MALCOLM PIRNIE | ARCADIS

The Water Division of ARCADIS

Technical Correspondence

Date: February 18, 2011

To: Buffalo Sewer Authority

Copy: USEPA, NYSDEC

From: Malcolm Pirnie, Inc.

Re: Comparison of Full 12-Month vs. 9-Month Recreational Period Typical Year Results

The following memo summarizes the comparison of the results for the full 12-Month 1986 Typical Year to the results for the 9-Month Recreational Period portion of the 1986 Typical Year for the current baseline version of the BSA's XP-SWMM collection system model.

Background

During the original LTCP effort, the 1986 precipitation year (with some modifications) was selected as the Typical Year hyetograph to be used when assessing the performance of the system. At the time, based on discussions with DEC, it was decided that only the 9-Month "Recreational Period" portion of the Typical Year (March through November) would be simulated. The Typical Year CSO overflow statistics (volume, activations, and duration) would be estimated through "annualizing" the 9-month results by multiplying them by 4/3. This approach was developed as a simple mechanism to address DEC concerns with modeling snowmelt in a collection system model.

While this approach was adequate during the initial LTCP phase when the critical metrics were the CSO overflow statistics, it causes complications with the current LTCP phase. The 9-Month results do not provide a mechanism for extrapolation to full 12-Month results for use with the water quality model simulations being performed during the current LTCP phase for the Buffalo receiving waters (Buffalo River, Scajaquada Creek, Niagara River, and Black Rock Canal). Additionally, improvements in computer processing speed and the modeling software over the last seven years had resulted in an industry-wide shift to performing continuous annual and multiyear model simulations. Similar approaches have been used by utilities such as the City of Fort Wayne, IN, Northern Kentucky Sanitation District No. 1, and the City of Columbus, OH. Because of this, the BSA LTCP project team proposes to switch from the 9-Month Recreational Period rainfall hyetograph to the Full 12-Month rainfall hyetograph for performing the Typical Year model simulations and use the 12-month simulation and CSO statistics for evaluation of CSO control alternatives and associated water quality benefits. This memorandum compares the "existing conditions" CSO overflow statistics generated by both modeling approaches.

Approach and Results

Two simulations were performed using the BSA 2009 Baseline XP-SWMM model with all the Phase I LTCP projects incorporated:

- One simulation using the 9-Month 1986 Recreational Period typical year rainfall hyetograph, the hyetograph that has been used for Typical Year analyses up until this point.

- A second simulation using the full 12-Month 1986 typical year rainfall hyetograph. Snowfall occurring during the Non-Recreational Period was handled by using the "equivalent rainfall" approach.

Once the simulations were completed, the CSO overflow statistics (overflow volume, overflow activations based on a 6-hour inter-event time, and overflow duration) were compiled and compared.

Table 1 below shows the comparison between the 12-Month results and the annualized 9-Month overflow volume results.

Table 1
Comparison of 9-Month Annualized and 12-Month Continuous Simulation Overflow Volumes

CSO Outfall	Model Link(s)	District	9-Month Sim. Annualized	Full 12-Month Sim.	% Difference	
			OF Volume (MG)	OF Volume (MG)		
001a	WETWELLOF	Scajaquada	0.0	0.0	0%	
003	5500	Parish	4.4	3.1	-30%	
004	10213 + 10221	Scajaquada	44.8	32.7	-27%	
005	5873	Scajaquada	0.0	0.0	0%	Closed
006[(1)]	5710	Scajaquada	526.2	384.6	-27%	
008	5906	Scajaquada	0.0	0.0	0%	Closed
010	5553	Scajaquada	13.2	10.1	-24%	
011	6729	Albany	162.1	143.7	-11%	
012	6363	Albany	152.8	113.8	-26%	
013	10047	South Central	25.2	18.2	-28%	
014	L9201	South Central	18.8	13.7	-27%	
015	15670	South Central	35.3	25.9	-27%	
016	14968 + SPP39w	South Central	10.4	8.9	-14%	
017	14584	South Central	315.1	246.4	-22%	
022	L14678	South Central	25.2	19.1	-25%	
025	15468	South Central	8.1	5.8	-28%	
026	12620	South Central	340.4	261.4	-23%	
027	10065	South Central	75.0	53.0	-29%	
028	7511 + 7512	South Central	152.4	123.9	-19%	
029	7735	South Central	1.2	1.0	-20%	
032	SPP120w	South Central	0.0	0.0	0%	
033	14414	South Central	90.8	65.6	-28%	
034	SPP344w	South Central	0.0	0.0	0%	Closed
035	7263	South Central	23.6	18.9	-20%	
037	7075	South Central	55.5	37.7	-32%	
039	7528	South Central	0.0	0.0	0%	

CSO Outfall	Model Link(s)	District	9-Month Sim. Annualized	Full 12-Month Sim.	% Difference
			OF Volume (MG)	OF Volume (MG)	
044	8118	South Central	8.3	5.9	-29%
046	7631	South Central	2.3	1.9	-18%
047	SPP113OF + SPP114OF	South Central	11.9	8.8	-26%
048	SPP118OF	South Central	0.0	0.0	0%
049	7571	South Central	0.1	0.1	-28%
050	7141	South Central	8.4	6.0	-28%
051	16184	South Central	5.0	3.6	-29%
052	7751	South Central	25.5	16.4	-36%
053[(1)]	5943	Scajaquada	456.0	419.29	-8%
054	17	Ontario	26.3	23.0	-13%
055	P8	Hertel	949.3	802.8	-15%
056	2604	Hertel	1.6	1.1	-30%
057	N33	Parish	0.1	0.0	-31%
058	6892	Parish	12.8	11.6	-9%
059	10254	Scajaquada	2.2	1.6	-27%
060	5781	Scajaquada	0.8	0.7	-6%
061	OF61B.1	Scajaquada	65.5	53.4	-18%
063	16139	South Central	1.8	1.3	-27%
064	L14809 + SPP135aw	South Central	25.3	19.3	-24%
066	14982	South Central	123.3	106.7	-13%
Total Overflow Volume (MG)/ % Difference			**3806.9**	**3071.1**	**-19%**

NOTE: (1) Volume does not include Scajaquada Creek inflow from Cheektowaga. Estimated Creek volumes (including dry-weather creek flow) discharged through the CSOs are as follows:

CSO Outfall	9-Month Sim. Annualized	Full 12-Month Sim.
	Creek Volume (MG)	Creek Volume (MG)
CSO-006	897.4	769.5
CSO-053	998.1	1131.9

Table 2 shows the comparison for the overflow activations.

Table 2
Comparison of 9-Month Annualized and 12-Month Continuous Simulation Overflow Activations

CSO Outfall	Model Link(s)	District	9-Month Sim. Annualized	Full 12-Month Sim.	Difference
			Events	Events	
001a	WETWELLOF	Scajaquada	0	0	0
003	5500	Parish	11	9	-2
004	10213 + 10221	Scajaquada	9	7	-2
005	5873	Scajaquada	0	0	0

CSO Outfall	Model Link(s)	District	9-Month Sim. Annualized	Full 12-Month Sim.	Difference
			Events	Events	
006	5710	Scajaquada	N/A	N/A	N/A
008	5906	Scajaquada	0	0	0
010	5553	Scajaquada	52	43	-9
011	6729	Albany	41	36	-5
012	6363	Albany	55	47	-8
013	10047	South Central	11	8	-3
014	L9201	South Central	7	5	-2
015	15670	South Central	20	15	-5
016	14968 + SPP39w	South Central	104	100	-4
017	14584	South Central	87	83	-4
022	L14678	South Central	24	19	-5
025	15468	South Central	15	11	-4
026	12620	South Central	91	83	-8
027	10065	South Central	49	44	-5
028	7511 + 7512	South Central	148	138	-10
029	7735	South Central	5	4	-1
032	SPP120w	South Central	0	0	0
033	14414	South Central	12	9	-3
034	SPP344w	South Central	0	0	0
035	7263	South Central	95	92	-3
037	7075	South Central	16	10	-6
039	7528	South Central	0	0	0
044	8118	South Central	7	5	-2
046	7631	South Central	88	89	1
047	SPP113OF + SPP114OF	South Central	43	32	-11
048	SPP118OF	South Central	1	1	0
049	7571	South Central	3	1	-2
050	7141	South Central	12	9	-3
051	16184	South Central	7	4	-3
052	7751	South Central	19	10	-9
053	5943	Scajaquada	N/A	N/A	N/A
054	17	Ontario	68	67	-1
055	P8	Hertel	48	44	-4
056	2604	Hertel	11	8	-3
057	N33	Parish	1	1	0
058	6892	Parish	81	76	-5
059	10254	Scajaquada	5	4	-1
060	5781	Scajaquada	48	37	-11
061	OF61B.1	Scajaquada	15	14	-1
063	16139	South Central	13	10	-3
064	L14809 + SPP135aw	South Central	72	66	-6
066	14982	South Central	88	82	-6

The overflow volume comparisons from Table 1 show that the overflow volumes for the 12-month simulation are lower than the annualized 9-month Recreational Period results (19% lower for the overall system overflow volume). The 12-month results also show less frequent overflow activations. These results can be explained by the lack of significant rainfall events during the Non-Recreational Period of the Typical Year, which was not previously simulated. Table 3 lists

all of the events during the 1986 Typical Year that have at least a 1-Month Return Period for one of the following partial storm durations: 1-Hr, 3-Hr, 6-Hr, 12-Hr, 24-Hr. For the BSA's collection system, the 3-Hr and 6-Hr partial storm durations are the most critical, due to the system's wet weather response times.

Table 3
Significant Events in BSA Typical Year (1986)

Event	TY Segment	Peak 1-Hr (in.)	Peak 1-Hr Return Period	Peak 3-Hr (in.)	Peak 3-Hr Return Period	Peak 6-Hr (in.)	Peak 6-Hr Return Period	Peak 12-Hr (in.)	Peak 12-Hr Return Period	Peak 24-Hr (in.)	Peak 24-Hr Return Period
4/17	Recreational Period	0.16	<1-Month	0.33	<1-Month	0.44	<1-Month	0.52	<1-Month	0.97	2-Month
4/20		0.13	<1-Month	0.37	<1-Month	0.54	<1-Month	0.74	1-Month	0.8	<1-Month
5/19		1.71	10-Year	2.27	10-Year	2.68	10-Year	2.95	10-Year	3.52	10-Year
6/1		0.53	3-Month	0.72	3-Month	1.02	4-Month	1.06	4-Month	1.14	3-Month
6/5		0.62	4-Month	0.79	4-Month	0.9	3-Month	0.97	3-Month	0.99	2-Month
7/7		0.64	4-Month	0.66	2-Month	0.66	1-Month	0.66	<1-Month	0.66	<1-Month
7/12		0.21	<1-Month	0.51	<1-Month	0.65	1-Month	0.67	<1-Month	0.7	<1-Month
8/7		0.42	1-Month	0.45	<1-Month	0.45	<1-Month	0.52	<1-Month	0.99	2-Month
8/15		0.9	1-Year	1.38	2-Year	1.5	1-Year	1.5	1-Year	1.5	6-Month
9/16		0.45	2-Month	0.69	2-Month	0.75	2-Month	0.75	1-Month	1.13	3-Month
9/30		0.74	9-Month	0.76	3-Month	0.96	4-Month	1.01	3-Month	1.02	2-Month
10/3		0.66	6-Month	1.25	1-Year	1.46	1-Year	1.72	1-Year	1.73	1-Year
10/13		0.25	<1-Month	0.57	1-Month	0.93	4-Month	1.01	3-Month	1.01	2-Month
11/26		0.13	<1-Month	0.32	<1-Month	0.45	<1-Month	0.73	1-Month	1	2-Month
12/2	Non-Recreational Period	0.18	<1-Month	0.46	<1-Month	0.79	2-Month	1.19	6-Month	1.46	6-Month
12/24		0.16	<1-Month	0.42	<1-Month	0.67	1-Month	0.78	1-Month	0.81	<1-Month

Color	Return Period[1]
	< 1-Month
	1-2 Month
	3-4 Month
	6-9 Month
	1-Year and Greater

(1) Rainfall depths for return periods of 1-Year and greater were taken from Technical Paper 40. For lower return periods, the rainfall depths were estimated through extrapolation using a combination of the Technical Paper 40 rainfall depths and the log-log slopes calculated from the rainfall frequency data for Northeast Ohio from the Rainfall Frequency Atlas of the Midwest (Huff and Angel, 1992).

As can be seen in Table 3, only two of the sixteen critical events fall within the typical non-recreational period. In addition, for the critical 3-6 Hr partial storm durations, the largest storm during the non-recreational period is only 2-months.

Conclusions and Recommendations

Based on the above findings, the LTCP project team recommends using the 12-Month Typical Year hyetograph for the current phase LTCP evaluations for the following reasons:

- It will support the ongoing water quality simulations.
- The full 12-Month hyetograph is still conservative as a "Typical Year" hyetograph, including as it does not only two storms with at least a 1-year return interval but also a 10-year storm event. Full 12-Month simulations, rather than annualizing the 9-Month results, provides a more realistic representation of "Typical Year" conditions than extrapolating from the 9-Month results.

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MEMO

To:
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Copies:
Buffalo Sewer Authority

From:
Malcolm Pirnie/ARCADIS.

Date:
April 4, 2011

ARCADIS Project No.:
01777122.0000

Subject:
Interevent Time (IET) for use in Reporting of CSO Frequency Statistics for Ongoing LTCP Update

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In recent discussions with the BSA attorneys, Malcolm Pirnie/ARCADIS have been asked to consider revising the interevent time (IET) for CSO activation frequency estimates from 6 hours to 12 hours or longer. This memo summarizes the comparison of the combined sewer overflow (CSO) frequency statistics (excluding stormwater or creek volumes) calculated using three different interevent periods.

The IET defines the period of time with no CSO discharges that separates one event from another. It is a counting mechanism for a given overflow hydrograph, and has no affect on annual overflow volumes. BSA has historically used a 6-hour IET for defining rainfall events and CSO activations. Project documentation from the 2001 Model Calibration Report indicates that the use of a 6-hour IET dates back to the 1992 Phase 2 CSO Study. In addition, the use of inter-event durations of approximately 6-8 hours is a de facto industry standard for many Midwestern and Eastern utilities. Table 1 documents interevent durations applied for both rainfall and overflow frequency analysis at selected utilities in the Midwest and East.

Based on a survey of several Midwestern and Eastern utilities (see Table 1), IETs from 6 to 24 hours have been applied for rainfall and overflow frequency analysis. To determine the potential effect of higher IETs on the estimated frequencies in the BSA system, overflow statistics were evaluated for Baseline conditions using several IETs. Table 2 shows the comparison of CSO only activations for the Baseline scenario using 6 hour, 12 hour and 24 hour IETs. As can be seen (in bold and italicized in the table), CSO activations decrease with increasing IET though in most cases the decreases are relatively small. The biggest changes are at CSOs with higher number of activations.

It should be noted that for typical CSO levels of control (annual average of 0-8 activations), the only substantive effect of going to a longer IET is it changes the existing condition (baseline) number of activations. For controlled conditions, where CSO activate at most a couple of times per month, a larger IET will typically have no impact on the size of a facility required to meet a target activation level. The only time the activation count would change for a given control facility is if two of the activations are less than 12 hours apart, which is always possible but is not the norm given the low number of activations per year.

Based on this evaluation, switching to the 12-hour IET will most likely not affect the recommended level of CSO control but may rather de-emphasize the accomplishments of the recommended LOC since only the baseline (and not recommended) conditions would show a lower number of activations. However, if the BSA believes that using 12-hour EIT is more advantageous for documenting the baseline conditions, Malcolm Pirnie/ARCADIS has no objections to using a 12-hour IET. Please note that the IET for precipitation events will remain at 6 hours.

Table 1
Comparison of Typical Interevent Times from Selected Midwestern and Eastern Utilities

Utility	Inter-Event Duration Used in Rainfall and Overflow Analysis	EPA Region	Reference
New York City DEP	12 hours	2	New York City Department of Environmental Protection, *Landside Modeling Report Volume 2 Bowery Bay WPCP* and *Volume 6 Newtown Creek WPCP*, FINAL October 2007
Albany Pool Communities	12 hours	2	Capital District Regional Planning Commission (CDRPC), *CSO Model Development and Baseline Conditions Albany Pool, Part B Long-term Control Plan*, October 2009
Kingston (NY)	12 hours	2	City of Kingston (NY), *Combined Sewer Overflow Long Term Control Plan,* FINAL October 2010
DC WASA	6 hours	3	District of Columbia Water and Sewer Authority, *Combined Sewer System Long-Term Control Plan – Final Report*, July 2002
City of Columbus, Ohio	6 hours	5	City of Columbus, *Wet-Weather Management Plan*, July 2005

Utility	Inter-Event Duration Used in Rainfall and Overflow Analysis	EPA Region	Reference
Rouge River Program (Michigan)	8 hours	5	City of Dearborn Heights, Wayne County Department of Environment, *CSO Basin Report - Dearborn Heights CSO Detention Basin*, March 2000
Sanitation District No. 1 of Northern Kentucky	7 hours	4	Sanitation District No. 1 of Northern Kentucky, *Draft Watershed Plans*, Public Comment Draft, May 2009
Allegheny County Sanitary Authority (ALCOSAN)	24 hours	3	ALCOSAN (Pittsburgh, PA), Internal technical communications and guidelines for Wet Weather Program Basin Planners, December 18, 2009

Table 2
Comparison of CSO Frequencies for Varying Interevent Times (IETs)

CSO Outfall	District	Receiving Water	Baseline CSO Only Events (6 hr IET)	Baseline CSO Only Events (12 hr IET)	Baseline CSO Only Events (24 hr IET)
004	Scajaquada	Black Rock Canal	9	9	9
005	Scajaquada	Black Rock Canal	0	0	0
006	Scajaquada	Black Rock Canal	***47***	***44***	***39***
008	Scajaquada	Black Rock Canal	0	0	0
010	Scajaquada	Black Rock Canal	***40***	***36***	***32***
012	Albany	Black Rock Canal	***48***	***44***	***39***
013	South Central	Black Rock Canal	9	9	9
061	Scajaquada	Black Rock Canal	***15***	***14***	14
063	South Central	Black Rock Canal	13	13	13
017	South Central	Buffalo River	***57***	***52***	***46***
022	South Central	Buffalo River	***57***	***52***	***46***
025	South Central	Buffalo River	11	11	11
026	South Central	Buffalo River	***91***	***81***	***68***
027	South Central	Buffalo River	***44***	***41***	***37***

CSO Outfall	District	Receiving Water	Baseline CSO Only Events (6 hr IET)	Baseline CSO Only Events (12 hr IET)	Baseline CSO Only Events (24 hr IET)
028	South Central	Buffalo River	***72***	***68***	***57***
029	South Central	Buffalo River	4	4	4
032	South Central	Buffalo River	0	0	0
033	South Central	Buffalo River	9	9	9
034	South Central	Buffalo River	0	0	0
049	South Central	Buffalo River	3	3	3
050	South Central	Buffalo River	16	***16***	***15***
051	South Central	Buffalo River	8	8	8
052	South Central	Buffalo River	10	10	10
064	South Central	Buffalo River	***67***	***62***	***55***
066	South Central	Buffalo River	11	11	11
035	South Central	Cazenovia Creek - B	7	7	7
037	South Central	Cazenovia Creek – C	14	14	13
039	South Central	Cazenovia Creek – C	1	1	1
044	South Central	Cazenovia Creek – C	8	8	8
046	South Central	Cazenovia Creek – C	***93***	***80***	***68***
047	South Central	Cazenovia Creek – C	***46***	***43***	***38***
048	South Central	Cazenovia Creek – C	3	3	3
055	Hertel	Cornelius Creek	***43***	***39***	***35***
014	South Central	Erie Basin	7	7	7
015	South Central	Erie Basin	15	15	15
016	South Central	Erie Basin	***97***	***83***	***69***
001a	Scajaquada	Niagara River	0	0	0
003	Parish	Niagara River	9	9	9
011	Albany	Niagara River	***40***	***39***	***35***
054	Ontario	Niagara River	1	1	1
053	Scajaquada	Scajaquada Creek	***70***	***64***	***54***
056	Hertel	Scajaquada Creek	8	8	8
057	Parish	Scajaquada Creek	1	1	1
058	Parish	Scajaquada Creek	11	11	11
059	Scajaquada	Scajaquada Creek	13	13	13
060	Scajaquada	Scajaquada Creek	9	9	9

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TECHNICAL MEMORANDUM

To:
Buffalo Sewer Authority

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From:
Malcolm Pirnie/ARCADIS

Date:
March 8, 2011

ARCADIS Project No.:
01777122.0000

Subject:
Reporting of CSO Statistics for Ongoing LTCP Update

This memo summarizes the comparison of the end-of-pipe (EOP) overflow statistics, which in many instances include a mix of both separate stormwater and CSO discharges, from the 2004 LTCP report to current baseline results. This comparison was done using the 9-month annualized simulations approach originally used in the 2004 LTCP. Since current baseline conditions include all Phase 1 sewer separation and improvement projects implemented (or underway) since the original LTCP development, this comparison identified those CSOs that may be affected by separate stormwater discharges in the EOP statistics when accounting for implementation of these Phase 1 projects. The outcome of this analysis showed the necessity to establish a further breakdown of the stormwater and CSO discharges in each EOP discharge. This breakdown of the EOP statistics was done by processing results from the full 12-Month 1986 Typical Year simulation for the current baseline version of BSA's XP-SWMM collection system model (including all Phase 1 projects). As documented in TM "Comparison of Full 12-Month vs. 9-Month Recreational Period Typical Year Results" dated February 18, 2011, the BSA intends to utilize the full 12-Month model simulations for development of the updated LTCP (subject to USEPA and NYSDEC concurrence).

