.

[3] The November and December 2009 BOD measurements were of Total BOD . They were not included above with the other 34 months of carbonaceous results. Influent ammonia was not measured until July of 2008.

[4] Only one sample is collected per month. Only one month of data from 2007 was provided so no annual average values were included above for that year.

Exhibit D. Summary Table (Page 2 of 4)

		Monthly Flow	BOD				TSS		Ammonia		SRT	HRT	Plant Size			General Treatment Type
			Total		Carbonaceous											
			Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent						
		MGD	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	days	hours	Small	Medium	Large	
City of Toronto - Ashbridges Bay WPCP															X	Activated Sludge
	2007	154			137	5	273	8	22.4	11.8						
Average	2008	173			101	4	274	9	18.2	11.8						
	2009	184			121	5	256	9	23.3	17.2						
Range		134-218			88-280	2-8	129-395	3-25	14.8-48.3	2.3-25.5						
City of Windsor - Lou Romano WPCP														X		Biological Aerated Filter
	2007	39	122	38			140	20	14.4	12.6						
Average	2008	42			94	7	128	14	11.7	5.2						
	2009	43	157			6	149	11	12.8	4.6						
Range		32-55	79-218	24-52	65-121	3-13	81-232	5-29	8.5-17.8	1.6-16.5						
American Plants																
Buffalo, NY Sewer Authority WWTP[5]															X	Activated Sludge
	2007	115	115	9			92	9	8.5	4.5	10.9	5.6				
Average	2008	138	114	9			88	8	7.5	4.8	11.3	4.6				
	2009	125	118	9			91	7	10.0	5.8	10.2	5.0				
Range		89-181	84-146	4-17			61-111	5-19	2.4-12.8	0.2-14.7	7.7-18.6	3.4-7.0				
Detroit WWTP															X	Activated Sludge
	2007	649			95	6	140	9	11.9	11.1	2.7	2.8				
Average	2008	704			88	7	118	9	11.1	9.9	2.7	2.7				
	2009	695			91	8	129	19	12.0	11.3	2.8	2.6				
Range		476-1,032			56-125	3-14	87-180	1-46	6.3-17.1	7.0-14.8	2.3-3.4	2.1-3.2				
Erie, PA Sewer Authority WWTP[6]														X		Activated Sludge
	2007	36	173	8			363	9	12.6	1.0						
Average	2008	38			227	8	364	13	14.3	2.2						
	2009	36			166	7	278	9	14.0	1.5						
Range		24-57			118-276	3-17	175-620	5-23	8.3-19.8	0.3-5.3						
Green Bay Metropolitan Sewage District														X		Activated Sludge (BNR)
	2007	21	200			3	198	4	27.4	0.2	7.2	4.3				
Average	2008	22	186			4	180	5	24.6	0.7	7.2	3.3				
	2009	21	210			4	192	6	23.5	0.3	10.0	3.1				
Range		17-38	91-316			2-5	97-264	3-8	5.2-34.8	0.02-4.0	5.4-13.8	2.4-4.9				
Michigan City (IN) Sanitary District													X			Activated Sludge (followed by shallow bed sand filtration)
	2007	9	107			2	101	2	12.2	0.1	35	19.5				
Average	2008	10	94			3	96	3	11.0	0.1	34	18.5				
	2009	10	88			3	94	4	10.0	0.1	35	17.0				
Range		7-16	64-130			2-4	73-124	2-5	5.7-16.3	0.03-0.6	29-43	12.1-24.6				

Note: All blank spaces indicate that data were not provided for those parameters.

[5]Mean Cell Residence Time (MCRT) is provided in lieu of Solids Retention Time (SRT). MCRT is calculated as total mass of solids in aeration and secondary clarifiers divided by the total mass of wasted solids.

[6]Total BOD was measured in 2007. In 2008 and 2009 carbonaceous BOD was measured.