It is recommended that the BSA should continue to report annual CSO statistics as EOP discharges, but that these required EOP metric summaries should be supplemented with additional summaries that present a breakdown of the stormwater and CSO components in addition to the EOP statistics. This will provide a better assessment of the effect of planned and completed separation projects on mitigating CSO discharges from the BSA system.

Background

During the original LTCP effort (2004), annual overflow statistics were presented at both the SPP and the CSO outfall (EOP) levels in Table 3-9 and Table 3-12, respectively. Using this approach for CSO discharge presentation on these tables as well as in the report Section 3 (see pp. 3-14 and 3-15), required the following explanations:

- Volumes presented by SPP represented the full predicted volume at each SPP. However, the sum of the volumes at SPPs did not always equal the total volume for each CSO outfall to which the SPPs are tributary, for two reasons:
  - Upstream SPPs may be configured in series, i.e., overflow from one SPP is re-regulated at a downstream SPP. Therefore, adding SPP volumes would double-account for some flows.
  - Locally separated stormwater may bypass SPPs and be discharged through the formal CSO point. The separate stormwater volume is included in the CSO outfall volume but not the tributary SPPs. Specifically, stormwater and non-BSA flows have been included in CSO outfall volumes for 028, 054, and 066, and not in the SPPs tributary to these CSOs.
- Total CSO outfall volumes represented the estimated volumes discharged at the formal CSO point. These volumes did not always match the sum of incremental volumes from upstream SPPs for a combination of two reasons presented above for the SPPs. The separate stormwater volume is included in the CSO outfall volume totals in this table.

The reason for reporting EOP metrics is that by the USEPA rules the CSO measurement/compliance point (e.g. for monthly DMRs) is the permitted CSO location, which for BSA (at least as of 2004) is the end of the pipe (EOP). The only locations where a different approach was taken were at 006 and 053, where the stream volumes from Scajaquada Creek were removed from the annual CSO statistics at these CSOs. To satisfy the USEPA EOP metric requirements for these two CSOs, the associated stream volumes were included in the footnotes for the annual CSO statistics table. Due to the above mentioned challenges, allocations of stormwater and CSO volumes for each EOP discharge were not done under the original LTCP nor was it necessary until the implementation of Phase 1 projects.

Impact of Phase 1 LTCP Projects with Respect to EOP Metrics

The need for additional breakdown of the CSO and stormwater discharges became apparent while evaluating impacts from Phase 1 projects during the ongoing LTCP update. Table 1 shows a comparison of the EOP volumes between the current baseline model with Phase 1 LTCP projects implemented and the 2004 Existing Conditions model. For most of the CSO outfall locations, the implementation of the Phase 1 projects translated to a reduction in overflows as defined using the EOP metrics. However, because the EOP metrics require the inclusion of stormwater, there were exceptions to this. These exceptions show up for CSOs 035, 054, and 066. For each of these, the Phase 1 LTCP projects that have already been implemented consisted of partial sewer separation projects where the resulting new storm sewers were tied into the existing CSO outfall line. As a result of this, the storm flow that was removed

from the combined system still shows up in the EOP metrics such that the EOP metrics remained the same or even increased – this despite the fact that the CSO regulators on the combined system for the location were less active as a result of the separation work. This may result in an unfavorable review of the effectiveness of the BSA's CSO control efforts without additional explanation of the results.

Table 1
Comparison of 2004 LTCP and Current Baseline Annual EOP Overflow Volumes
(9-Month Simulation Annualized)

CSO Outfall	District	2004 Existing Conditions	Current Baseline with Phase 1 LTCP Projects	Absolute Difference (MG)	% Difference	Comments
		OF Volume (MG)	OF Volume (MG)			
001a	Scajaquada	0	0.0	0.0	0.0	
003	Parish	22.7	4.4	-18.3	-80.5	Phase 1 weir raising and orifice plate removal projects
004	Scajaquada	80.1	44.8	-35.3	-44.0	Phase 1 separation project for CSO 060
005	Scajaquada	1.7	0.0	-1.7	-100.0	Closed as a result of Phase 1 flow redirection project
006[(1)]	Scajaquada	589.6	526.2	-63.5	-10.8	Revised representation of SPP170A
008	Scajaquada	24.4	0.0	-24.4	-100.0	Closed as a result of Phase 1 flow redirection project
010	Scajaquada	29.7	13.2	-16.4	-55.3	Phase 1 separation project
011	Albany	156.5	162.1	5.6	3.6	
012	Albany	179.1	152.8	-26.3	-14.7	Refinement of Albany Street calibration during 2009 model update
013	South Central	45.6	25.2	-20.5	-44.9	Phase I weir raising and flow redirection projects
014	South Central	52.1	18.8	-33.3	-64.0	Phase 1 weir raising projects
015	South Central	30.1	35.3	5.2	17.3	Raising of the SPP206A&B weirs by 1.95 ft forced the HGL in Swan Trunk higher
016	South Central	11.5	10.4	-1.1	-9.7	

CSO Outfall	District	2004 Existing Conditions	Current Baseline with Phase 1 LTCP Projects	Absolute Difference (MG)	% Difference	Comments
		OF Volume (MG)	OF Volume (MG)			
017	South Central	305.0	315.1	10.2	3.3	
022	South Central	12.7	25.2	12.6	99.2	Representation of CSO 064 outfall line in 2004 model impacted splitting of overflow volumes between CSOs 017, 022, and 064; baseline updated this representation
025	South Central	7.7	8.1	0.4	5.7	
026	South Central	350.0	340.4	-9.6	-2.7	
027	South Central	52.4	75.0	22.6	43.1	Raising of weirs for Phase 1 projects forced the HGL in South Interceptor and Swan Trunk higher
028	South Central	151.7	152.4	0.7	0.4	
029	South Central	1.1	1.2	0.2	14.6	<0.25 MG Difference - may be due to difference in SWMM Engine
032	South Central	0.0	0.0	0.0	0.0	
033	South Central	78.2	90.8	12.6	16.1	2004 Results were incorrectly reported.
034	South Central	0.6	0.0	-0.6	-100.0	Closed as a result of Phase 1 project
035	South Central	22.9	23.6	0.7	3.1	
037	South Central	82.5	55.5	-27.0	-32.7	Phase 1 weir raising and sewer separation projects
039	South Central	0.5	0.0	-0.5	-100.0	Phase 1 weir raising and sewer separation projects

CSO Outfall	District	2004 Existing Conditions	Current Baseline with Phase 1 LTCP Projects	Absolute Difference (MG)	% Difference	Comments
		OF Volume (MG)	OF Volume (MG)			
044	South Central	20.7	8.3	-12.4	-60.0	Mumford Street sewer improvement project and Phase 1 weir raising and sewer separation projects
046	South Central	4.9	2.3	-2.7	-54.1	Phase 1 weir raising and sewer separation projects
047	South Central	26.1	11.9	-14.2	-54.4	Phase 1 weir raising and sewer separation projects
048	South Central	3.2	0.0	-3.2	-99.6	Phase 1 weir raising and sewer separation projects
049	South Central	0.0	0.1	0.0	94.2	<0.25 MG Difference - may be due to difference in SWMM Engine
050	South Central	12.9	8.4	-4.5	-34.9	Phase 1 weir raising and sewer separation projects
051	South Central	14.0	5.0	-9.0	-64.2	Phase 1 weir raising and sewer separation projects
052	South Central	34.8	25.5	-9.3	-26.7	Phase 1 weir raising and sewer separation projects
053[(1)]	Scajaquada	301.5	456.0	154.5	51.2	Revised representation of SPP170A
054	Ontario	17.4	26.3	8.9	51.3	Phase 1 separation project
055	Hertel	898.8	949.3	50.5	5.6	
056	Hertel	1.7	1.6	-0.1	-7.4	
057	Parish	0.8	0.1	-0.7	-93.2	Phase 1 weir raising project
058	Parish	12.1	12.8	0.6	5.4	
059	Scajaquada	15.7	2.2	-13.5	-85.9	Phase 1 separation project
060	Scajaquada	22.7	0.8	-21.9	-96.7	Phase 1 separation project
061	Scajaquada	52.4	65.5	13.1	24.9	Phase 1 flow redirection project for CSO 008

CSO Outfall	District	2004 Existing Conditions	Current Baseline with Phase 1 LTCP Projects	Absolute Difference (MG)	% Difference	Comments
		OF Volume (MG)	OF Volume (MG)			
063	South Central	4.1	1.8	-2.3	-55.0	Phase 1 separation project
064	South Central	56.8	25.3	-31.5	-55.5	Representation of CSO 064 outfall line in 2004 model impacted splitting of overflow volumes between CSOs 017, 022, and 064; baseline updated this representation
066	South Central	110.0	123.3	13.3	12.1	Phase 1 separation project
Totals		**3,899.0**	**3,816.8**	**-82.2**	**-2.1**	

(1) Volumes for CSOs 006 and 053 do not include creek volumes.

Establishment of Updated LTCP Baseline Conditions

Based on the above discussion and based on the recommendations included in TM "Comparison of Full 12-Month vs. 9-Month Recreational Period Typical Year Results" (February 18, 2011), it is recommended that the evaluation baseline for the LTCP update should be the EOP metrics for the 12-month continuous Typical Year simulation for the current baseline model with Phase 1 projects implemented, supplemented by additional metrics that show the breakdown between the CSO and stormwater components of the flow. Table 2 below shows annual CSO volumes and frequencies for this scenario for the total EOP discharges and with a breakdown of CSO and stormwater components. As can be seen, the EOP statistics at ten CSOs are significantly affected by the inclusion of stormwater discharges. Most significant among them include the CSOs associated with the Scajaquada Drain (053, 006 – already presented with the stream volumes from Scajaquada Creek removed from the annual CSO statistics in 2004 LTCP), 054 in Ontario and 028, 035, and 066 in South Central. Several CSOs, when accounting for stormwater discharges, show significantly reduced CSO volumes due to Phase 1 separation and weir modification projects.

Table 2
Current Baseline Annual EOP and Stormwater-Adjusted Volumes and Frequencies (12-Month Continuous Simulation)

CSO Outfall	District	EOP Volume - Storm and Creek Flow Included (MG)	CSO Volume (OF Volume - Storm and Creek Flow) (MG)	Storm and Creek Volume (MG)	EOP No. of Events - Storm and Creek Flow Included	CSO Events – (Storm and Creek Flow Excluded)
001a	Scajaquada	0.0	0.0	0.0	0	0
003	Parish	3.1	3.1	0.0	9	9
004	Scajaquada	32.7	32.7	0.0	7	7
005	Scajaquada	0.0	0.0	0.0	0	0
006	Scajaquada	1154.2	384.6	769.6	N/A	N/A
008	Scajaquada	0.0	0.0	0.0	0	0
010	Scajaquada	10.1	10.1	0.0	43	43
011	Albany	143.7	143.7	0.0	36	36
012	Albany	113.8	113.8	0.0	47	47
013	South Central	18.2	18.2	0.0	8	8
014	South Central	13.7	13.7	0.0	5	5
015	South Central	25.9	25.9	0.0	15	15
016	South Central	8.9	8.9	0.0	100	100
017	South Central	246.4	222.4	24.0	83	72
022	South Central	19.1	19.1	0.0	19	19

CSO Outfall	District	EOP Volume - Storm and Creek Flow Included (MG)	CSO Volume (OF Volume - Storm and Creek Flow) (MG)	Storm and Creek Volume (MG)	EOP No. of Events - Storm and Creek Flow Included	CSO Events – (Storm and Creek Flow Excluded)
025	South Central	5.8	5.8	0.0	11	11
026	South Central	261.4	261.4	0.0	83	83
027	South Central	53.0	53.0	0.0	44	44
028	South Central	123.9	75.2	48.7	138	76
029	South Central	1.0	1.0	0.0	4	4
032	South Central	0.0	0.0	0.0	0	0
033	South Central	65.6	65.6	0.0	9	9
034	South Central	0.0	0.0	0.0	0	0
035	South Central	18.9	7.0	11.9	92	7
037	South Central	37.7	37.7	0.0	10	10
039	South Central	0.0	0.0	0.0	0	0
044	South Central	5.9	5.9	0.0	5	5
046	South Central	1.9	1.9	0.0	89	89
047	South Central	8.8	8.8	0.0	32	32
048	South Central	0.0	0.0	0.0	1	1
049	South Central	0.1	0.1	0.0	1	1
050	South Central	6.0	6.0	0.0	9	9

CSO Outfall	District	EOP Volume - Storm and Creek Flow Included (MG)	CSO Volume (OF Volume - Storm and Creek Flow) (MG)	Storm and Creek Volume (MG)	EOP No. of Events - Storm and Creek Flow Included	CSO Events – (Storm and Creek Flow Excluded)
051	South Central	3.6	3.6	0.0	4	4
052	South Central	16.4	15.7	0.7	10	8
053	Scajaquada	1579.0	419.3	1159.7	N/A	N/A
054	Ontario	23.0	4.7	18.3	67	1
055	Hertel	802.8	802.8	0.0	44	44
056	Hertel	1.1	1.1	0.0	8	8
057	Parish	0.0	0.0	0.0	1	1
058	Parish	11.6	0.6	11.0	76	11
059	Scajaquada	1.6	1.6	0.0	4	4
060	Scajaquada	0.7	0.0	0.7	37	0
061	Scajaquada	53.4	53.4	0.0	14	14
063	South Central	1.3	1.3	0.0	10	10
064	South Central	19.3	19.3	0.0	66	66
066	South Central	106.7	19.2	87.5	82	12
Totals		**5,000**	**2,868**	**2,132**	**138**	**100**

Appendix 11-2 Predicted Annual CSO Only (Excluding Stormwater and Stream Inflows) Volumes, Frequencies and Durations by SPP

SPP	CSO Outfall	Receiving Water	CSO-only Volume (Million Gallons)		CSO-only Frequency		CSO-only Durations (hours)	
			Existing (2004)	Revised Baseline	Existing (2004)	Revised Baseline	Existing (2004)	Revised Baseline
3	003	Parish	0.0	0.0	0	0	0	0
4	003	Parish	0.2	0.0	5	0	6	0
5	003	Parish	0.2	0.0	5	1	7	1
7	003	Parish	0.0	0.0	0	0	0	0
8	003	Parish	0.0	0.0	1	0	1	0
9	003	Parish	0.0	0.0	0	0	0	0
10	003	Parish	3.5	0.0	34	0	67	0
11	003	Parish	0.4	0.1	14	6	19	6
185	003	Parish	0.0	0.0	0	0	0	0
186	003	Parish	0.0	0.0	0	0	0	0
13	004	Scajaquada	16.2	11.2	24	18	37	34
14A	005	Scajaquada	0.1	0.0	4	4	5	5
17	006	Scajaquada	855.1	855.7	N/A	N/A	N/A	N/A
179	006	Scajaquada	5.7	5.7	6	6	13	13
180	006	Scajaquada	21.9	21.9	44	44	126	126
331	006	Scajaquada	9.9	9.9	38	38	90	89
332	006	Scajaquada	29.3	29.3	19	20	64	65
19	008	Scajaquada	8.2	6.1	42	39	106	90
21	010	Scajaquada	11.8	11.9	44	44	103	103
24	011	Albany	125.7	134.3	41	41	240	243
23	012	Albany	9.8	10.1	18	18	58	58
296	012	Albany	42.2	42.4	44	44	92	92
304	013	South Central	13.6	6.8	14	7	58	25
206A&B	014	South Central	25.8	4.2	16	4	43	8
35	015	South Central	5.0	5.4	10	10	15	15
36	015	South Central	0.7	0.7	13	13	20	20
42	016	South Central	0.0	0.0	4	0	5	0
48	017	South Central	0.3	0.1	0	0	0	0
50	017	South Central	0.0	0.3	1	2	1	4
51	017	South Central	0.1	0.1	4	3	9	6
53	017	South Central	0.7	0.8	5	4	12	11
53	017	South Central	0.6	0.8	3	4	5	11
55	017	South Central	1.1	0.3	8	3	18	6
65	017	South Central	1.1	0.1	4	2	8	2
67	017	South Central	73.2	52.8	34	18	153	76
128	017	South Central	0.4	0.3	6	5	8	7
130	017	South Central	2.8	2.8	49	49	124	124
281	017	South Central	30.6	13.1	55	14	166	37
282	017	South Central	2.0	0.0	4	0	8	0
326	017	South Central	7.1	2.6	6	4	11	7
139	021	South Central	1.1	Closed	14	Closed	22	Closed
138	022	South Central	0.4	0.6	19	12	32	16
144	022	South Central	0.5	0.5	25	20	48	33
145	022	South Central	0.2	1.2	10	15	15	25
209	025	South Central	1.4	1.4	11	11	17	17
68	026	South Central	0.1	0.1	4	5	6	7
69	026	South Central	0.5	0.6	15	20	24	34
74	026	South Central	0.0	0.0	3	3	8	7
75	026	South Central	3.2	3.3	61	63	232	247
77	026	South Central	0.1	0.2	4	4	8	9
78	026	South Central	0.0	0.1	4	4	6	8
79	026	South Central	0.2	0.2	6	5	8	10
80	026	South Central	0.0	0.1	4	5	6	10
81	026	South Central	0.0	0.0	2	2	3	4
82	026	South Central	0.0	0.0	0	2	0	3
84	026	South Central	0.2	0.2	5	7	10	13
85	026	South Central	0.1	0.1	3	2	7	5
87	026	South Central	0.1	0.3	4	5	8	10
88	026	South Central	0.4	0.6	8	9	15	18
89	026	South Central	2.5	0.5	7	5	27	14
90	026	South Central	0.4	0.4	12	12	44	38
91	026	South Central	0.4	0.3	3	4	9	8
92	026	South Central	0.1	0.3	2	5	6	10
94	026	South Central	0.3	0.0	2	3	5	6
148	026	South Central	0.1	0.1	4	4	9	9
149	026	South Central	4.9	0.6	18	2	75	8
149	026	South Central	0.0	0.6	3	2	6	8
150	026	South Central	0.1	0.0	3	2	5	2
151	026	South Central	0.0	0.0	1	0	1	0
152	026	South Central	0.0	0.0	0	0	0	0
197A	026	South Central	0.0	0.0	0	0	0	0
197B	026	South Central	0.0	0.0	0	5	0	7

197C	026	South Central	5.9	2.1	21	6	87	26
198B	026	South Central	6.2	4.1	11	8	46	28
199A	026	South Central	0.4	0.7	5	6	10	12
199B	026	South Central	6.4	3.3	15	8	33	19
199C	026	South Central	0.4	1.9	6	8	13	23
217	026	South Central	30.2	30.2	37	38	156	170
218	026	South Central	1.9	1.9	10	10	28	28
248	026	South Central	0.2	0.1	3	1	5	2
249	026	South Central	0.0	0.0	2	0	2	0
277	026	South Central	0.0	0.0	2	0	2	0
314	026	South Central	2.2	2.2	46	48	103	109
317	026	South Central	36.2	23.6	27	13	113	55
318	026	South Central	1.8	2.6	15	16	23	47
319	026	South Central	0.0	0.0	1	2	1	2
97	027	South Central	18.7	30.9	6	7	25	31
97A	027	South Central	0.7	0.7	40	40	88	88
208	028	South Central	0.1	0.0	10	4	16	6
123A	028	South Central	8.6	7.1	17	13	47	32
123B	028	South Central	17.9	17.9	71	71	348	348
124	028	South Central	9.0	15.8	15	16	54	58
123C	028	South Central	4.7	4.7	55	55	196	195
125A	028	South Central	0.0	0.0	1	1	1	1
125	029	South Central	4.0	0.0	11	0	32	0
126	029	South Central	0.0	0.0	0	0	0	0
120	032	South Central	0.0	0.0	0	0	0	0
104	033	South Central	21.4	23.5	8	9	20	21
344	034	South Central	0.1	Closed	5	Closed	8	Closed
107	035	South Central	4.1	0.9	30	5	59	9
107A	035	South Central	0.8	0.0	13	0	21	0
122	037	South Central	21.2	23.3	14	13	42	40
311	039	South Central	0.0	0.0	2	0	2	0
121	044	South Central	6.5	2.3	15	7	37	12
308	046	South Central	0.3	0.0	9	1	37	1
309	046	South Central	0.0	0.0	2	0	3	0
310	046	South Central	0.0	0.0	4	0	5	0
113	047	South Central	0.0	0.0	4	0	4	0
114	047	South Central	10.4	8.7	47	44	112	97
118	048	South Central	1.5	0.0	12	0	42	0
119	049	South Central	0.0	0.0	0	0	0	0
105	050	South Central	4.1	3.2	22	14	47	22
307	051	South Central	3.7	1.2	16	4	56	14
106	052	South Central	13.6	10.9	12	10	117	76
106A	052	South Central	0.0	0.0	4	7	25	18
156	053	Scajaquada	0.0	0.0	1	0	1	0
157	053	Scajaquada	0.5	0.3	6	5	9	7
163	053	Scajaquada	5.0	5.0	28	28	48	48
164	053	Scajaquada	0.5	0.4	5	5	6	6
165	053	Scajaquada	3.0	3.0	28	28	47	47
165A	053	Scajaquada	1.9	1.9	16	16	28	28
165B	053	Scajaquada	20.6	20.6	56	56	233	233
166	053	Scajaquada	0.1	0.1	4	4	5	5
170A	053	Scajaquada	1373.4	1373.5	N/A	N/A	N/A	N/A
170B	053	Scajaquada	59.9	59.2	65	65	322	320
174	053	Scajaquada	3.6	3.6	7	7	17	17
175	053	Scajaquada	2.5	2.5	13	13	20	20
176	053	Scajaquada	0.2	0.2	6	6	7	7
177	053	Scajaquada	0.4	0.4	6	6	8	8
178	053	Scajaquada	2.3	2.3	16	16	48	48
200A	053	Scajaquada	0.9	0.8	5	5	7	7
200B	053	Scajaquada	0.0	0.0	0	0	0	0
201	053	Scajaquada	0.1	0.1	3	3	4	3
202	053	Scajaquada	1.0	0.9	4	4	6	6
203	053	Scajaquada	3.5	3.5	8	8	12	12
204	053	Scajaquada	1.7	1.7	10	10	24	24
210	053	Scajaquada	0.0	0.0	4	4	5	5
229A	053	Scajaquada	2.7	2.7	4	4	10	10
335A	053	Scajaquada	0.1	0.1	5	4	7	5
335B	053	Scajaquada	1.0	1.0	11	11	16	16
336A	053	Scajaquada	9.2	9.2	38	38	78	78
336B	053	Scajaquada	96.4	94.2	46	45	224	220
337	053	Scajaquada	35.0	35.0	34	34	83	83
338	053	Scajaquada	23.9	23.9	15	15	38	38
339	053	Scajaquada	57.1	9.1	57	5	223	11
340	053	Scajaquada	64.5	110.0	61	61	251	344
341A	053	Scajaquada	19.6	18.6	60	60	190	185
341B	053	Scajaquada	0.0	Closed	0	Closed	0	Closed
342A	053	Scajaquada	0.1	0.1	6	6	7	7
342B	053	Scajaquada	0.4	0.4	8	8	11	11
345	053	Scajaquada	0.3	0.3	5	5	7	7
East Ferry & Wohlers	053	Scajaquada	0.0	0.0	0	0	0	0
187	054	Ontario	0.1	0.0	4	0	4	0
188	054	Ontario	0.0	0.0	1	2	1	2
189	054	Ontario	0.0	0.0	0	0	0	0
190	054	Ontario	0.0	0.0	0	0	0	0

191	054	Ontario	0.0	0.0	0	0	0	0
192	054	Ontario	0.0	Closed	0	Closed	0	Closed
1	055	Hertel	613.6	601.1	40	41	184	174
244	056	Hertel	0.0	0.0	1	1	1	1
245	056	Hertel	0.0	0.0	5	5	5	5
195	057	Parish	0.3	0.0	11	0	15	0
213	058	Parish	0.0	0.2	2	7	2	10
181	059	Scajaquada	1.5	0.5	6	4	11	8
182	059	Scajaquada	1.5	0.6	13	6	20	11
183	059	Scajaquada	2.1	1.1	18	11	35	17
230	060	Scajaquada	0.3	0.1	6	3	19	9
231	060	Scajaquada	0.1	0.0	5	1	6	1
232	060	Scajaquada	0.1	0.0	5	1	5	1
233	060	Scajaquada	0.0	0.0	3	1	3	1
234	060	Scajaquada	0.0	0.0	1	0	1	0
235	060	Scajaquada	0.3	0.0	6	4	8	4
236	060	Scajaquada	0.0	0.0	4	1	4	1
237	060	Scajaquada	0.2	0.0	6	4	8	4
238	060	Scajaquada	0.2	0.0	5	2	5	2
239	060	Scajaquada	0.2	0.0	5	3	6	3
240	060	Scajaquada	1.4	0.4	12	6	16	8
330	061	Scajaquada	33.8	31.2	10	10	32	28
283	063	South Central	1.5	0.6	50	13	110	19
129	064	South Central	1.2	1.3	44	40	83	76
131	064	South Central	5.2	1.6	20	4	44	9
132	064	South Central	0.8	0.1	6	1	8	1
133	064	South Central	0.9	1.0	12	12	17	18
135A	064	South Central	4.0	4.5	54	56	155	181
211	066	South Central	1.7	1.3	15	12	24	18
212	066	South Central	0.1	0.1	1	1	1	1
291	066	South Central	0.4	0.1	16	5	32	10
292	066	South Central	0.0	0.0	4	3	6	3
293	066	South Central	0.1	0.0	4	4	6	6
294	066	South Central	0.1	0.0	4	1	6	1
295	066	South Central	0.0	0.0	4	1	6	1
329	066	South Central	0.0	0.0	0	0	0	0
322	066	South Central	0.1	0.1	1	1	4	4
254	Quarry	Scajaquada	21.5	21.5	55	55	541	541
255	Quarry	Scajaquada	1.8	1.8	6	6	14	14
259	Quarry	Scajaquada	0.0	0.0	3	3	3	3
260	Quarry	Scajaquada	0.4	0.4	31	31	72	72
261	Quarry	Scajaquada	0.1	0.1	6	6	8	8
262	Quarry	Scajaquada	0.0	0.0	5	5	6	6
263	Quarry	Scajaquada	0.0	0.0	5	5	6	6
264	Quarry	Scajaquada	0.0	0.0	1	1	1	1
265	Quarry	Scajaquada	0.0	0.0	5	5	5	5
266, 267	Quarry	Scajaquada	0.0	0.0	8	8	11	11
268	Quarry	Scajaquada	0.0	0.0	5	5	6	6
269, 270	Quarry	Scajaquada	0.1	0.1	8	8	11	11
271, 272	Quarry	Scajaquada	0.3	0.3	21	21	38	38
274	Quarry	Scajaquada	4.4	4.4	37	37	99	99
275	Quarry	Scajaquada	0.1	0.1	8	8	13	13
276	Quarry	Scajaquada	0.1	0.1	5	5	7	7
Old 259	Quarry	Scajaquada	0.0	0.0	0	0	0	0

APPENDIX 11-3

ALTERNATIVE UA1 - Updated 2004 Preferred System-wide Alternative with Original Foundation Costs

FINANCIAL ASSUMPTIONS

Current ENR CCI:	9,011	i (interest rate):	5.00%
2004 BSA LTCP ENR CCI:	6,695	j (discount rate):	2.50%
Project Contingency Percentage:	25%	t (time horizon for plan):	20
Engineering Percentage:	15%	Present Worth Factor:	15.30
O/M Contingency Percentage:	10%	Assumed Escalation (for O&M) per year:	3.50%

Storage (data provided by collection system modeling)

BSA 2004 COST CURVE (unit cost per gal stored) $Cost = 220 * V^{-0.27}$

ALCOSAN COST CURVE (Dec 2008) $Cost = 3.4 \times V^{0.826}$

EPA CSO Cost Manual (using costs for sed basins) - 1995 $Cost_{O\&M} = 15.174 \times Capacity^{0.8996}$

	Receiving Basin	Volume (MG)					Construction Cost ($ millions) - Updated BSA Curve					Construction Cost ($ millions) - ALCOSAN Curve					Present Worth O/M Cost ($ millions)					Total Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-003	Niagara River	0.05	0.00	0.00	0.00	0.00	*$0.74*	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.28*	*$0.01*	*$0.01*	*$0.00*	*$0.00*	$0.07	$0.01	$0.01	$0.00	$0.00	$0.35	$0.02	$0.02	$0.00	$0.00
CSO-013/063	Black Rock Canal	2.30	1.61	0.44	0.00	0.00	*$13.04*	*$10.05*	*$3.91*	*$0.00*	*$0.00*	*$7.13*	*$5.31*	*$1.83*	*$0.00*	*$0.00*	$0.64	$0.53	$0.26	$0.00	$0.00	$7.77	$5.83	$2.08	$0.00	$0.00
CSO-055	Cornelius Creek	69.02	53.48	35.53	26.93	14.96	*$156.28*	*$129.73*	*$96.25*	*$78.62*	*$51.19*	######	*$95.88*	*$68.40*	*$54.40*	*$33.48*	$4.30	$3.73	$2.97	$2.54	$1.83	$122.67	$99.61	$71.36	$56.94	$35.31
CSO-056/060	Scajaquada Creek	0.42	0.30	0.14	0.00	0.00	*$3.77*	*$2.95*	*$1.69*	*$0.00*	*$0.00*	*$1.75*	*$1.33*	*$0.71*	*$0.00*	*$0.00*	$0.25	$0.21	$0.13	$0.00	$0.00	$2.00	$1.53	$0.84	$0.00	$0.00
Total		**71.8**	**55.4**	**36.1**	**26.9**	**15.0**	***$173.83***	***$142.77***	***$101.89***	***$78.62***	***$51.19***	######	***$102.52***	***$70.94***	***$54.40***	***$33.48***	***$5.26***	***$4.47***	***$3.36***	***$2.54***	***$1.83***	***$132.78***	***$106.99***	***$74.30***	***$56.94***	***$35.31***

Storage Consolidation Piping (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length (ft)	Dimension s	Unit Cost ($/ft)	Construction Cost ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CSO 055 (in)	Cornelius Creek	1,262	H=11', W=24'	$5,801	$7.32	$7.32	$7.32	$7.32	$7.32
CSO 055 (out)	Cornelius Creek	384	H=11', W=24'	$5,801	$2.23	$2.23	$2.23	$2.23	$2.23
CSO 003 (in)	Niagara River	159	D=7'	$1,072	$0.17	$0.00	$0.00	$0.00	$0.00
CSO 003 (out)	Niagara River	143	D=7'	$1,072	$0.15	$0.00	$0.00	$0.00	$0.00
CSO 060 (in)	Scajaquada Creek	234	D=4.5'	$559	$0.13	$0.13	$0.13	$0.00	$0.00
CSO 056 (in)	Scajaquada Creek	355	D=4'	$478	$0.17	$0.17	$0.17	$0.00	$0.00
CSO 056/060 (OUT)	Scajaquada Creek	64	D=6'	$842	$0.05	$0.05	$0.05	$0.00	$0.00
CSO 063 (in)	Black Rock Canal	2,224	D=2.5'	$289	$0.64	$0.64	$0.64	$0.00	$0.00
CSO 013 (in)	Black Rock Canal	3,469	W=10', H=8.5'	$2,141	$7.43	$7.43	$7.43	$0.00	$0.00
CSO 013/063 (out)	Black Rock Canal	767	D=11'	$2,327	$1.78	$1.78	$1.78	$0.00	$0.00
Total		**9,060**			**$20.08**	**$19.75**	**$19.75**	**$9.55**	**$9.55**

Storage Dewatering Force Main (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter) (O&M costs assumed to be zero)

	Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Cost ($ millions)				
			0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO 055	Cornelius Creek	707	78	66	54	48	24	$1,030	$680	$449	$365	$161	*$0.73*	*$0.48*	*$0.32*	*$0.26*	*$0.11*
CSO 013/063	Black Rock Canal	368	12	8	4	0	0	$68	$46	$32	$0	$0	*$0.03*	*$0.02*	*$0.01*	*$0.00*	*$0.00*
CSO 003	Niagara River	291	4	0	0	0	0	$32	$0	$0	$0	$0	*$0.01*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 056/060	Scajaquada Creek	2,496	8	4	4	0	0	$46	$32	$32	$0	$0	*$0.12*	*$0.08*	*$0.08*	*$0.00*	*$0.00*
Total		**3,862**											***$0.88***	***$0.58***	***$0.41***	***$0.26***	***$0.11***

High Rate Treatment (data provided by collection system modeling)

ALCOSAN COST CURVE (DEC 2008) $Price = 640,000 \times Capacity^{0.778}$

ALCOSAN COST CURVE (DEC 2008) $Cost_{O\&M} = 98.2510^{0.8403}$

BSA O&M (2004) $O/M Cost = 4347.2 \times Flow + 18228$

ALCOSAN COST CURVE (DEC 2008) - Intermed. i ALCOSAN COST CURVE (DEC 2008) - Source 1 $Cost = 385002 \times Flow(inMGD)^{0.6841}$ $Cost = (770.4 + 925.8) \times Flow + (536.9$ (Additional O/M Cost for HRT and for PS)

(Using AlCOSAN cost curves)

	Receiving Basin	Peak Flow (mgd)					Construction Cost ($ millions) - Alcosan Curve					resent Worth O/M Cost ($ millions) - Alcosan Curv					Present Worth O/M Cost ($ millions) - BSA Curve					PS Construction Cost ($ millions) - ALCOSAN CW					HRT PS O/M Cost ($ millions) - ALCOSAN Curv					Total Present Worth O/M Cost ($ millions)					Total Construction Cost ($ millions)					Total Present Worth Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-014	Erie Basin	25.9	18.1	0.0	0.0	0.0	*$6.75*	*$5.24*	*$0.00*	*$0.00*	*$0.00*	*$11.04*	*$8.94*	*$0.00*	*$0.00*	*$0.00*	*$2.54*	*$1.89*	*$0.00*	*$0.00*	*$0.00*	*$7.43*	*$5.40*	*$0.00*	*$0.00*	*$0.00*	*$1.07*	*$0.84*	*$0.00*	*$0.00*	*$0.00*	*$12.11*	*$9.78*	*$0.00*	*$0.00*	*$0.00*	*$14.18*	*$10.64*	*$0.00*	*$0.00*	*$0.00*	$26.29	$20.43	$0.00	$0.00	$0.00
CSO-015	Erie Basin	54.9	25.9	18.1	4.4	0.1	*$11.50*	*$6.75*	*$5.24*	*$1.91*	*$0.12*	*$17.25*	*$11.04*	*$8.94*	*$3.85*	*$0.37*	*$5.00*	*$2.54*	*$1.89*	*$0.72*	*$0.36*	*$14.58*	*$7.43*	*$5.40*	*$1.51*	*$0.04*	*$1.90*	*$1.07*	*$0.84*	*$0.45*	*$0.33*	*$19.16*	*$12.11*	*$9.78*	*$4.30*	*$0.70*	*$26.08*	*$14.18*	*$10.64*	*$3.42*	*$0.16*	$45.24	$26.29	$20.43	$7.72	$0.86
CSO-017	Buffalo River	113.1	58.2	25.9	6.5	3.2	*$19.18*	*$11.98*	*$6.75*	*$2.53*	*$1.55*	*$26.45*	*$17.84*	*$11.04*	*$4.86*	*$3.22*	*$9.92*	*$5.28*	*$2.54*	*$0.90*	*$0.63*	*$27.81*	*$15.35*	*$7.43*	*$2.15*	*$1.16*	*$3.58*	*$2.00*	*$1.07*	*$0.51*	*$0.42*	*$30.03*	*$19.84*	*$12.11*	*$5.37*	*$3.64*	*$46.99*	*$27.32*	*$14.18*	*$4.68*	*$2.71*	$77.02	$47.16	$26.29	$10.05	$6.35
CSO-022	Buffalo River	1.3	1.0	0.2	0.2	0.2	*$0.81*	*$0.66*	*$0.19*	*$0.19*	*$0.19*	*$1.87*	*$1.58*	*$0.55*	*$0.55*	*$0.55*	*$0.46*	*$0.44*	*$0.37*	*$0.37*	*$0.37*	*$0.51*	*$0.40*	*$0.08*	*$0.08*	*$0.08*	*$0.36*	*$0.35*	*$0.33*	*$0.33*	*$0.33*	*$2.24*	*$1.93*	*$0.88*	*$0.88*	*$0.88*	*$1.32*	*$1.06*	*$0.27*	*$0.27*	*$0.27*	$3.55	$2.99	$1.14	$1.14	$1.14
CSO-025	Buffalo River	3.1	2.8	1.6	0.0	0.0	*$1.50*	*$1.39*	*$0.95*	*$0.00*	*$0.00*	*$3.15*	*$2.95*	*$2.14*	*$0.00*	*$0.00*	*$0.62*	*$0.59*	*$0.49*	*$0.00*	*$0.00*	*$1.12*	*$1.01*	*$0.62*	*$0.00*	*$0.00*	*$0.41*	*$0.40*	*$0.37*	*$0.00*	*$0.00*	*$3.56*	*$3.35*	*$2.51*	*$0.00*	*$0.00*	*$2.62*	*$2.40*	*$1.57*	*$0.00*	*$0.00*	$6.18	$5.75	$4.08	$0.00	$0.00
CSO-026	Buffalo River	103.4	100.2	58.2	37.5	15.7	*$18.00*	*$17.60*	*$11.98*	*$8.77*	*$4.74*	*$25.09*	*$24.62*	*$17.84*	*$13.76*	*$8.22*	*$9.10*	*$8.83*	*$5.28*	*$3.53*	*$1.68*	*$25.67*	*$24.95*	*$15.35*	*$10.36*	*$4.76*	*$3.30*	*$3.21*	*$2.00*	*$1.40*	*$0.78*	*$28.38*	*$27.82*	*$19.84*	*$15.16*	*$8.99*	*$43.67*	*$42.55*	*$27.32*	*$19.14*	*$9.50*	$72.05	$70.37	$47.16	$34.29	$18.49
CSO-027	Buffalo River	32.3	19.4	3.9	1.3	0.1	*$7.90*	*$5.50*	*$1.76*	*$0.81*	*$0.13*	*$12.60*	*$9.31*	*$3.59*	*$1.87*	*$0.40*	*$3.09*	*$2.00*	*$0.68*	*$0.46*	*$0.36*	*$9.07*	*$5.75*	*$1.36*	*$0.51*	*$0.05*	*$1.25*	*$0.88*	*$0.44*	*$0.36*	*$0.33*	*$13.85*	*$10.19*	*$4.03*	*$2.24*	*$0.73*	*$16.97*	*$11.25*	*$3.12*	*$1.32*	*$0.18*	$30.83	$21.44	$7.15	$3.55	$0.91
CSO-028	Buffalo River	74.3	64.6	42.0	22.6	12.9	*$14.25*	*$12.90*	*$9.51*	*$6.14*	*$4.13*	*$20.63*	*$18.99*	*$14.72*	*$10.20*	*$7.33*	*$6.64*	*$5.82*	*$3.91*	*$2.27*	*$1.45*	*$19.11*	*$16.86*	*$11.47*	*$6.60*	*$4.00*	*$2.46*	*$2.18*	*$1.53*	*$0.97*	*$0.70*	*$23.09*	*$21.18*	*$16.25*	*$11.18*	*$8.02*	*$33.35*	*$29.77*	*$20.98*	*$12.73*	*$8.13*	$56.45	$50.94	$37.23	$23.91	$16.15
CSO-033	Buffalo River	84.0	67.9	22.6	6.5	1.6	*$15.54*	*$13.36*	*$6.14*	*$2.53*	*$0.95*	*$22.18*	*$19.55*	*$10.20*	*$4.86*	*$2.14*	*$7.46*	*$6.10*	*$2.27*	*$0.90*	*$0.49*	*$21.32*	*$17.61*	*$6.60*	*$2.15*	*$0.62*	*$2.74*	*$2.28*	*$0.97*	*$0.51*	*$0.37*	*$24.92*	*$21.82*	*$11.18*	*$5.97*	*$2.51*	*$36.86*	*$30.97*	*$12.73*	*$4.68*	*$1.57*	$61.78	$52.80	$23.91	$10.05	$4.08
CSO-050	Buffalo River	0.8	0.0	0.0	0.0	0.0	*$0.56*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$1.39*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.42*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.32*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.35*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$1.73*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.89*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	$2.62	$0.00	$0.00	$0.00	$0.00
CSO-051	Buffalo River	3.2	0.9	0.0	0.0	0.0	*$1.55*	*$0.63*	*$0.00*	*$0.00*	*$0.00*	*$3.22*	*$1.52*	*$0.00*	*$0.00*	*$0.00*	*$0.63*	*$0.43*	*$0.00*	*$0.00*	*$0.00*	*$1.16*	*$0.37*	*$0.00*	*$0.00*	*$0.00*	*$0.42*	*$0.35*	*$0.00*	*$0.00*	*$0.00*	*$3.64*	*$1.87*	*$0.00*	*$0.00*	*$0.00*	*$2.71*	*$1.00*	*$0.00*	*$0.00*	*$0.00*	$6.35	$2.87	$0.00	$0.00	$0.00
CSO-052	Buffalo River	7.1	6.1	1.9	0.0	0.0	*$2.70*	*$2.44*	*$1.08*	*$0.00*	*$0.00*	*$5.14*	*$4.71*	*$2.38*	*$0.00*	*$0.00*	*$0.96*	*$0.87*	*$0.52*	*$0.00*	*$0.00*	*$2.34*	*$2.06*	*$0.73*	*$0.00*	*$0.00*	*$0.53*	*$0.50*	*$0.38*	*$0.00*	*$0.00*	*$5.67*	*$5.21*	*$2.76*	*$0.00*	*$0.00*	*$5.05*	*$4.49*	*$1.81*	*$0.00*	*$0.00*	$10.72	$9.71	$4.57	$0.00	$0.00
CSO-064	Buffalo River	38.8	12.9	2.6	1.3	0.1	*$8.99*	*$4.13*	*$1.32*	*$0.81*	*$0.16*	*$14.04*	*$7.33*	*$2.83*	*$1.87*	*$0.48*	*$3.64*	*$1.45*	*$0.57*	*$0.46*	*$0.37*	*$10.68*	*$4.00*	*$0.95*	*$0.51*	*$0.07*	*$1.44*	*$0.70*	*$0.40*	*$0.36*	*$0.33*	*$15.48*	*$8.02*	*$3.22*	*$2.24*	*$0.81*	*$19.67*	*$8.13*	*$2.27*	*$1.32*	*$0.22*	$35.14	$16.15	$5.49	$3.55	$1.03
CSO-066	Buffalo River	43.3	29.1	23.3	15.5	8.4	*$9.72*	*$7.33*	*$6.26*	*$4.70*	*$3.04*	*$14.98*	*$11.84*	*$10.37*	*$8.16*	*$5.67*	*$4.02*	*$2.82*	*$2.32*	*$1.67*	*$1.07*	*$11.79*	*$8.26*	*$6.76*	*$4.71*	*$2.72*	*$1.57*	*$1.16*	*$0.99*	*$0.77*	*$0.57*	*$16.55*	*$13.00*	*$11.37*	*$8.93*	*$6.24*	*$21.51*	*$15.59*	*$13.02*	*$9.41*	*$5.76*	$38.06	$28.59	$24.39	$18.34	$12.00
Total		**586**	**407**	**200**	**96**	**42**	***$118.94***	***$89.90***	***$51.16***	***$28.38***	***$14.99***	######	***$140.22***	***$84.60***	***$49.98***	***$28.38***	***$54.50***	***$39.04***	***$20.84***	***$11.28***	***$6.77***	***$152.91***	***$109.45***	***$56.76***	***$28.58***	***$13.50***	***$21.37***	***$15.91***	***$9.32***	***$5.66***	***$4.13***	***$200.41***	***$156.13***	***$93.92***	***$55.64***	***$32.51***	***$271.85***	***$199.34***	***$107.92***	***$56.96***	***$28.49***	***$472.26***	***$355.47***	***$201.84***	***$112.60***	***$61.00***