Exhibit D. Summary Table (Page 3 of 4)

		Monthly Flow	BOD				TSS		Ammonia		SRT	HRT	Plant Size			General Treatment Type
			Total		Carbonaceous											
			Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent						
		MGD	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	days	hours	Small	Medium	Large	
Milwaukee Metro Sewerage District - Jones Island WWTP[7]															X	Activated Sludge
	2007	84	263	5			239	6	12.5	0.2	13.1	16.2				
Average	2008	98	237	5			203	6	11.6	0.2	10.3	14.5				
	2009	104	255	6			226	7	12.3	0.3	7.8	13.8				
Range		59-155	165-331	3-8			143-286	4-9	6.8-18.0	0.1-0.9	5.9-23.6	9.8-20.7				
Milwaukee Metro Sewerage District - South Shore WWTP[7]															X	Activated Sludge
	2007	100	193	7			222	7	16.2	0.7	12.8	9.1				
Average	2008	115	223	9			248	8	15.2	0.9	12.5	8.3				
	2009	94	260	7			293	6	15.7	0.6	15.3	9.3				
Range		56-188	107-381	4-17			134-430	4-19	7.3-24.0	0.1-2.1	8.8-20.0	4.8-12.9				
Muskegon Co. WWMS Metro WWTP[8]														X		Lagoon
	2007	21	324	2			949	7	13.2	0.05						
Average	2008	20	252	2			541	6	15.0	0.07						
	2009	15	222	2			292	6	21.6	0.08						
Range		13-23	175-512	2.0-3.2			166-1880	2-22	10.1-26.8	0.02-0.20						
Niagara Falls WWTP[9]														X		Activated Carbon (followed by chemical oxidation)
	2007	31					75	14.1								
Average	2008	33					44	16.6								
	2009	31					50	16.3								
Range		28-40					31-212	10.6-22.7								
NEORSD, Cleveland, OH - Westerly WWTP														X		Trickling Filter/Solids Contact Process
	2007	28	89	15			139	6	6.3	5.2						
Average	2008	29	86	13			137	6	6.4	4.1						
	2009	26	95	16			121	5	7.5	5.2						
Range		20-51	52-121	9-24			95-190	3-9	3.1-9.1	2.1-7.5						
NEORSD, Cleveland, OH - Easterly WWTP															X	Activated Sludge
	2007	92	89	9			162	6	5.6	2.1						
Average	2008	99	84	8			153	4	5.2	0.9						
	2009	86	106	13			180	7	5.6	2.4						
Range		68-163	50-123	4-19			83-259	2-12	2.4-7.7	0.5-6.4						
Rochester Pure Waters District - VanLare Plant[10]															X	Activated Sludge
	2007	88	174	11			174	11	15.7	15.4						
Average	2008	106	159	11			185	14	16.3	14.7						
	2009	91	145	12			162	12	16.2	16.0						
Range		69-145	100-224	9-22			118-235	7-28	9.1-23.4	10.2-20.4						

Note: All blank spaces indicate that data were not provided for those parameters.

[7]Mean Cell Residence Time (MCRT) is provided in lieu of Solids Retention Time (SRT). MCRT is calculated as total mass of solids in aeration and secondary clarifiers divided by the total mass of wasted solids.

[8]The 2007 annual averages are based on the last 10 months of the year. January and February of 2007 data were not provided.

[9]Niagara Falls WWTP measured TOC, not BOD. Monthly TOC data for the plant is included in Appendix A.

[10]The 2007 annual averages are based on the last 6 months of the year. Data from the preceding months of 2007 were not provided.

Exhibit D. Summary Table (Page 4 of 4)

		Monthly Flow	BOD				TSS		Ammonia		SRT	HRT	Plant Size			General Treatment Type
			Total		Carbonaceous											
			Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent						
		MGD	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	days	hours	Small	Medium	Large	
Rochester Pure Waters District - NW Quadrant Plant														X		Activated Sludge
	2007	15			113	5	158	8	23.7	15.8						
Average	2008	16			103	6	156	9	22.8	19.3						
	2009	16			90	6	162	9	22.1	22.1						
Range		10-23			64-159	2-11	88-227	5-13	12.3-33.4	4.8-27.5						
City of Superior (WI) WWTP													X			Activated Sludge
	2007	3.7			135	6	182	8		16.1						
Average	2008	4.3			134	10	156	11		17.1						
	2009	3.3			133	8	183	10		26.4						
Range		2.0-6.6			66-223	4-19	100-246	5-22		4.2-39.9						
Traverse City Regional WWTP[11]													X			Membrane Bioreactor
	2007	4.1			274	2	256	1	27.8	0.1	4.1					
Average	2008	4.3			282	2	278	1	27.0	0.2	4.3					
	2009	4.5			265	2	253	1	27.7	0.2	4.5					
Range		3.7-5.2			248-299	2.0-2.4	207-540	1-2	25.0-30.2	0.01-0.7	3.7-5.2					
City of Toledo - Bay View WWTP[12]															X	Activated Sludge
	2007	71			104	5	183	9	13.7	0.3	9.8	5.7				
Average	2008	76			82	4	172	8	14.1	0.3	10.2	5.6				
	2009	66			101	4	187	8	14.2	0.7	12.2	6.8				
Range		42-128			46-150	3-11	112-313	5-13	7.1-20.7	0.1-3.2	7.2-14.3	3.3-9.4				

Note: All blank spaces indicate that data were not provided for those parameters.