High Rate CCT (data provided by collection system modeling)

ALCOSAN COST CURVE (DEC 2008)

$$Cost = 3.4 \times V^{0.826}$$

	Receiving Basin	CCT Volume (MG)					Construction Cost ($ millions) - ALCOSAN Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-014	Erie Basin	0.09	0.06	0.00	0.00	0.00	*$0.49*	*$0.36*	*$0.00*	*$0.00*	*$0.00*
CSO-015	Erie Basin	0.19	0.09	0.06	0.02	0.00	*$0.91*	*$0.49*	*$0.36*	*$0.11*	*$0.00*
CSO-017	Buffalo River	0.39	0.20	0.09	0.02	0.01	*$1.66*	*$0.96*	*$0.49*	*$0.16*	*$0.09*
CSO-022	Buffalo River	0.00	0.00	0.00	0.00	0.00	*$0.04*	*$0.03*	*$0.01*	*$0.01*	*$0.01*
CSO-025	Buffalo River	0.01	0.01	0.01	0.00	0.00	*$0.08*	*$0.08*	*$0.05*	*$0.00*	*$0.00*
CSO-026	Buffalo River	0.36	0.35	0.20	0.13	0.05	*$1.54*	*$1.50*	*$0.96*	*$0.66*	*$0.32*
CSO-027	Buffalo River	0.11	0.07	0.01	0.00	0.00	*$0.59*	*$0.39*	*$0.10*	*$0.04*	*$0.00*
CSO-028	Buffalo River	0.26	0.22	0.15	0.08	0.04	*$1.17*	*$1.04*	*$0.73*	*$0.44*	*$0.28*
CSO-033	Buffalo River	0.29	0.24	0.08	0.02	0.01	*$1.30*	*$1.09*	*$0.44*	*$0.16*	*$0.05*
CSO-050	Buffalo River	0.00	0.00	0.00	0.00	0.00	*$0.03*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-051	Buffalo River	0.01	0.00	0.00	0.00	0.00	*$0.09*	*$0.03*	*$0.00*	*$0.00*	*$0.00*
CSO-052	Buffalo River	0.02	0.02	0.01	0.00	0.00	*$0.17*	*$0.15*	*$0.06*	*$0.00*	*$0.00*
CSO-064	Buffalo River	0.13	0.04	0.01	0.00	0.00	*$0.68*	*$0.28*	*$0.07*	*$0.04*	*$0.01*
CSO-066	Buffalo River	0.15	0.10	0.08	0.05	0.03	*$0.75*	*$0.54*	*$0.45*	*$0.32*	*$0.19*
Total		**2.03**	**1.41**	**0.70**	**0.33**	**0.15**	**$9.49**	**$6.93**	**$3.72**	**$1.94**	**$0.95**

High Rate Treatment Disinfection (data provided by collection system modeling)

EPA Cost Curve (1993)

$$Cost = 0.121Q^{0.464}$$

EPA Cost Curve (1993)

$$Cost = 0.1144Q^{0.479}$$

	Receiving Basin	Volume of Tank					Construction Cost ($ millions) - EPA Curve					Present Worth O&M Cost ($ millions) - EPA Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-014	Erie Basin	25.9	18.1	0.0	0.0	0.0	*$1.03*	*$0.87*	*$0.00*	*$0.00*	*$0.00*	*$0.02*	*$0.01*	*$0.00*	*$0.00*	*$0.00*
CSO-015	Erie Basin	54.9	25.9	18.1	4.4	0.1	*$1.46*	*$1.03*	*$0.87*	*$0.45*	*$0.07*	*$0.02*	*$0.02*	*$0.01*	*$0.01*	*$0.00*
CSO-017	Buffalo River	113.1	58.2	25.9	6.5	3.2	*$2.04*	*$1.50*	*$1.03*	*$0.54*	*$0.39*	*$0.03*	*$0.02*	*$0.02*	*$0.01*	*$0.01*
CSO-022	Buffalo River	1.3	1.0	0.2	0.2	0.2	*$0.26*	*$0.22*	*$0.10*	*$0.10*	*$0.10*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-025	Buffalo River	3.1	2.8	1.6	0.0	0.0	*$0.38*	*$0.36*	*$0.28*	*$0.00*	*$0.00*	*$0.01*	*$0.01*	*$0.00*	*$0.00*	*$0.00*
CSO-026	Buffalo River	103.4	100.2	58.2	37.5	15.7	*$1.95*	*$1.93*	*$1.50*	*$1.22*	*$0.82*	*$0.03*	*$0.03*	*$0.02*	*$0.02*	*$0.01*
CSO-027	Buffalo River	32.3	19.4	3.9	1.3	0.1	*$1.14*	*$0.90*	*$0.43*	*$0.26*	*$0.08*	*$0.02*	*$0.01*	*$0.01*	*$0.00*	*$0.00*
CSO-028	Buffalo River	74.3	64.6	42.0	22.6	12.9	*$1.68*	*$1.57*	*$1.29*	*$0.97*	*$0.74*	*$0.03*	*$0.02*	*$0.02*	*$0.01*	*$0.01*
CSO-033	Buffalo River	84.0	67.9	22.6	6.5	1.6	*$1.78*	*$1.61*	*$0.97*	*$0.54*	*$0.28*	*$0.03*	*$0.02*	*$0.01*	*$0.01*	*$0.00*
CSO-050	Buffalo River	0.8	0.0	0.0	0.0	0.0	*$0.20*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-051	Buffalo River	3.2	0.9	0.0	0.0	0.0	*$0.39*	*$0.22*	*$0.00*	*$0.00*	*$0.00*	*$0.01*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-052	Buffalo River	7.1	6.1	1.9	0.0	0.0	*$0.56*	*$0.53*	*$0.31*	*$0.00*	*$0.00*	*$0.01*	*$0.01*	*$0.00*	*$0.00*	*$0.00*
CSO-064	Buffalo River	38.8	12.9	2.6	1.3	0.1	*$1.24*	*$0.74*	*$0.35*	*$0.26*	*$0.09*	*$0.02*	*$0.01*	*$0.01*	*$0.00*	*$0.00*
CSO-066	Buffalo River	43.3	29.1	23.3	15.5	8.4	*$1.31*	*$1.09*	*$0.98*	*$0.81*	*$0.61*	*$0.02*	*$0.02*	*$0.01*	*$0.01*	*$0.01*
Total		**586**	**407**	**200**	**96**	**42**		**$12.56**	**$8.09**	**$5.14**	**$3.18**	**$0.23**	**$0.19**	**$0.12**	**$0.08**	**$0.05**

HRT Piping (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length (ft)	Dimensions	Unit Cost ($/ft)	Cost ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CSO-014	Erie Basin	207	D=6'	$842	*$0.18*	*$0.18*	*$0.00*	*$0.00*	*$0.00*
CSO-014	Erie Basin	216	D=6'	$842	*$0.18*	*$0.18*	*$0.00*	*$0.00*	*$0.00*
CSO-015	Erie Basin	350	D=8'	$1,336	*$0.47*	*$0.47*	*$0.47*	*$0.47*	*$0.47*
CSO-015	Erie Basin	75	D=9'	$1,633	*$0.12*	*$0.12*	*$0.12*	*$0.12*	*$0.12*
CSO-022	Buffalo River	753	7.25' x 8' mod. basket handle	$1,963	*$1.48*	*$1.48*	*$1.48*	*$1.48*	*$1.48*
CSO-022	Buffalo River	68	7.25' x 8' mod. basket handle	$1,963	*$0.13*	*$0.13*	*$0.13*	*$0.13*	*$0.13*
CSO-025	Buffalo River	194	D=3'	$362	*$0.07*	*$0.07*	*$0.07*	*$0.00*	*$0.00*
CSO-025	Buffalo River	87	D=3'	$362	*$0.03*	*$0.03*	*$0.03*	*$0.00*	*$0.00*
CSO-026	Buffalo River	580	W=16', H=10.75'	$4,113	*$2.39*	*$2.39*	*$2.39*	*$2.39*	*$2.39*
CSO-026	Buffalo River	95	W=16', H=10.75'	$4,113	*$0.39*	*$0.39*	*$0.39*	*$0.39*	*$0.39*
CSO-027	Buffalo River	384	D=6'	$842	*$0.32*	*$0.32*	*$0.32*	*$0.32*	*$0.32*
CSO-027	Buffalo River	155	D=6'	$842	*$0.13*	*$0.13*	*$0.13*	*$0.13*	*$0.13*
CSO-028	Buffalo River	9	D=6.5'	$953	*$0.01*	*$0.01*	*$0.01*	*$0.01*	*$0.01*
CSO-028	Buffalo River	26	D=6.5'	$953	*$0.03*	*$0.03*	*$0.03*	*$0.03*	*$0.03*
CSO-028	Buffalo River	234	D=4.5'	$559	*$0.13*	*$0.13*	*$0.13*	*$0.13*	*$0.13*
CSO-028	Buffalo River	73	D=10'	$1,963	*$0.14*	*$0.14*	*$0.14*	*$0.14*	*$0.14*
CSO-033	Buffalo River	327	W=3.25', H=8.25'	$842	*$0.28*	*$0.28*	*$0.28*	*$0.28*	*$0.28*
CSO-033	Buffalo River	103	W=3.25', H=8.25'	$842	*$0.09*	*$0.09*	*$0.09*	*$0.09*	*$0.09*
CSO-050	Buffalo River	159	D=3.5'	$420	*$0.07*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-050	Buffalo River	127	D=3.5'	$420	*$0.05*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-051	Buffalo River	46	D=6.2'	$953	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.00*
CSO-051	Buffalo River	46	D=6.2'	$953	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.00*
CSO-052	Buffalo River	151	D=8'	$1,336	*$0.20*	*$0.20*	*$0.20*	*$0.00*	*$0.00*
CSO-052	Buffalo River	150	D=8'	$1,336	*$0.20*	*$0.20*	*$0.20*	*$0.00*	*$0.00*
CSO-064	Buffalo River	89	13.5' H x 16.5' W mod. basket handle	$5,801	*$0.51*	*$0.51*	*$0.51*	*$0.51*	*$0.51*
CSO-064	Buffalo River	217	13.5' H x 16.5' W mod. basket handle	$5,801	*$1.26*	*$1.26*	*$1.26*	*$1.26*	*$1.26*
CSO-066	Buffalo River	108	D=9'	$1,633	*$0.18*	*$0.18*	*$0.18*	*$0.18*	*$0.18*
CSO-066	Buffalo River	99	D=9'	$1,633	*$0.16*	*$0.16*	*$0.16*	*$0.16*	*$0.16*
CSO-017	Buffalo River	45	H=13', W=16'	$4,920	*$0.22*	*$0.22*	*$0.22*	*$0.22*	*$0.22*
CSO-018	Buffalo River	43	H=13', W=16'	$4,920	*$0.21*	*$0.21*	*$0.21*	*$0.21*	*$0.21*
Total		**3857**			***$9.72***	***$9.60***	***$9.15***	***$8.65***	***$8.65***

Sewer Separation (Based on similar projects, partial separation is $25,000/ac and full separation is $50,000/ac)

Receiving Basin	Area (ac)					Construction Cost ($ millions)		
	Partial Sewer Separation	Full Sewer Separation	Proposed Foundation Partial Separation	Full Separation	Total	Partial Sewer Separation	Full Sewer Separation + Foundation Separation	Total
Buffalo River	*261*	*0*	0	0	*261*	*$8.80*	*$0.00*	*$8.80*
Cazenovia Creek - B	*0*	*82*	0	82	*82*	*$0.00*	*$5.54*	*$5.54*
Cazenovia Creek - C	*0*	*932*	739	193	*932*	*$0.00*	*$37.87*	*$37.87*
Total	***261***	***1,014***	***739***	276	***1,276***	***$8.80***	***$43.41***	***$52.21***

Dynamic Head (ft): 125
Efficiency (%): 67%
Electricity Cost ($/kWhr): 0.1

Tunnel Storage (data provided by collection system model); 0 LOC cost curve for BRC updated by EMH 4/18/2012

BSA 2004 Curve

$$ScajCost = 2846725.52 \times dia.$$

ALCOSAN cost curve (deep tunnel dewatering, Fig D-3)

$$Cost = 910439 \times Flow^{0.9421}$$

Calculation Based on per Gal Pumped

ALCOSAN COST CURVE (DEC 2008) - Source 2

$$Cost = 749.43 \times VOL + 17816$$

ALCOSAN COST CURVE (DEC 2008) - Source 2

$$Cost = 959.78 * VOL + 22246$$

BSA 2004 LTCP Equation

[illegible]

	Receiving Basin	Volume (MG) or Dewatering (MGD) or Diameter (ft)					Length (ft)	Tunnel Cost ($ millions) - linear curve					Dewatering PS Cost ($ millions) - Alcosan Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South Volume	Black Rock Canal	49.6	31.4	18.9	11.8	4.5	7400 (9,500 for the 0	$92.55	$73.02	$56.87	$43.41	$27.26	$40.86	$26.59	$16.50	$10.59	$4.25
North-South Diameter		30	27	21	16	10											
East-West Volume	Scajaquada Creek	49.44	43.38	23.94	14.39	8.98	14,200	$91.96	$88.12	$65.14	$49.81	$38.32	$40.76	$36.04	$20.58	$12.75	$8.17
East-West Diameter		24	23	17	13	10											
Total		99.0	74.8	42.9	26.2	13.5	14,200	$184.50	$161.14	$122.00	$93.22	$65.57	$81.63	$62.63	$37.09	$23.34	$12.42

	Total Construction Cost with Collectors ($ millions)					Annual Volume Pumped (MG)					Present Worth O/M Costs - Energy ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South Volume / Diameter	$140.61	$106.81	$80.57	$61.20	$38.71	301.2	273.7	226	200	179.1	$0.27	$0.25	$0.20	$0.18	$0.16
East-West Volume / Diameter	$182.26	$173.71	$135.26	$112.10	$96.03	502.3	496.6	430.8	377.4	309	$0.45	$0.45	$0.39	$0.34	$0.28
Total	$322.87	$280.52	$215.83	$173.30	$134.73	803.5	770.3	656.8	577.4	488.1	$0.72	$0.69	$0.59	$0.52	$0.44

	Present Worth O/M Costs - Materials ($ millions)					Present Worth O/M Costs - Labor ($ millions)					Present Worth O/M Costs - Tunnel ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South Volume / Diameter	$0.93	$0.70	$0.54	$0.45	$0.36	$1.19	$0.89	$0.69	$0.57	$0.45	$5.39	$5.14	$4.97	$4.88	$4.78
East-West Volume / Diameter	$0.93	$0.85	$0.61	$0.49	$0.42	$1.19	$1.09	$0.77	$0.62	$0.53	$5.39	$5.31	$5.04	$4.91	$4.84
Total	$1.86	$1.56	$1.15	$0.94	$0.78	$2.37	$1.98	$1.46	$1.19	$0.98	$10.78	$10.45	$10.02	$9.79	$9.61

	Present Worth O/M Costs - Total ($ millions)					Costs - Total ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South Volume / Diameter	$7.78	$6.98	$6.41	$6.08	$5.75	$148.39	$113.79	$86.98	$67.28	$44.45
East-West Volume / Diameter	$7.96	$7.69	$6.80	$6.35	$6.06	$190.22	$181.40	$142.07	$118.45	$102.08
Total	$15.74	$14.68	$13.21	$12.43	$11.80	$338.61	$295.19	$229.04	$185.73	$146.54

Tunnel Collectors (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length (ft)	Diameter (ft)	Unit Cost ($/ft)	Construction Costs - Total ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CSO 004	Black Rock Canal	977	6.0	$842	$0.82	$0.82	$0.82	$0.82	$0.00
CSO 008	Black Rock Canal	387	3.0	$362	$0.14	$0.14	$0.14	$0.14	$0.14
CSO 010	Black Rock Canal	1,496	3.5	$420	$0.63	$0.63	$0.63	$0.63	$0.63
CSO 011	Niagara River	1,512	9.0	$1,633	$2.47	$2.47	$2.47	$2.47	$2.47
CSO 012	Black Rock Canal	22	8.0	$1,336	$0.03	$0.03	$0.03	$0.03	$0.03
CSO 057	Scajaquada Creek	862	2.5	$289	$0.25	$0.25	$0.25	$0.25	$0.00
CSO 058	Scajaquada Creek	324	2.5	$289	$0.09	$0.09	$0.09	$0.09	$0.00
CSO 059	Scajaquada Creek	1,639	3.0	$362	$0.59	$0.59	$0.59	$0.00	$0.00
CSO 061	Black Rock Canal	239	5.0	$645	$0.15	$0.15	$0.15	$0.15	$0.00
SPP156	Scajaquada Creek	105	1.0	$188	$0.00	$0.00	$0.00	$0.00	$0.00
SPP157	Scajaquada Creek	772	2.5	$289	$0.22	$0.22	$0.22	$0.00	$0.00
SPP163	Scajaquada Creek	837	3.0	$362	$0.30	$0.30	$0.30	$0.00	$0.00
SPP165a&b	Scajaquada Creek	123	2.5	$289	$0.04	$0.04	$0.04	$0.04	$0.04
SPP166	Scajaquada Creek	247	2.0	$247	$0.06	$0.06	$0.00	$0.00	$0.00
SPP170b	Scajaquada Creek	1,036	5.5	$739	$0.77	$0.77	$0.77	$0.77	$0.77
SPP178	Scajaquada Creek	1,385	4.0	$478	$0.66	$0.66	$0.66	$0.66	$0.66
SPP200a&b	Scajaquada Creek	130	2.5	$289	$0.04	$0.04	$0.04	$0.00	$0.00
SPP201	Scajaquada Creek	1,123	3.5	$420	$0.47	$0.47	$0.47	$0.00	$0.00
SPP202	Scajaquada Creek	774	3.0	$362	$0.28	$0.28	$0.28	$0.00	$0.00
SPP203	Scajaquada Creek	39	3.0	$362	$0.01	$0.01	$0.01	$0.01	$0.00
SPP204	Scajaquada Creek	1,752	4.0	$478	$0.84	$0.84	$0.84	$0.84	$0.00
SPP229a	Scajaquada Creek	92	3.5	$420	$0.04	$0.04	$0.00	$0.00	$0.00
SPP335	Scajaquada Creek	1,706	3.0	$362	$0.62	$0.62	$0.62	$0.00	$0.00
SPP335a	Scajaquada Creek	24	1.5	$183	$0.004	$0.004	$0.00	$0.00	$0.00
SPP336a	Scajaquada Creek	144	2.5	$289	$0.04	$0.04	$0.04	$0.04	$0.04
SPP336b	Scajaquada Creek	2,324	5.0	$645	$1.50	$1.50	$1.50	$1.50	$1.50
SPP337	Scajaquada Creek	1,418	5.5	$739	$1.05	$1.05	$1.05	$1.05	$1.05
SPP338	Scajaquada Creek	1,905	5.0	$645	$1.23	$1.23	$0.00	$0.00	$0.00
SPP339	Scajaquada Creek	1,285	4.0	$478	$0.61	$0.61	$0.00	$0.00	$0.00
SPP340	Scajaquada Creek	1,164	5.5	$739	$0.86	$0.86	$0.86	$0.86	$0.00
SPP341a	Scajaquada Creek	957	3.0	$362	$0.35	$0.35	$0.35	$0.35	$0.35
SPP342a&b	Scajaquada Creek	1,628	2.0	$247	$0.40	$0.40	$0.40	$0.00	$0.00
SPP345	Scajaquada Creek	1,735	2.0	$247	$0.43	$0.43	$0.43	$0.00	$0.00
Total		30,160			$16.00	$16.00	$14.05	$10.69	$7.66

Dynamic Head (ft): 125
Efficiency (%): 67%

Tunnel Dewatering Force Main (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
Scajaquada Creek	231	90	72	54	18	10	$1,560	$837	$449	$121	$54	$0.36	$0.19	$0.10	$0.03	$0.01
Black Rock Canal	1,267	60	54	48	24	8	$553	$449	$365	$161	$46	$0.70	$0.57	$0.46	$0.20	$0.06
Total	1,497											$1.06	$0.76	$0.57	$0.23	$0.07

Total - Construction Cost

Receiving Basin	Alternative UA1				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$159.38	$123.76	$94.03	$62.97	$39.50
Buffalo River	$270.17	$208.71	$125.21	$76.90	$49.24
Cazenovia Creek - B	$5.54	$5.54	$5.54	$5.54	$5.54
Cazenovia Creek - C	$37.87	$37.87	$37.87	$37.87	$37.87
Cornelius Creek	$128.64	$105.91	$78.26	$64.21	$43.14
Erie Basin	$45.09	$28.52	$12.47	$4.58	$0.83
Niagara River	$3.08	$2.48	$2.48	$2.47	$2.47
Scajaquada Creek	$196.24	$187.23	$146.21	$118.55	$100.43
Sub-Total	$846.01	$700.00	$502.07	$373.09	$279.01

Sub-Total - Present Worth O/M

Receiving Basin	Alternative UA1				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$8.42	$7.51	$6.66	$6.08	$5.75
Buffalo River	$169.34	$134.40	$84.24	$51.42	$31.86
Cazenovia Creek - B	$0.00	$0.00	$0.00	$0.00	$0.00
Cazenovia Creek - C	$0.00	$0.00	$0.00	$0.00	$0.00
Cornelius Creek	$4.30	$3.73	$2.97	$2.54	$1.83
Erie Basin	$31.30	$21.93	$9.81	$4.31	$0.71
Niagara River	$0.07	$0.01	$0.01	$0.00	$0.00
Scajaquada Creek	$8.20	$7.90	$6.94	$6.35	$6.06
Sub-Total	$221.64	$175.47	$110.63	$70.70	$46.20

Sub-Total -Engineering

Receiving Basin	Alternative UA1				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$23.91	$18.56	$14.10	$9.45	$5.93
Buffalo River	$40.53	$31.31	$18.78	$11.54	$7.39
Cazenovia Creek - B	$0.83	$0.83	$0.83	$0.83	$0.83
Cazenovia Creek - C	$5.68	$5.68	$5.68	$5.68	$5.68
Cornelius Creek	$19.30	$15.89	$11.74	$9.63	$6.47
Erie Basin	$6.76	$4.28	$1.87	$0.69	$0.12
Niagara River	$0.46	$0.37	$0.37	$0.37	$0.37
Scajaquada Creek	$29.44	$28.08	$21.93	$17.78	$15.06
Sub-Total	***$126.90***	***$105.00***	***$75.31***	***$55.96***	***$41.85***

Sub-Total - Present Worth O/M Contigency

Receiving Basin	Alternative UA1				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$0.84	$0.75	$0.67	$0.61	$0.57
Buffalo River	$16.93	$13.44	$8.42	$5.14	$3.19
Cazenovia Creek - B	$0.00	$0.00	$0.00	$0.00	$0.00
Cazenovia Creek - C	$0.00	$0.00	$0.00	$0.00	$0.00
Cornelius Creek	$0.43	$0.37	$0.30	$0.25	$0.18
Erie Basin	$3.13	$2.19	$0.98	$0.43	$0.07
Niagara River	$0.01	$0.00	$0.00	$0.00	$0.00
Scajaquada Creek	$0.82	$0.79	$0.69	$0.63	$0.61
Sub-Total	***$22.16***	***$17.55***	***$11.06***	***$7.07***	***$4.62***

Sub-Total - Project Contingency

Receiving Basin	Alternative UA1				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$45.82	$35.58	$27.03	$18.10	$11.36
Buffalo River	$77.67	$60.00	$36.00	$22.11	$14.16
Cazenovia Creek - B	$1.59	$1.59	$1.59	$1.59	$1.59
Cazenovia Creek - C	$10.89	$10.89	$10.89	$10.89	$10.89
Cornelius Creek	$36.98	$30.45	$22.50	$18.46	$12.40
Erie Basin	$12.96	$8.20	$3.58	$1.32	$0.24
Niagara River	$0.88	$0.71	$0.71	$0.71	$0.71
Scajaquada Creek	$56.42	$53.83	$42.04	$34.08	$28.87
Sub-Total	***$243.23***	***$201.25***	***$144.35***	***$107.26***	***$80.22***

Sub-Total - Present Worth O/M with Contingency

Receiving Basin	Alternative UA1				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$9.26	$8.26	$7.33	$6.69	$6.32
Buffalo River	$186.28	$147.84	$92.67	$56.56	$35.04
Cazenovia Creek - B	$0.00	$0.00	$0.00	$0.00	$0.00
Cazenovia Creek - C	$0.00	$0.00	$0.00	$0.00	$0.00
Cornelius Creek	$4.73	$4.10	$3.26	$2.80	$2.01
Erie Basin	$34.43	$24.12	$10.79	$4.75	$0.78
Niagara River	$0.08	$0.01	$0.01	$0.00	$0.00
Scajaquada Creek	$9.02	$8.69	$7.63	$6.98	$6.66
Sub-Total	***$243.80***	***$193.02***	***$121.69***	***$77.77***	***$50.82***

Total - Project Cost with Contingencies

Receiving Basin	Foundation Alternative	Alternative UA1				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$9.44	$229.11	$177.90	$135.17	$90.52	$56.79
Buffalo River	$76.69	$388.37	$300.02	$180.00	$110.55	$70.78
Cazenovia Creek - B	$17.20	$7.97	$7.97	$7.97	$7.97	$7.97
Cazenovia Creek - C	$17.58	$54.43	$54.43	$54.43	$54.43	$54.43
Cornelius Creek	$0.00	$184.92	$152.24	$112.50	$92.30	$62.01
Erie Basin	$1.20	$64.82	$41.00	$17.92	$6.58	$1.19
Niagara River	$0.00	$4.42	$3.56	$3.56	$3.55	$3.55
Scajaquada Creek	$2.17	$282.09	$269.14	$210.18	$170.42	$144.36
Sub-Total		***$1,216.14***	***$1,006.26***	***$721.73***	***$536.31***	***$401.08***
Total (with Foundation Alternative)	***$124.27***	***$1,340.41***	***$1,130.53***	***$846.00***	***$660.58***	***$525.35***

Total - Project Cost and Present Worth O/M with Contingencies

Receiving Basin	Foundation Alternative	Alternative UA1				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$9.44	$238.38	$186.16	$142.50	$97.21	$63.11
Buffalo River	$76.69	$574.65	$447.86	$272.66	$167.10	$105.83
Cazenovia Creek - B	$17.20	$7.97	$7.97	$7.97	$7.97	$7.97
Cazenovia Creek - C	$17.58	$54.43	$54.43	$54.43	$54.43	$54.43
Cornelius Creek	$0.00	$189.65	$156.34	$115.76	$95.09	$64.02
Erie Basin	$1.20	$99.25	$65.11	$28.71	$11.32	$1.97
Niagara River	$0.00	$4.50	$3.57	$3.57	$3.55	$3.55
Scajaquada Creek	$2.17	$291.12	$277.82	$217.81	$177.40	$151.02
Sub-Total		***$1,459.95***	***$1,199.27***	***$843.42***	***$614.08***	***$451.90***
Total (with Foundation Alternative)	***$124.27***	***$1,584.22***	***$1,323.54***	***$967.69***	***$738.35***	***$576.17***

Figure A: Present Worth Costs vs. Frequency of Activation for Black Rock Canal (System-wide Alternative UA1) 1993 TY - 2012 Dollars

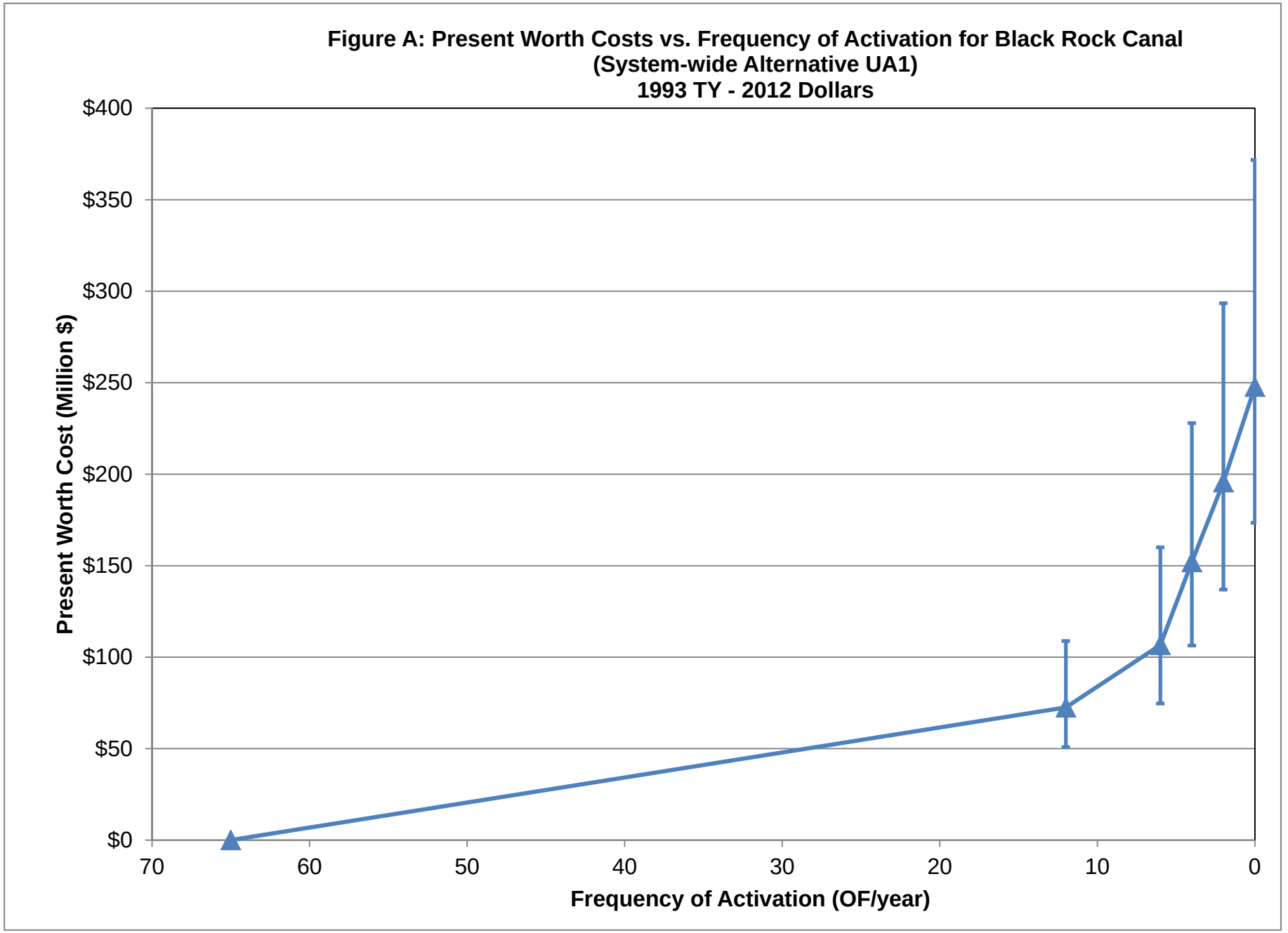


Figure B: Present Worth Costs vs. Frequency of Activation for Buffalo River (System-wide Alternative UA1) 1993 TY - 2012 Dollars

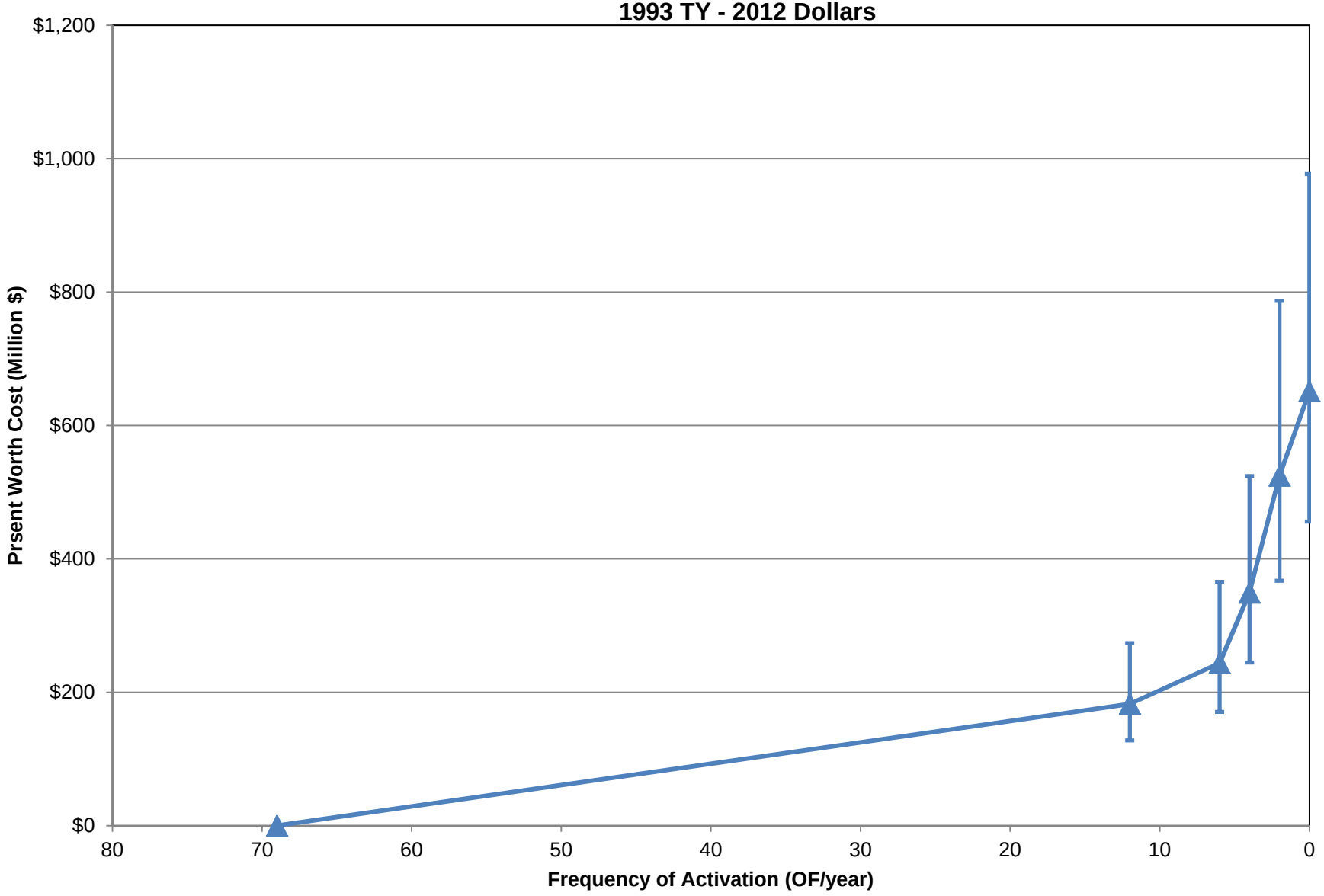


Figure C: Present Worth Costs vs. Frequency of Activation for Cazenovia Creek (B)
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

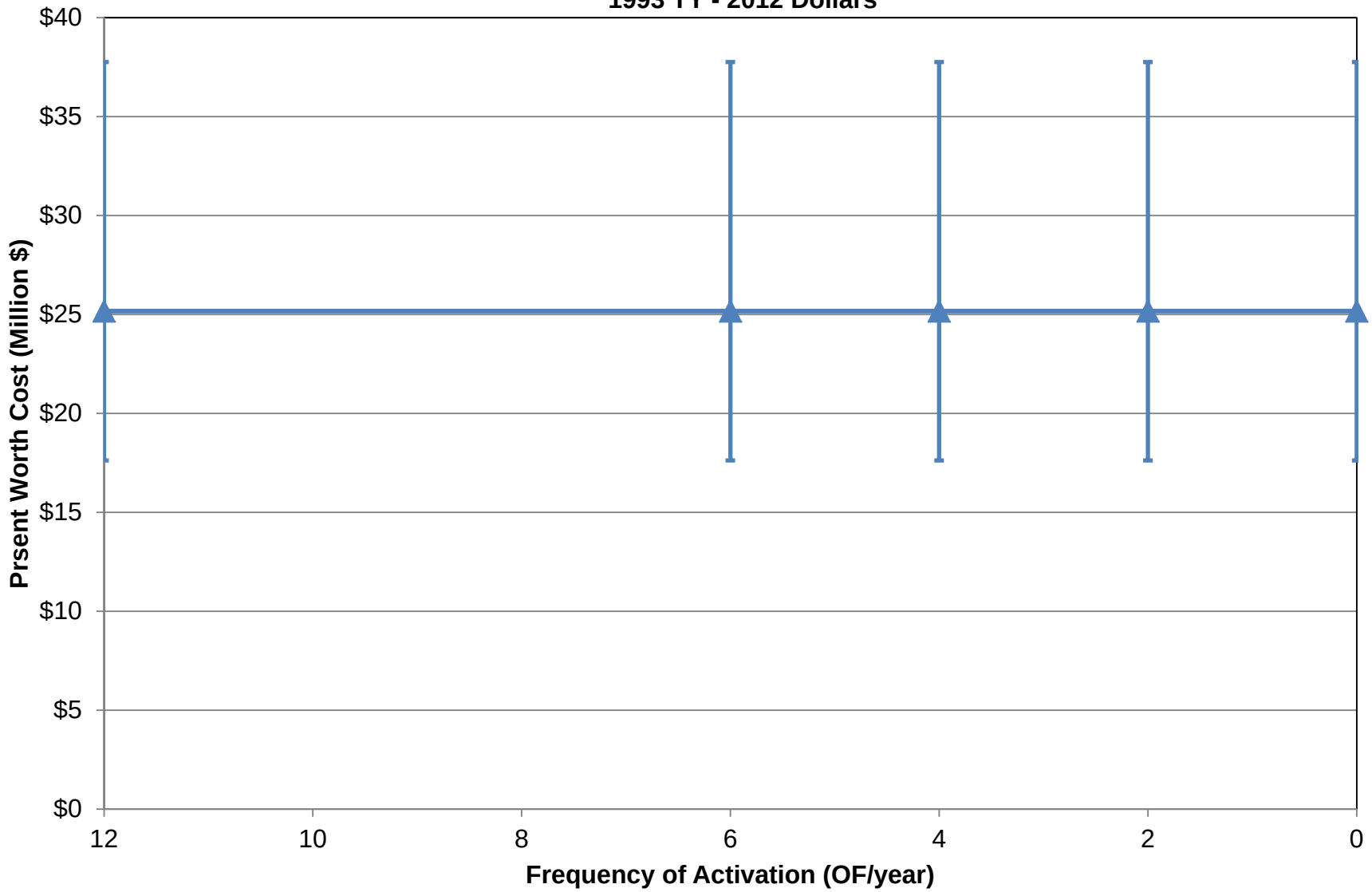


Figure D - Present Worth Costs vs. Frequency of Activation for Cazenovia Creek C (System-wide Alternative UA1) 1993 TY - 2012 Dollars