[11] The 2007 annual averages are based on 10 months of the year. January and February data were not provided. 2007 annual averages are based on 9 months of the year. Data from March, April and October 2008 were not provided.

[12] The monthly average data provided by the plant does not include values that were below detection limits. Below detection limit values are common for effluent CBOD so the monthly averages reported for that parameter are significantly higher than if the below detection limit values were included.

Figure 2. Detroit WWTP Distribution Plot

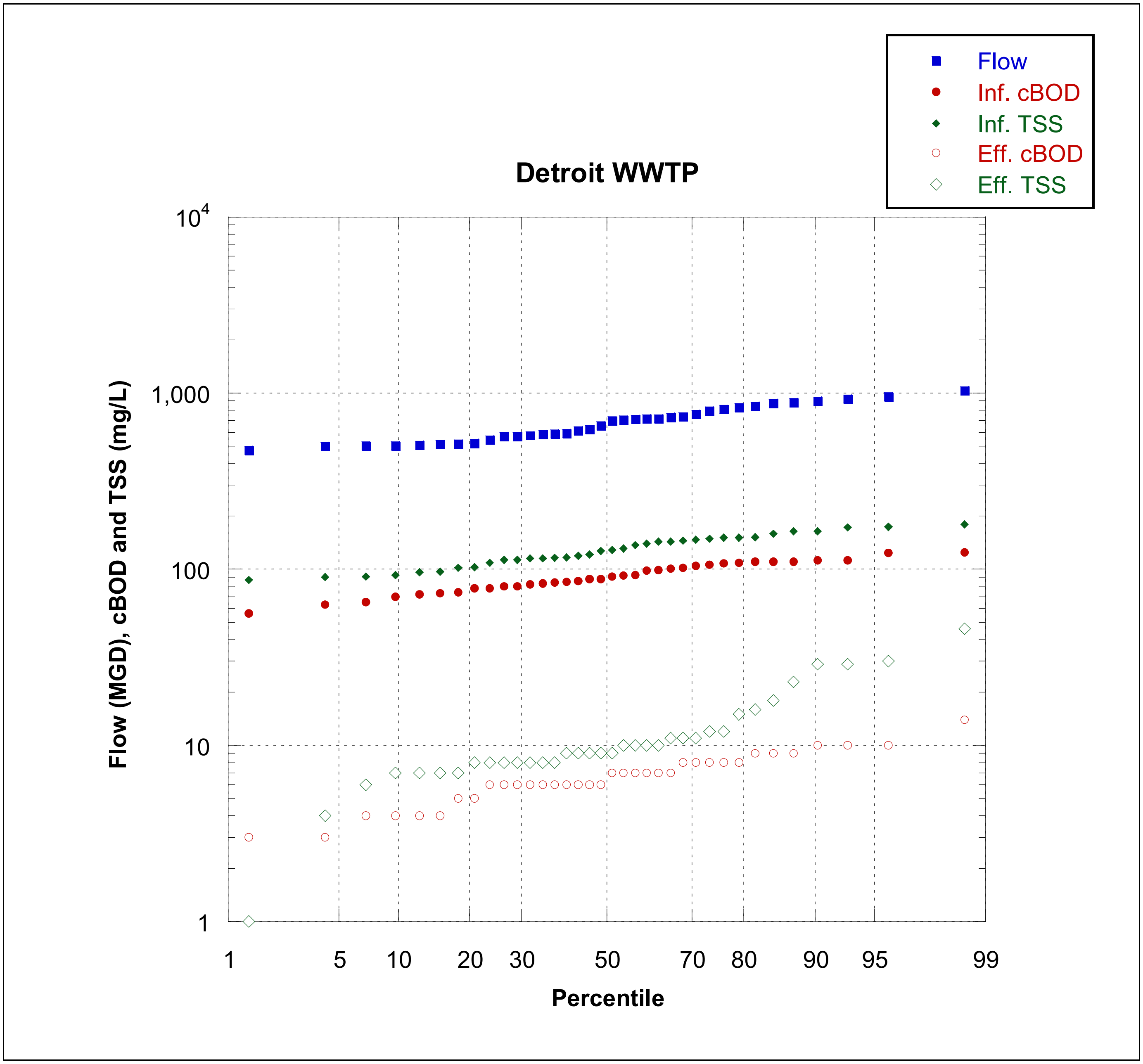


Figure 3. Green Bay WWTP Distribution Plot

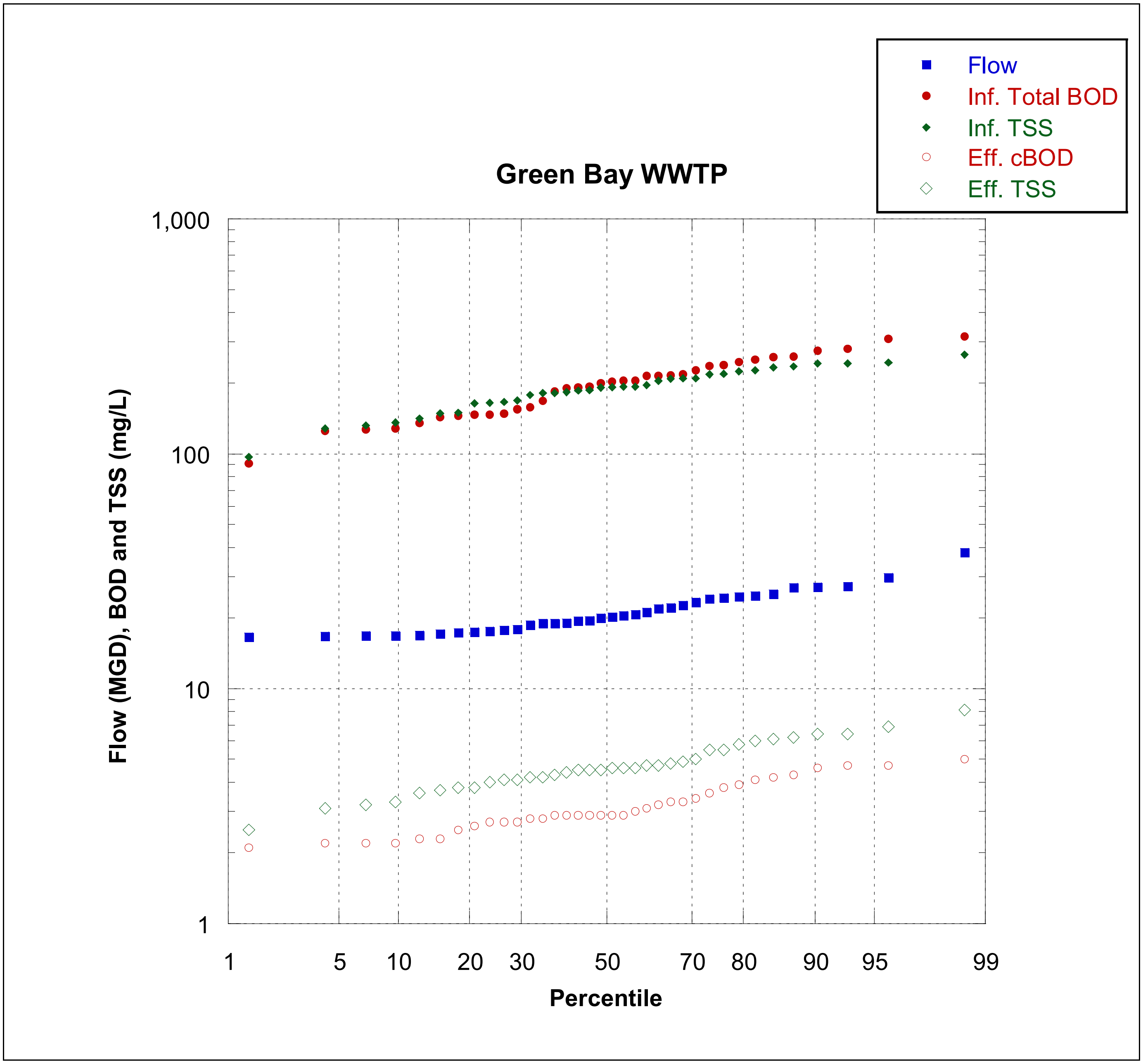


Figure 4. Traverse City WWTP Distribution Plot

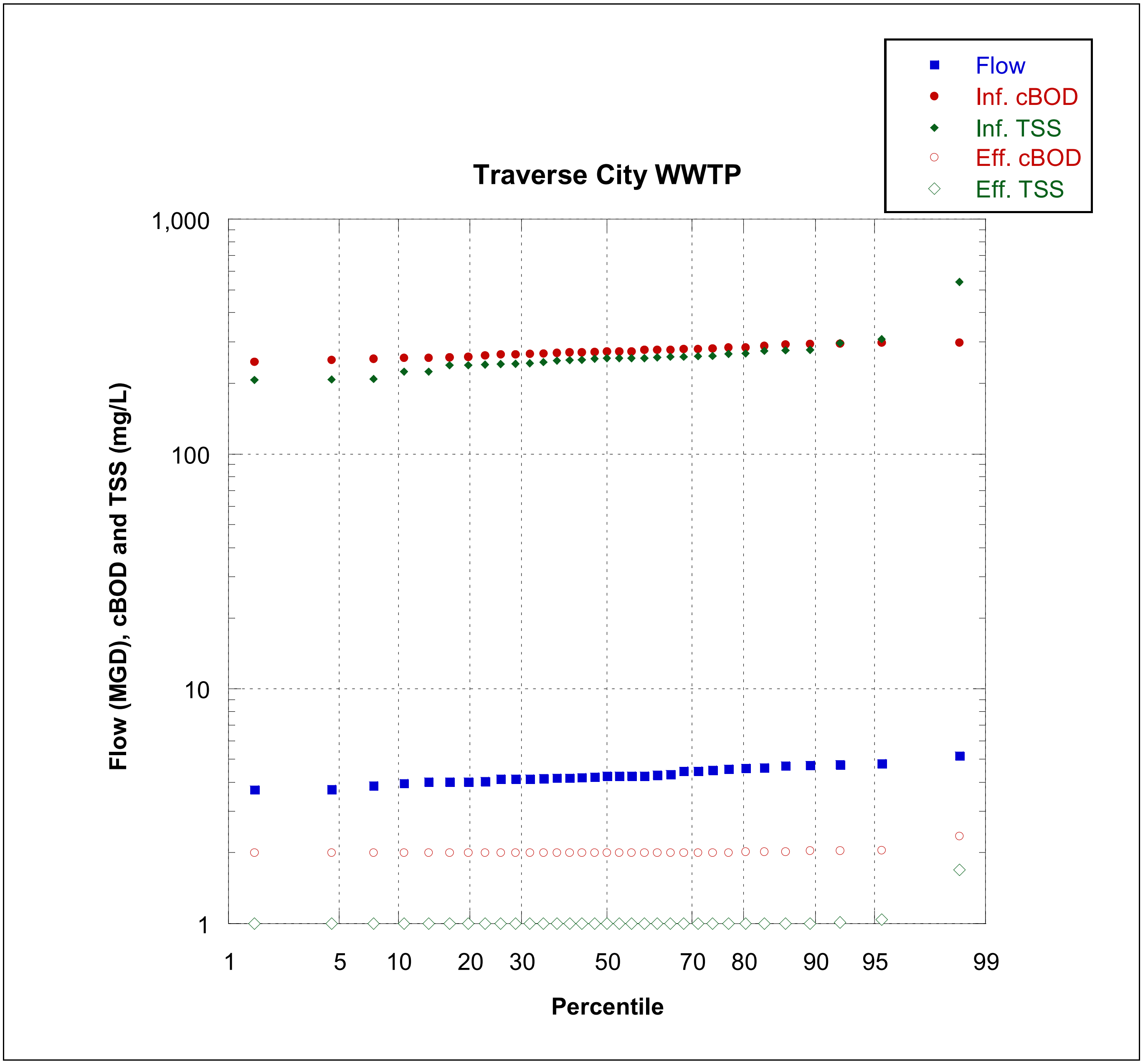
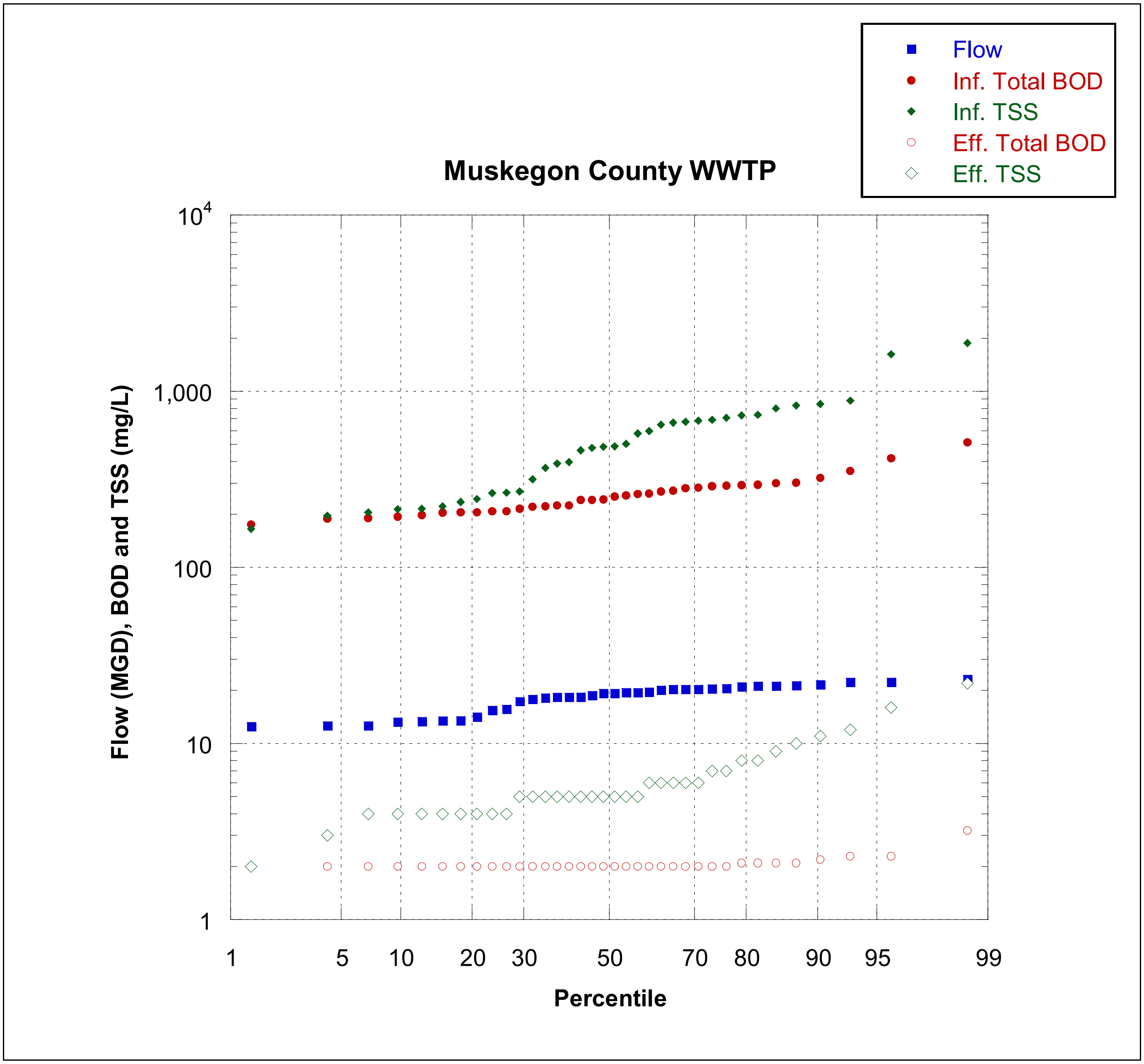