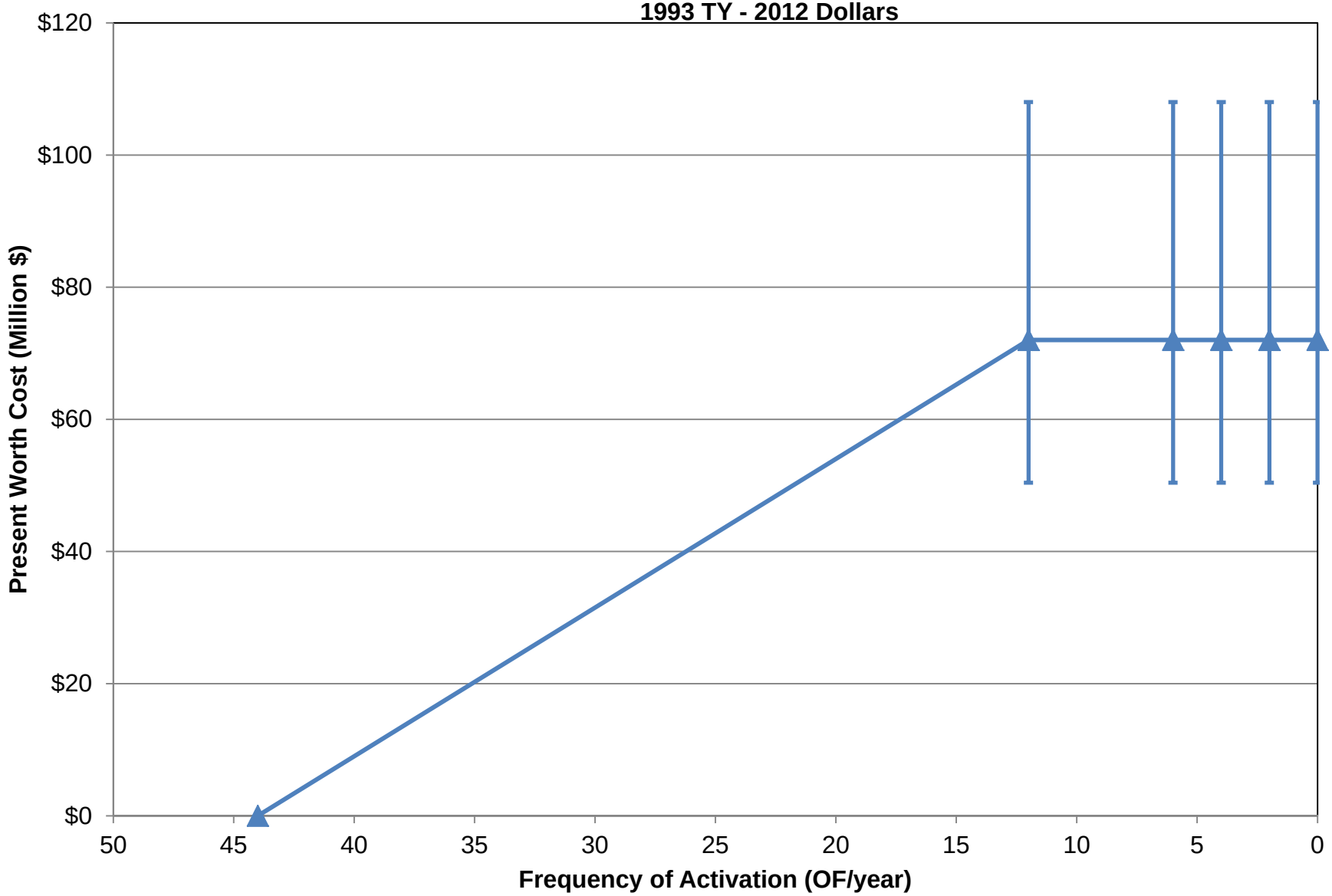


Figure E: Present Worth Costs vs. Frequency of Activation for Niagara River and CSO-055
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

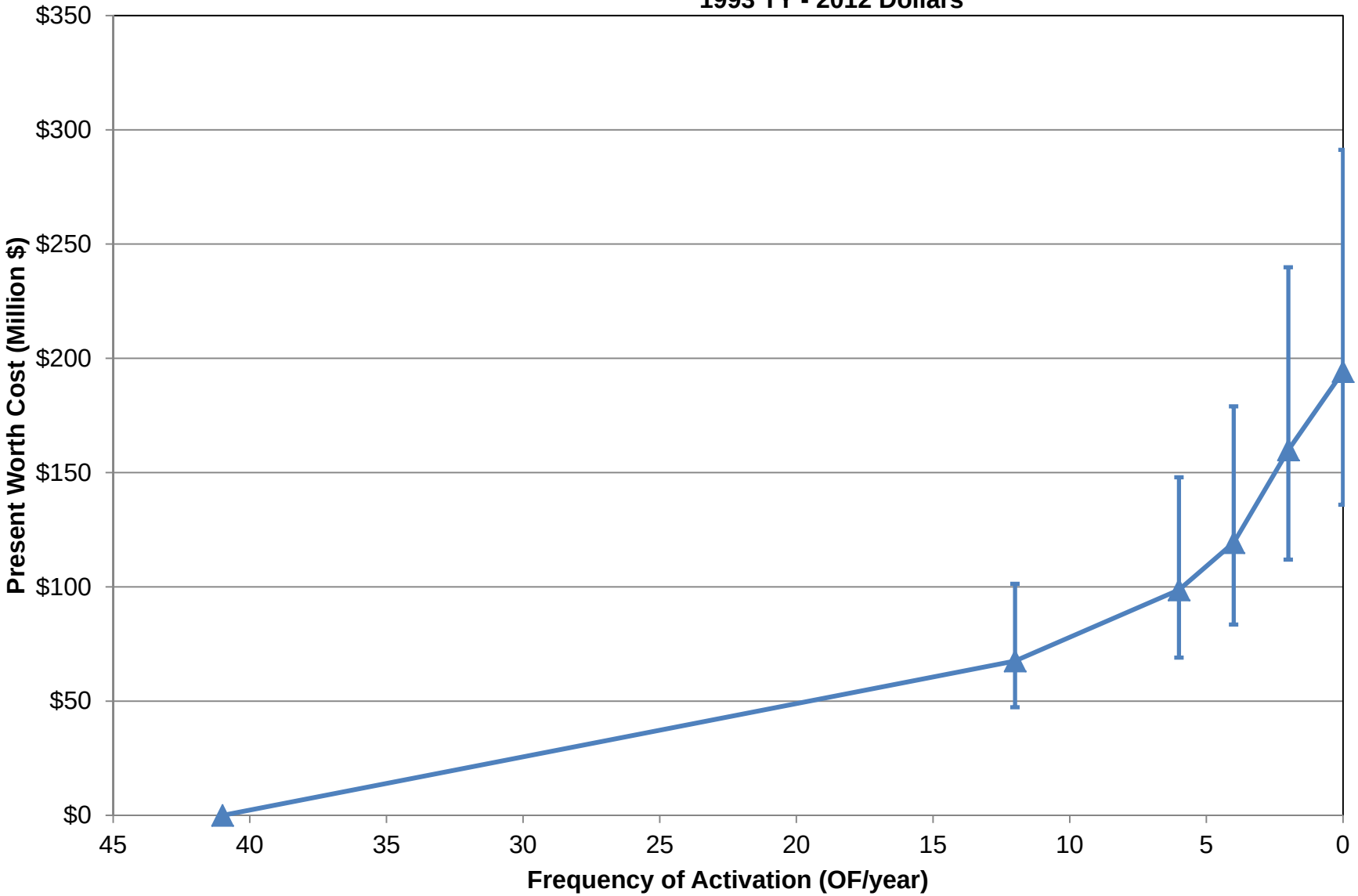


Figure F: Present Worth Costs vs. Frequency of Activation for Erie Basin
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

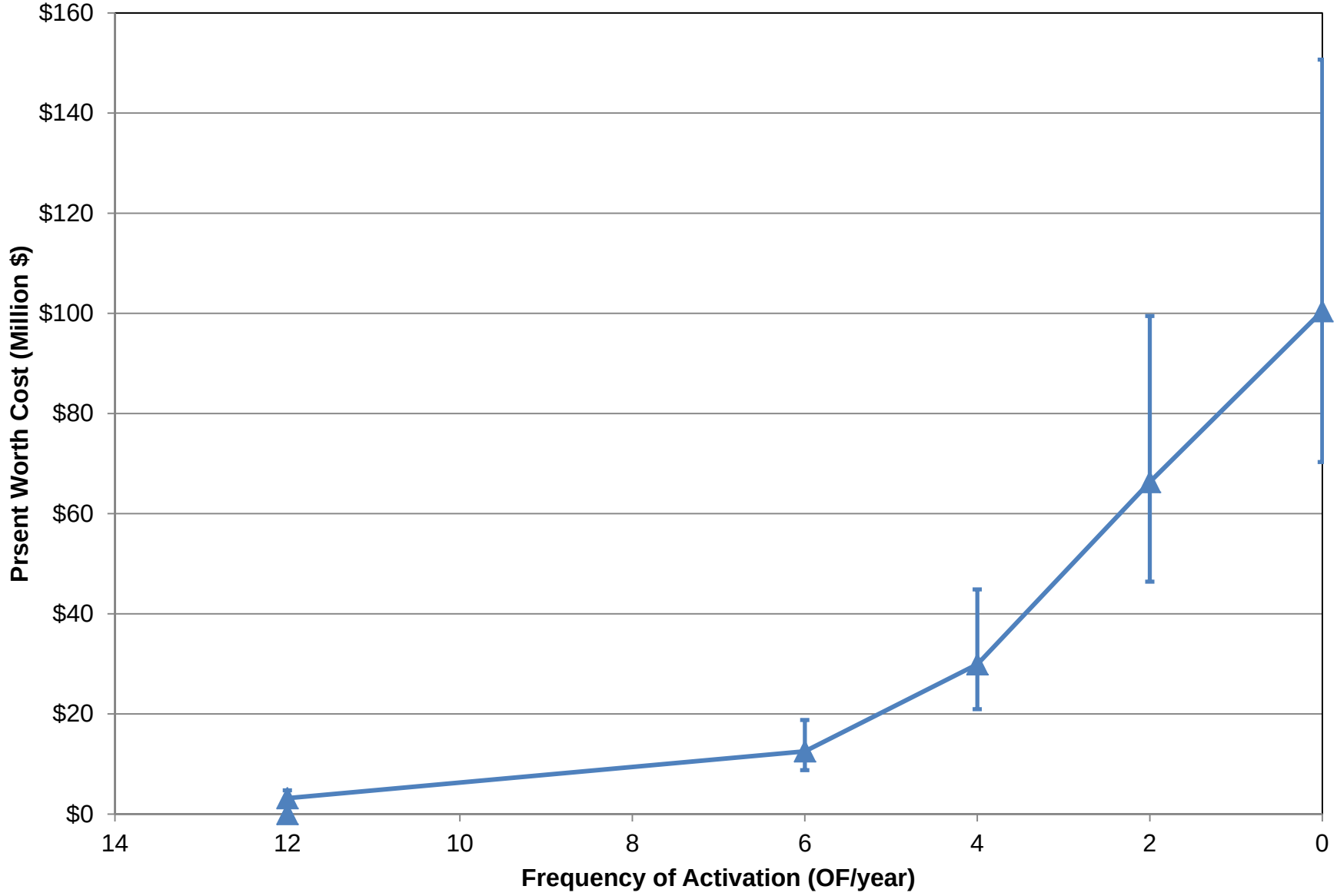


Figure G: Present Worth Costs vs. Frequency of Activation for Scajaquada Creek (System-wide Alternative UA1) 1993 TY - 2012 Dollars

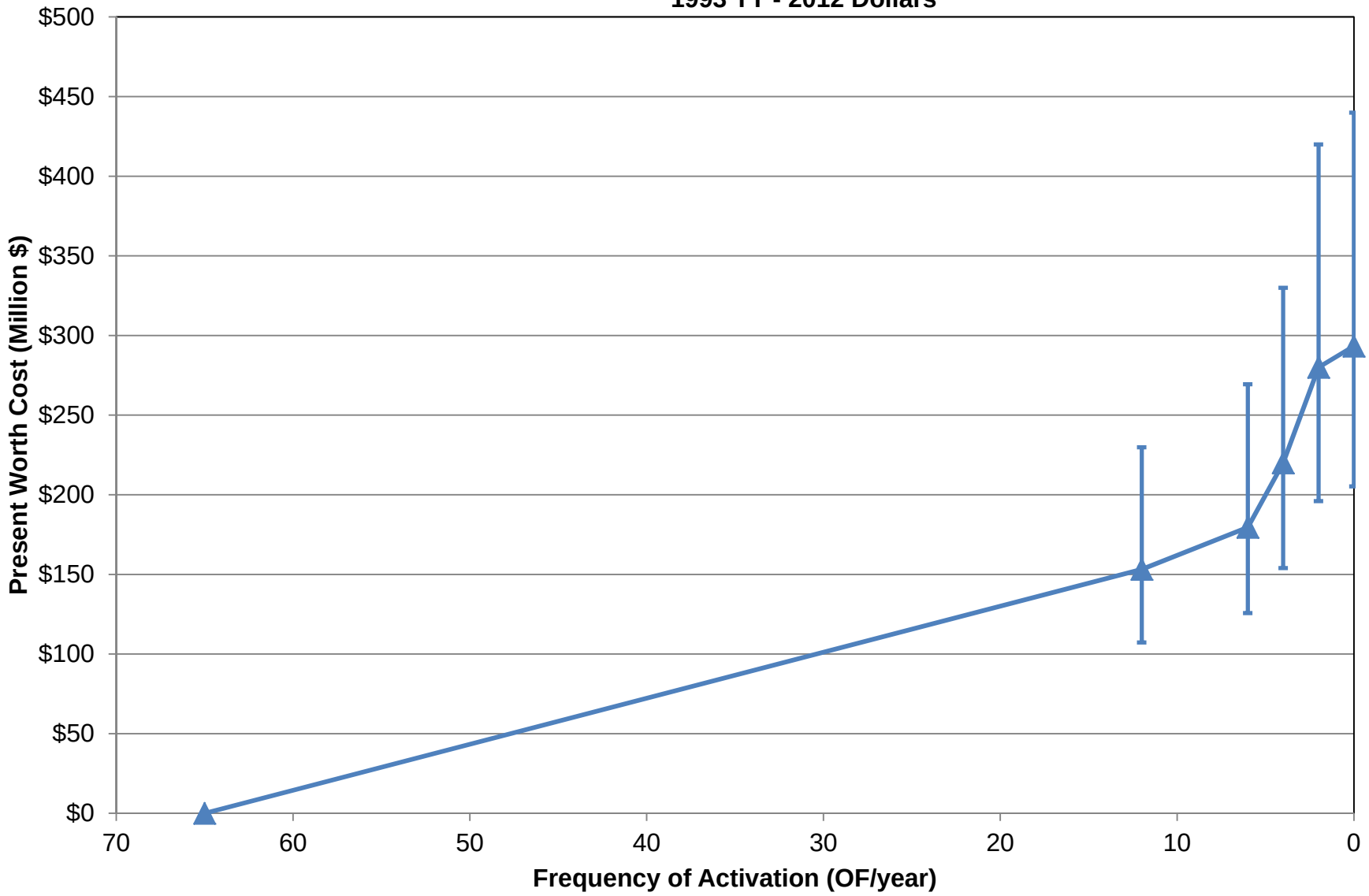


Figure H: Present Worth Costs vs. Remaining CSO Volumes for Black Rock Canal
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

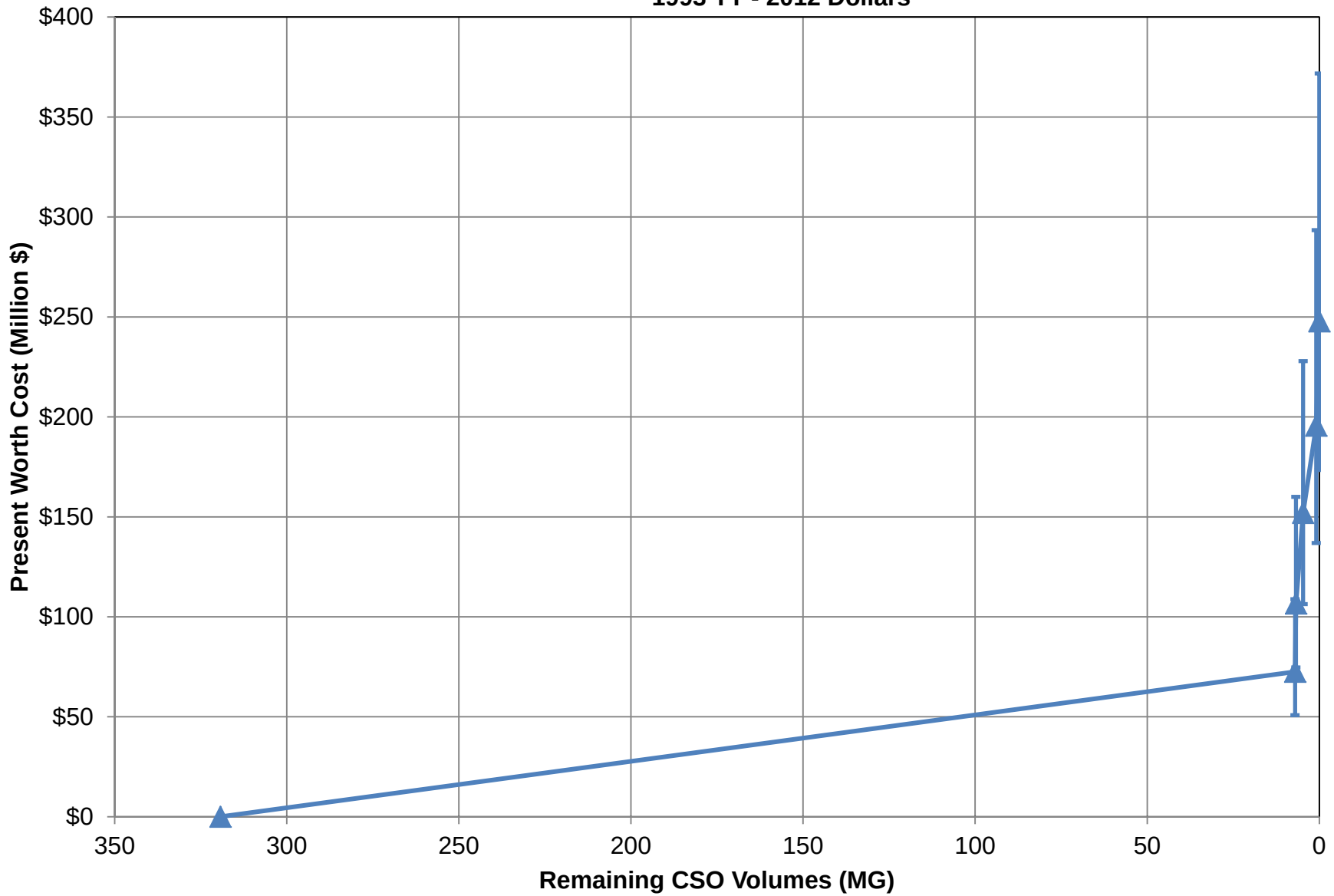


Figure I: Present Worth Costs vs. Remaining CSO Volumes for Buffalo River
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

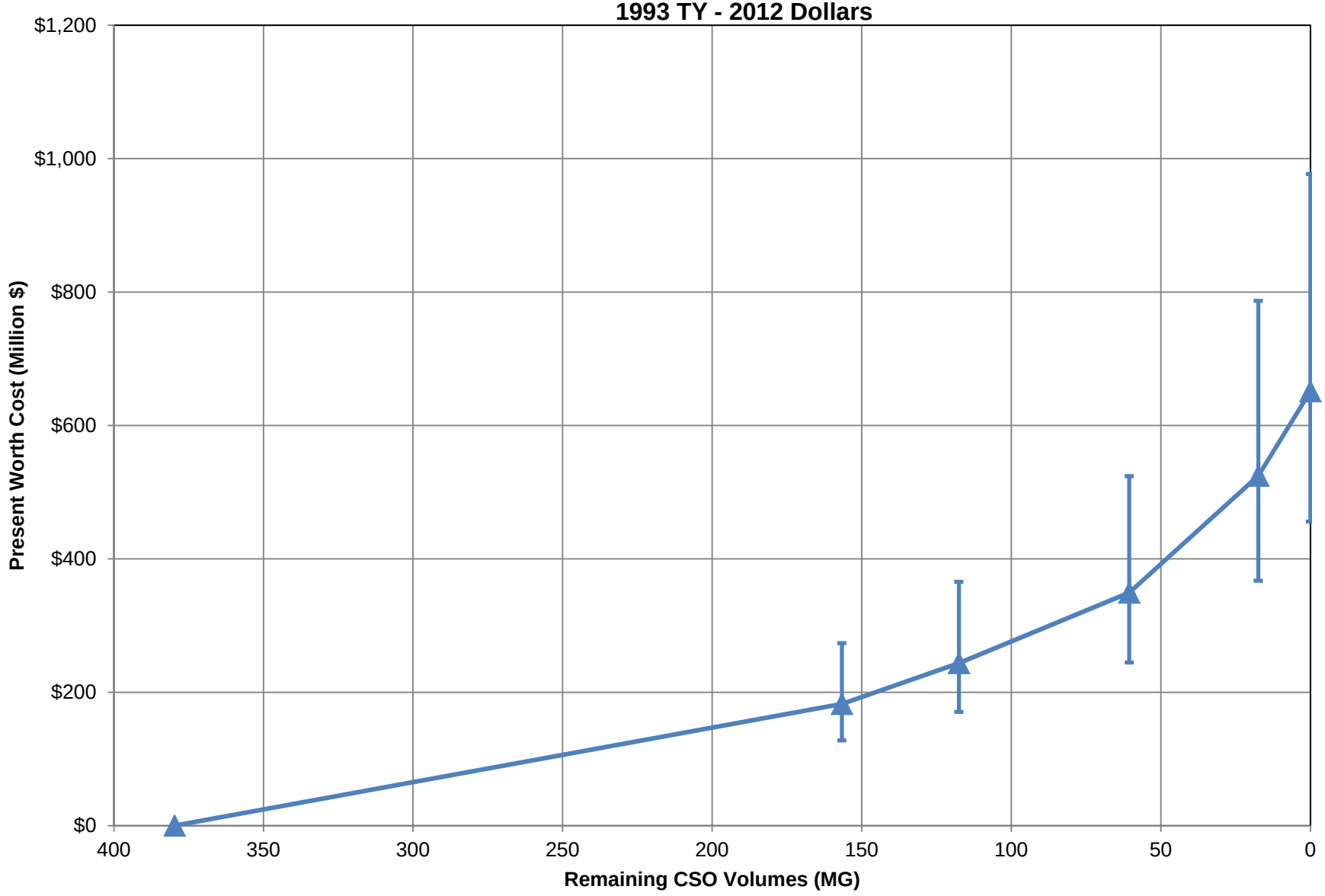
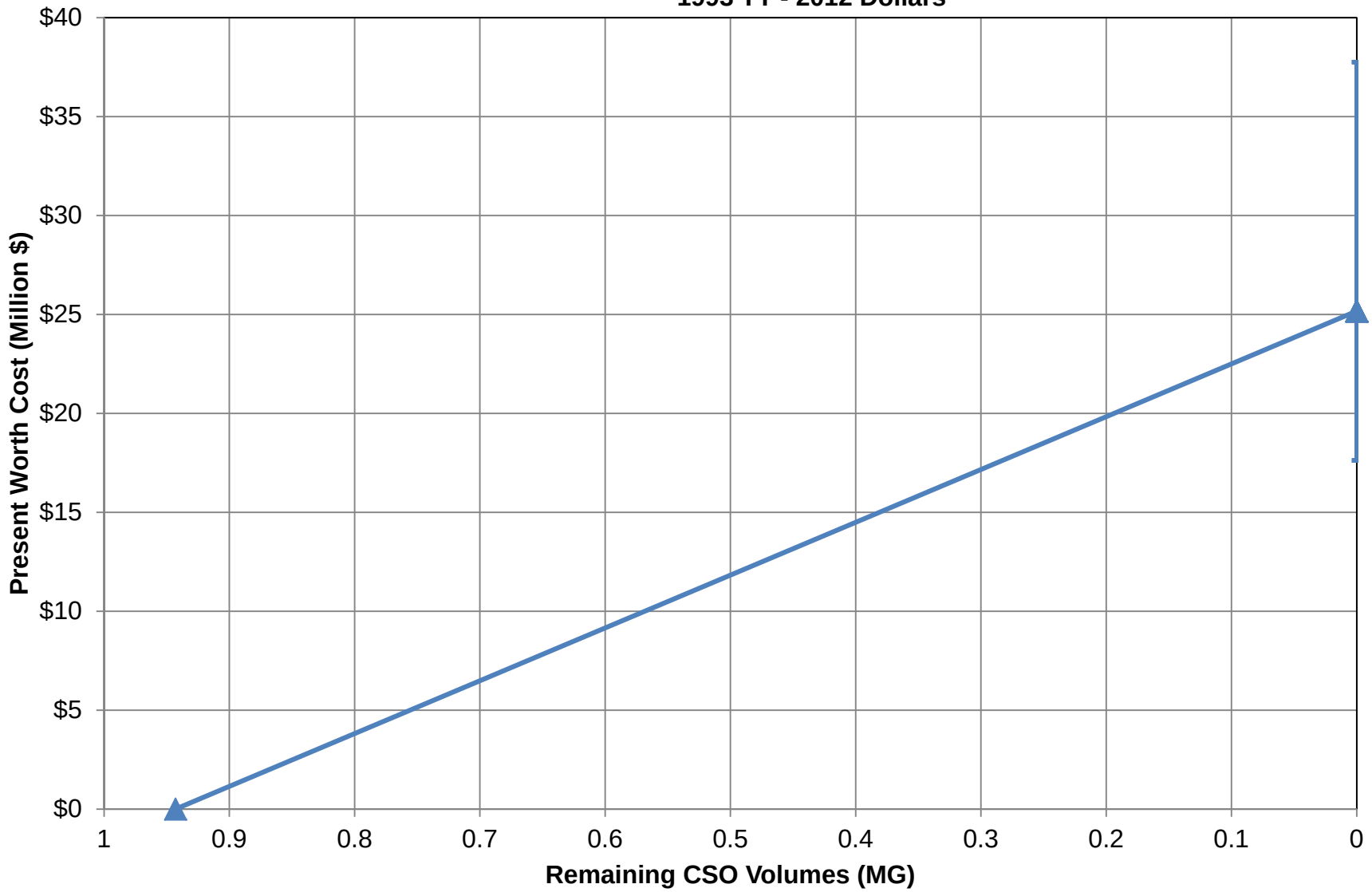


Figure J: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (B)
(System-wide Alternative UA1)
1993 TY - 2012 Dollars



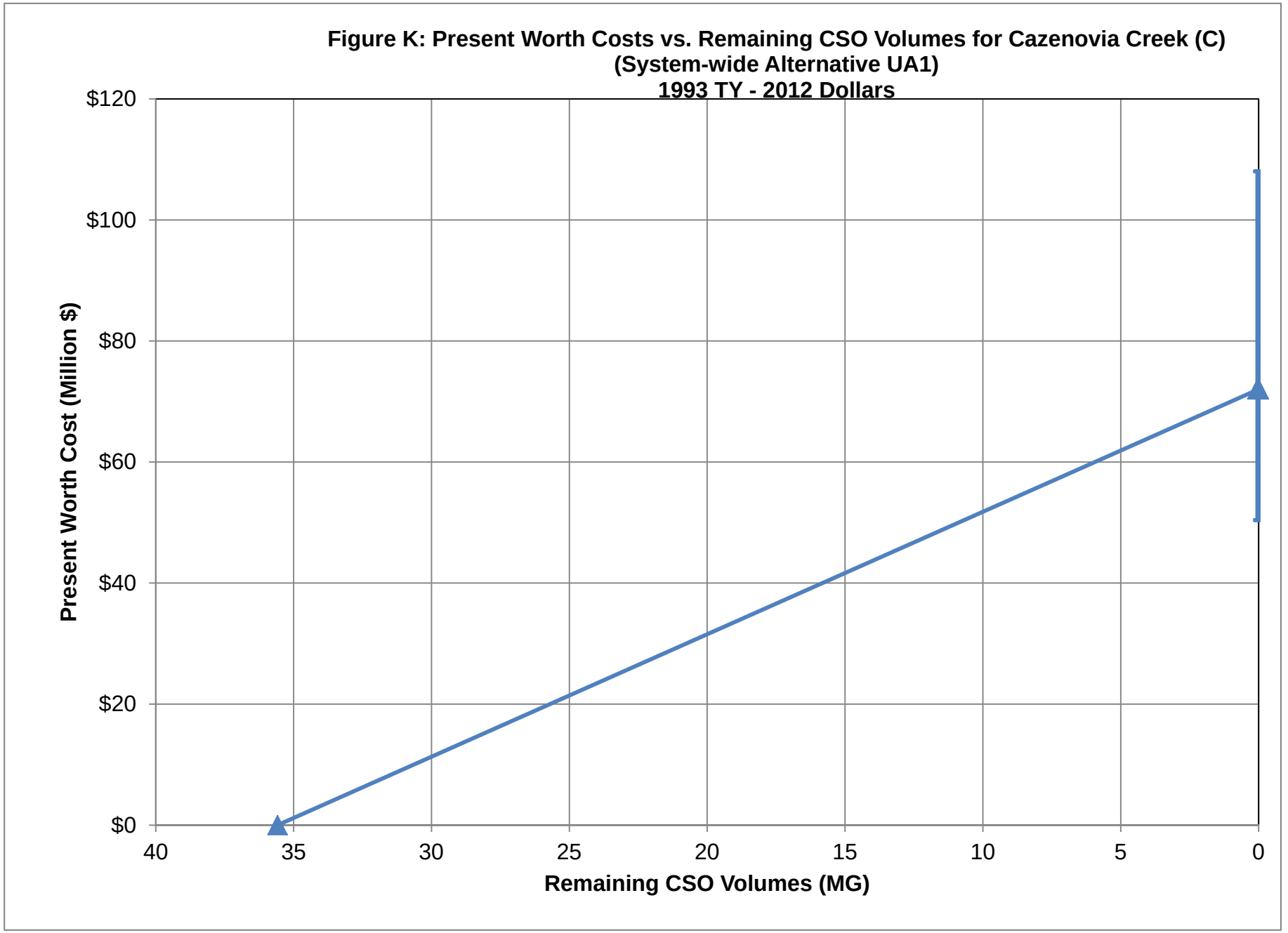


Figure K: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (C)
(System-wide Alternative UA1)
1993 TY - 2012 Dollars
Present Worth Cost (Million $)
$120
$100
$80
$60
$40
$20
$0
40
35
30
25
20
15
10
5
0
Remaining CSO Volumes (MG)

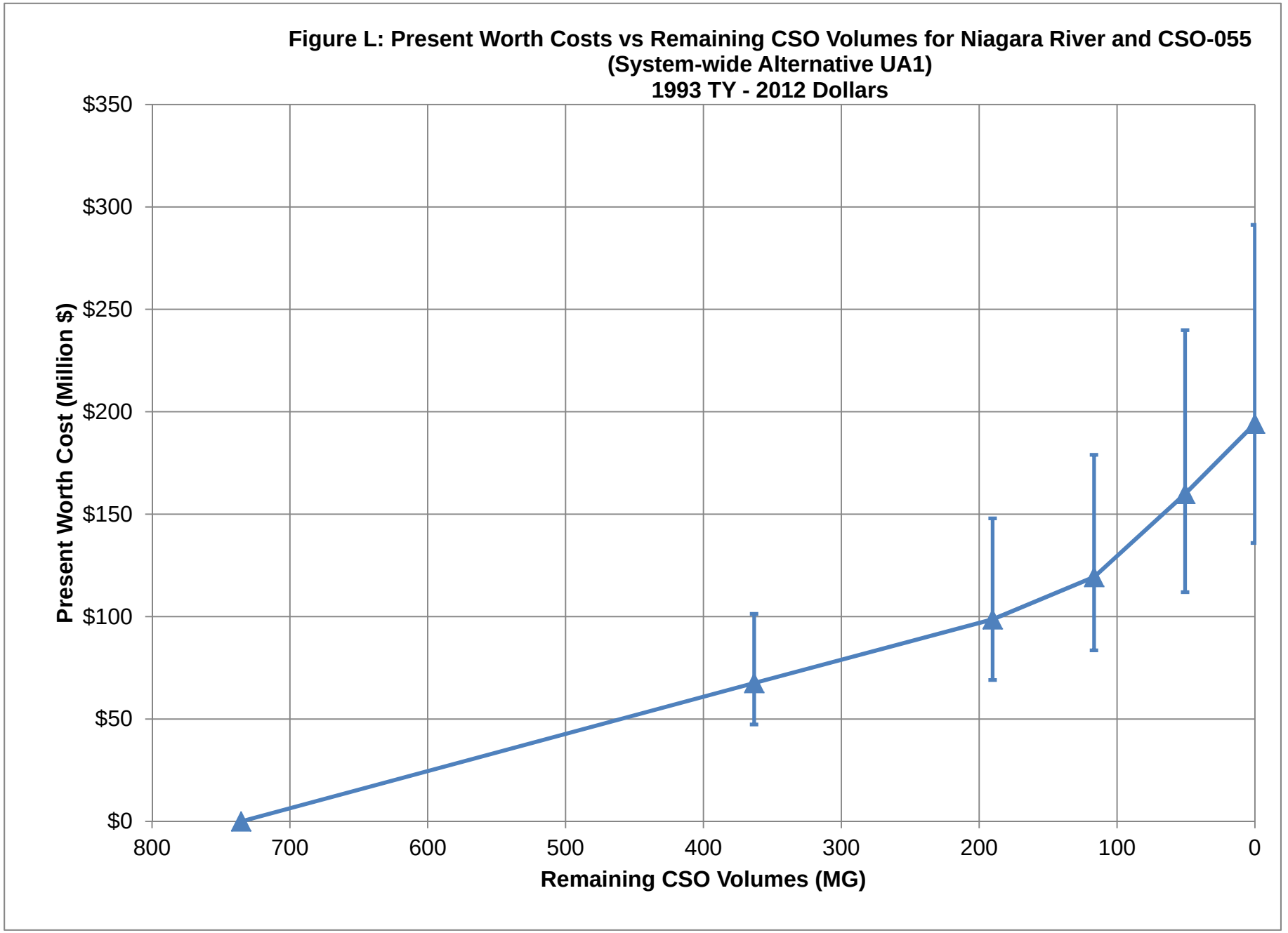


Figure L: Present Worth Costs vs Remaining CSO Volumes for Niagara River and CSO-055
(System-wide Alternative UA1)
1993 TY - 2012 Dollars
Present Worth Cost (Million $)
$350
$300
$250
$200
$150
$100
$50
$0
800
700
600
500
400
300
200
100
0
Remaining CSO Volumes (MG)

Figure M: Present Worth Costs vs. Remaining CSO Volumes for Erie Basin
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

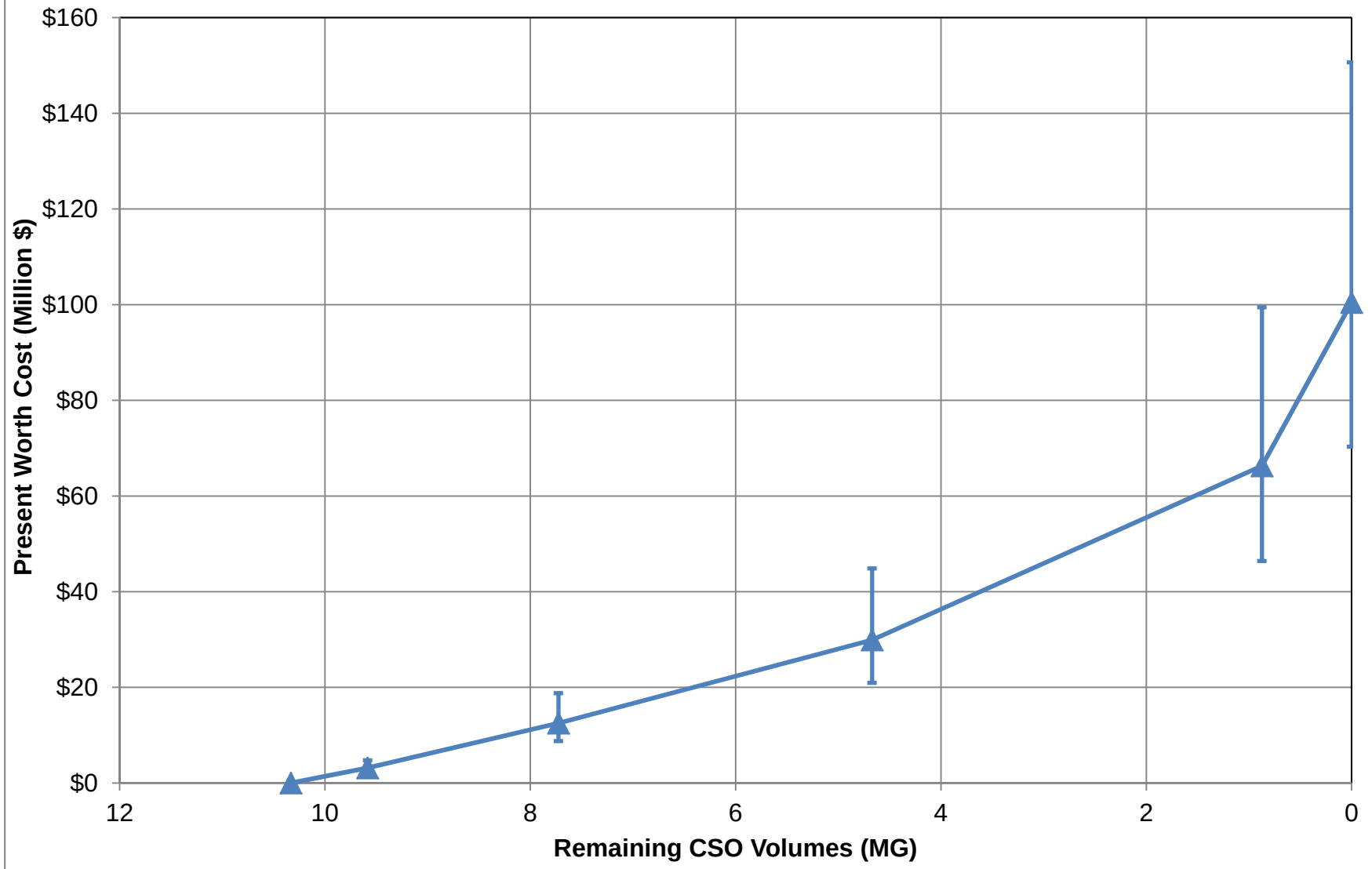


Figure N: Present Worth Costs vs. Remaining CSO Volumes for Scajaquada Creek
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

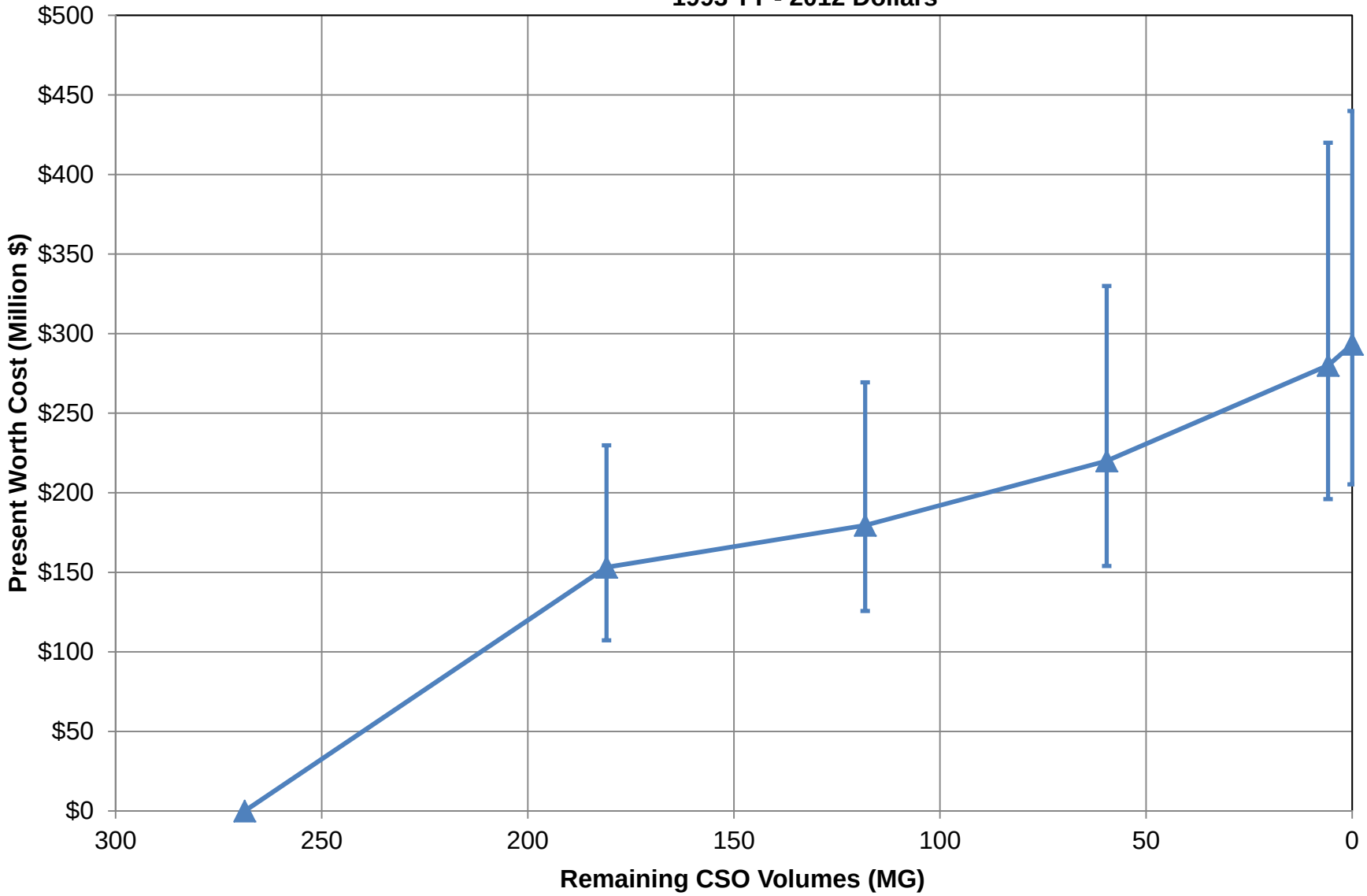


Fig O: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for System-wide Alternative UA1
1993 TY - 2012 Dollars