Figure 5. Muskegon County WWTP Distribution Plot



1.6 References

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APPENDIX A: WWTP OPERATIONAL DATA

The plant information and data sheets are included in this appendix in the following order:

- Buffalo, NY Sewer Authority WWTP
- Region of Halton – Burlington Skyway WPCP
- NEORSD, Cleveland, OH – Easterly WWTP
- NEORSD, Cleveland, OH – Westerly WWTP
- Detroit WWTP
- Erie, PA Sewer Authority WWTP
- Green Bay Metropolitan Sewage District WWTP
- City of Hamilton – Woodward Avenue WPCP
- Kincardine Lagoons (Township of Bruce-Tiverton, Ontario)
- City of Kingston – Ravensview WPCP
- Michigan City (IN) Sanitary District WTTP
- Milwaukee Metro Sewerage District – Jones Island WWTP
- Milwaukee Metro Sewerage District – South Shore WWTP
- Muskegon Co. WWMS Metro WWTP
- Napanee WPCP
- Niagara Falls (NY) WWTP
- Township of Nipigon WPCP
- Rochester Pure Waters District – NW Quadrant Plant
- Rochester Pure Waters District – VanLare Plant
- City of Superior (WI) WWTP
- City of Thunder Bay WPCP
- City of Toledo – Bay View WWTP
- City of Toronto – Ashbridges Bay WPCP
- Traverse City Regional WWTP
- City of Windsor – Lou Romano WPCP