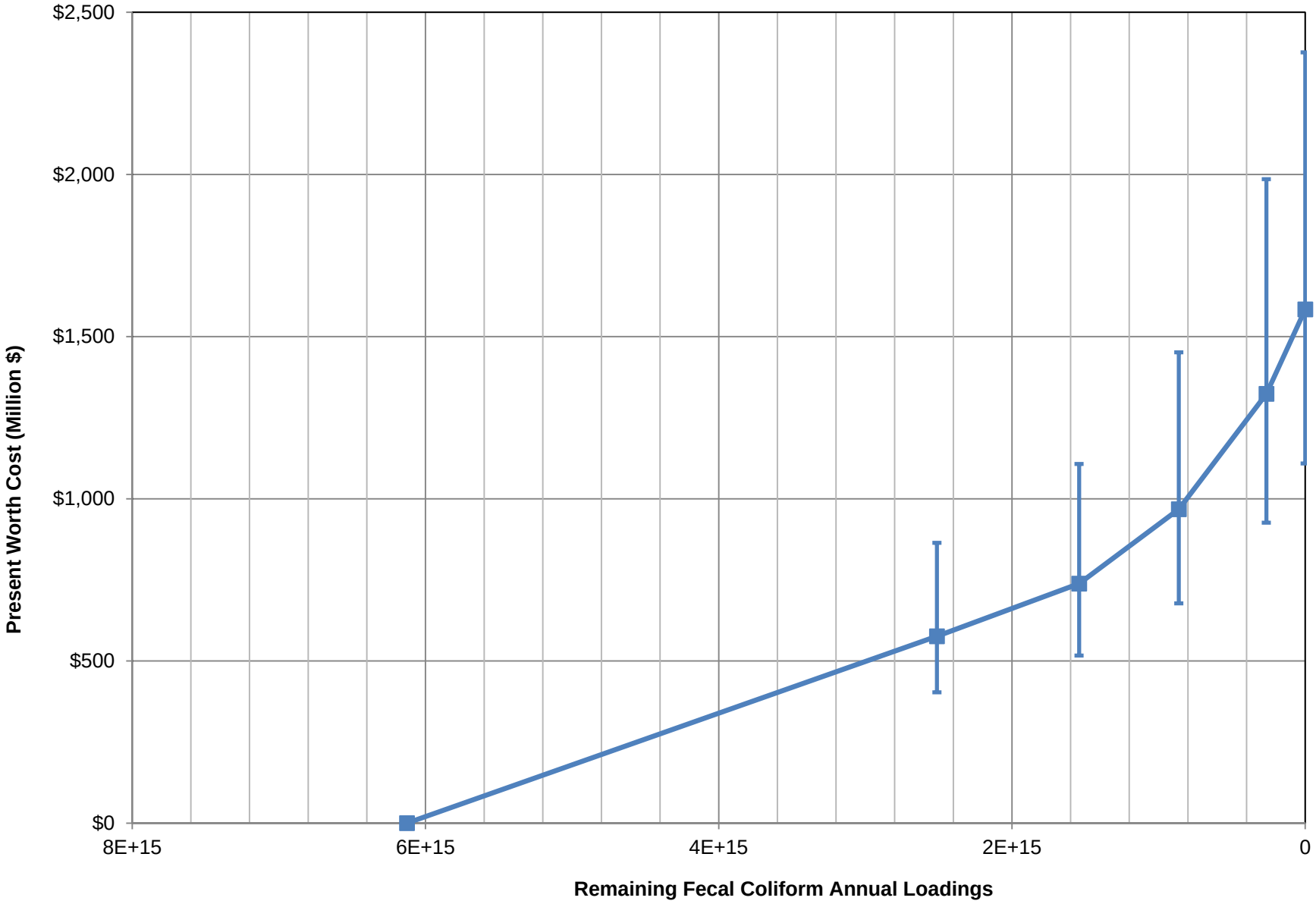


Figure P: Present Worth Costs vs. Remaining Fecal Coliform Loadings for Black Rock Canal
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

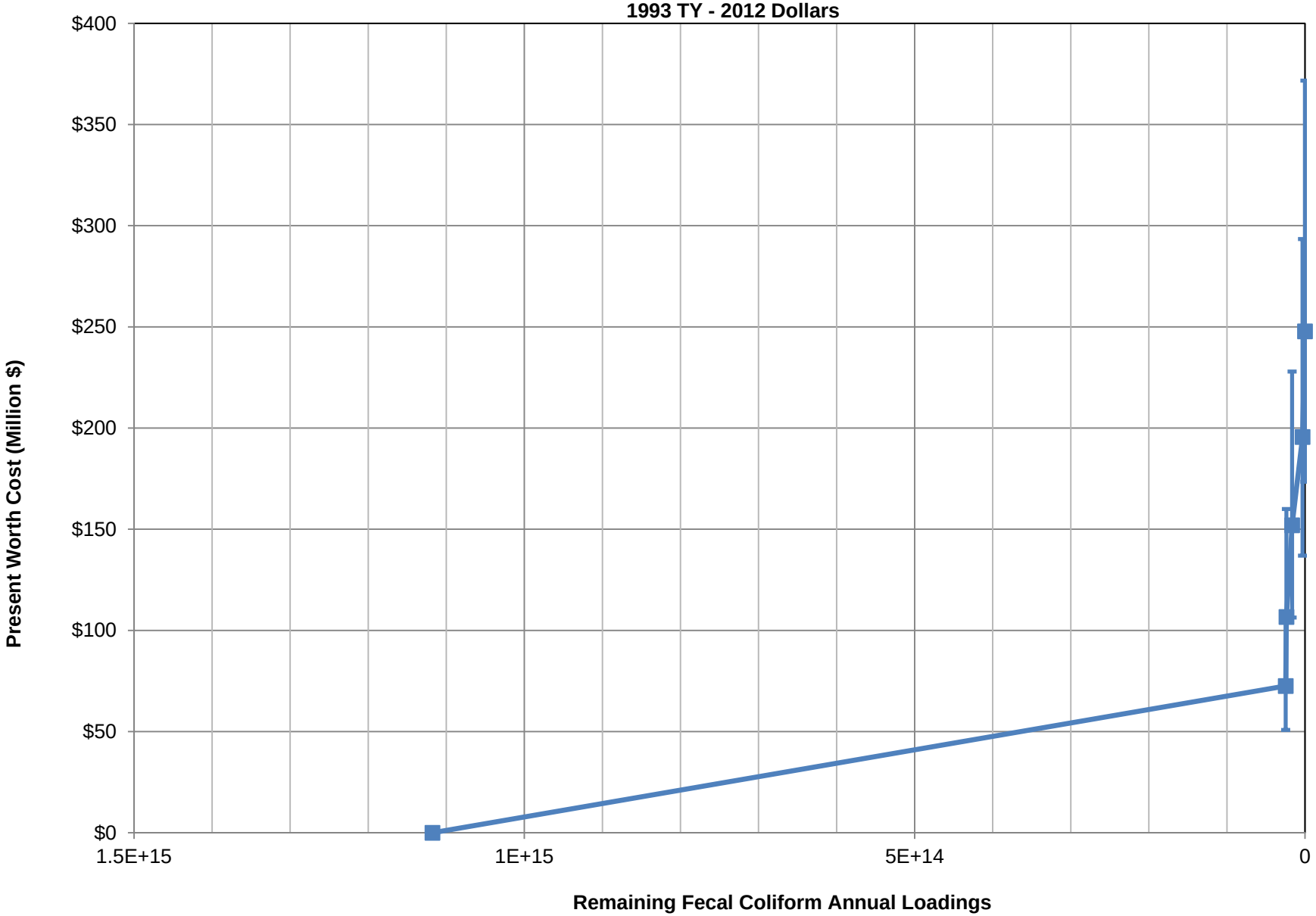


Figure Q: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Buffalo River
(System-wide Alternative UA1)
1993 TY - 2012 Dollars (includes O&M)

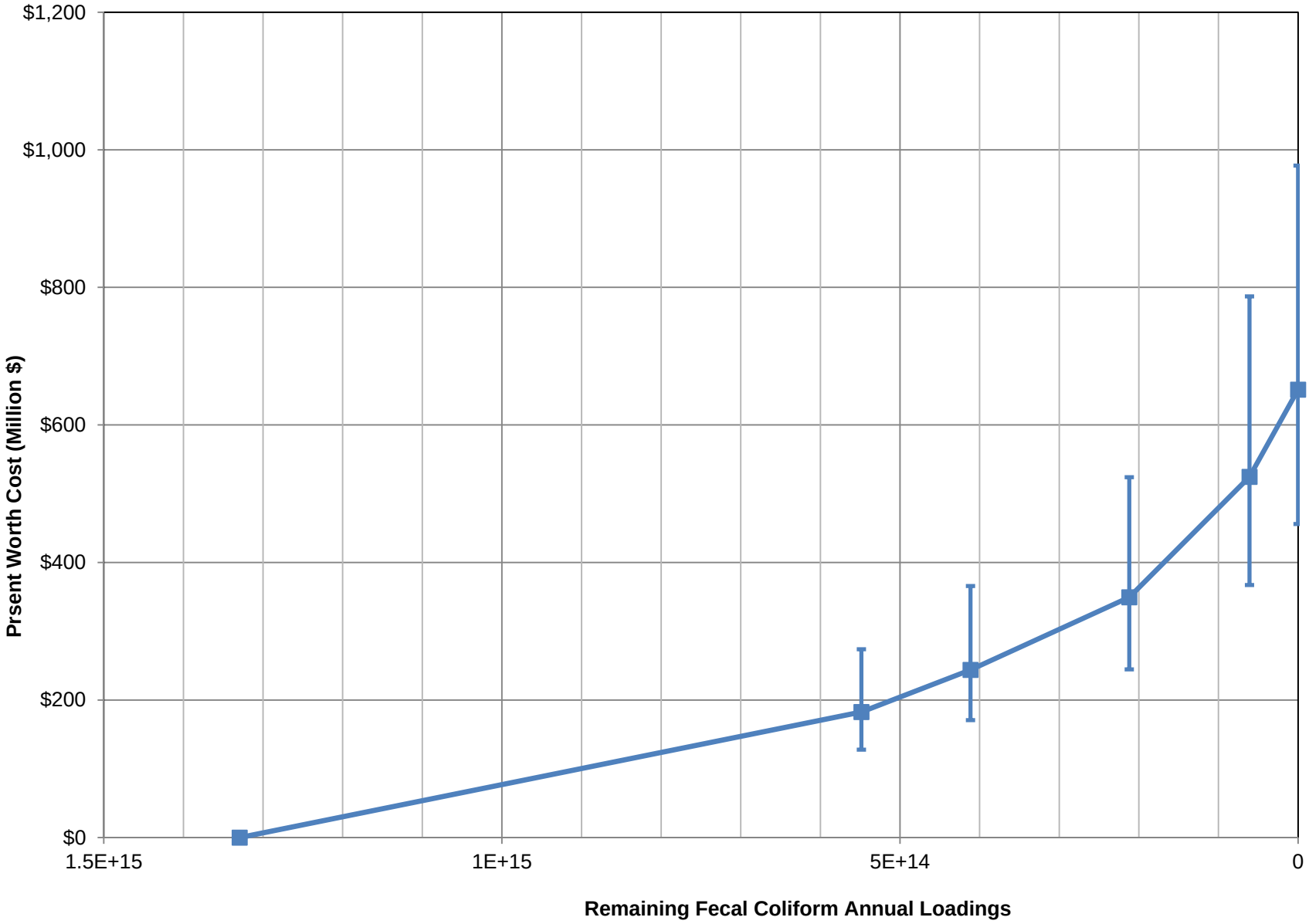


Figure R: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Cazenovia Creek (B)
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

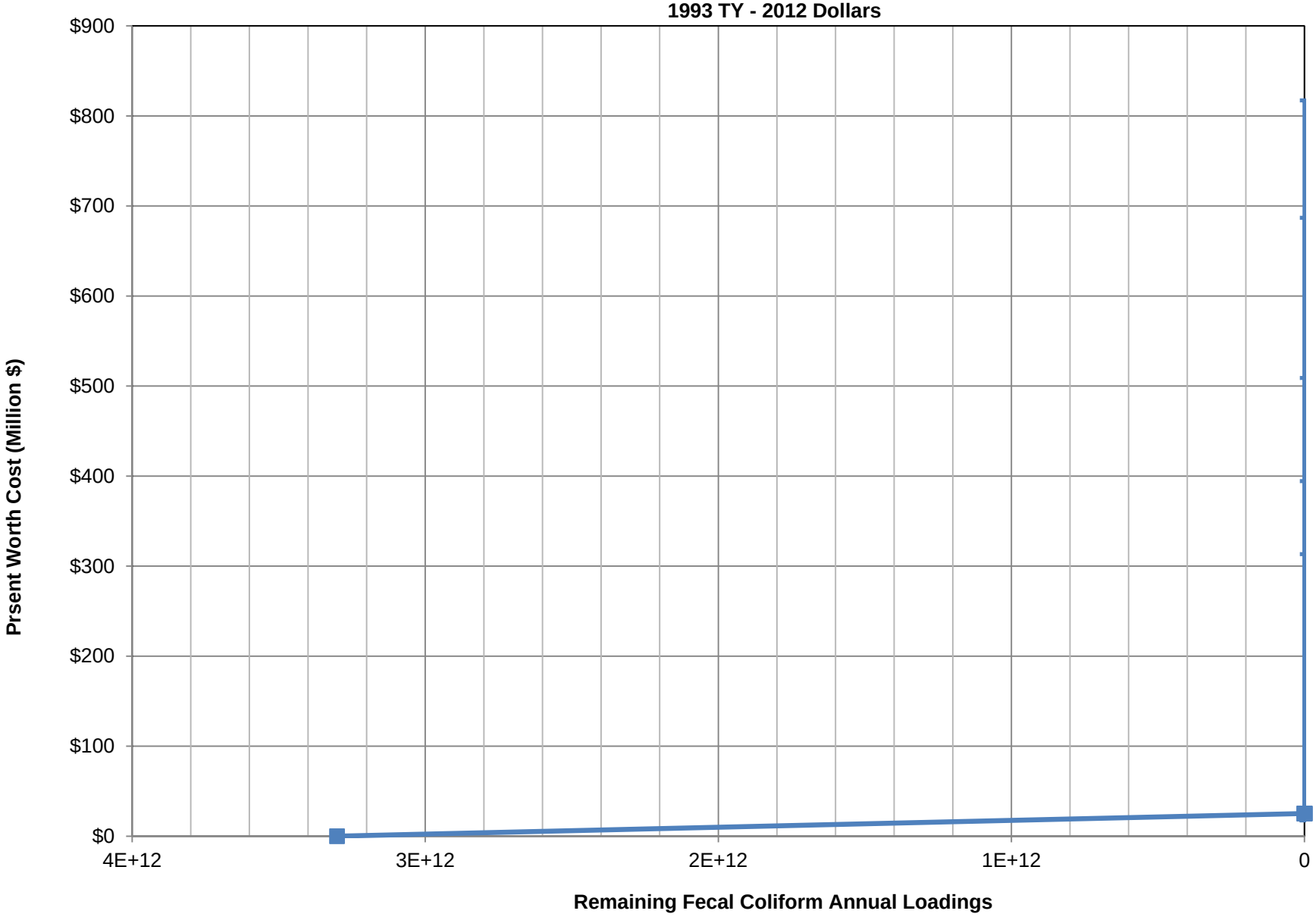


Figure S: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Cazenovia Creek (C)
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

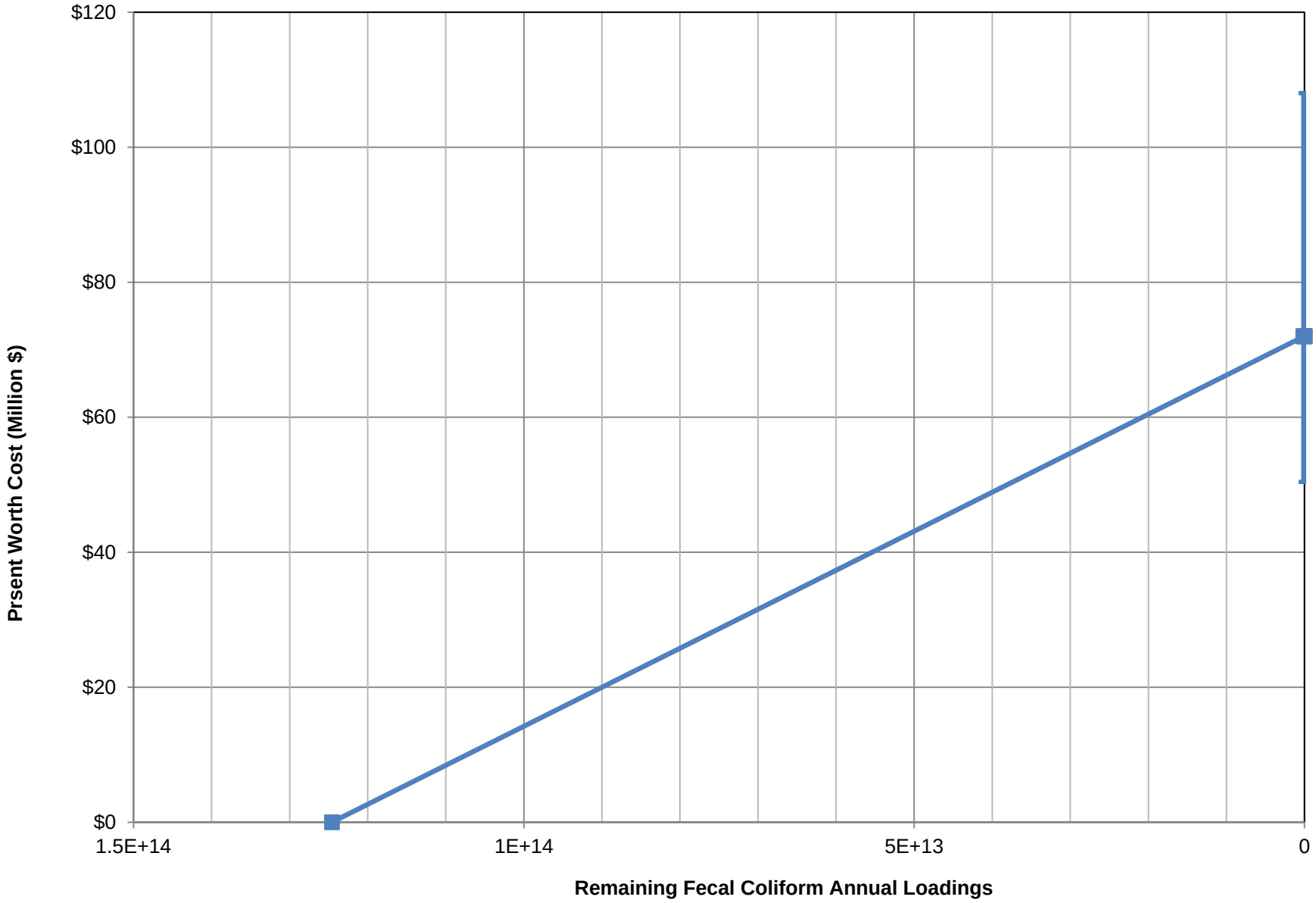


Figure T: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Niagara River - CSO 055 (System-wide Alternative UA1) 1993 TY - 2012 Dollars

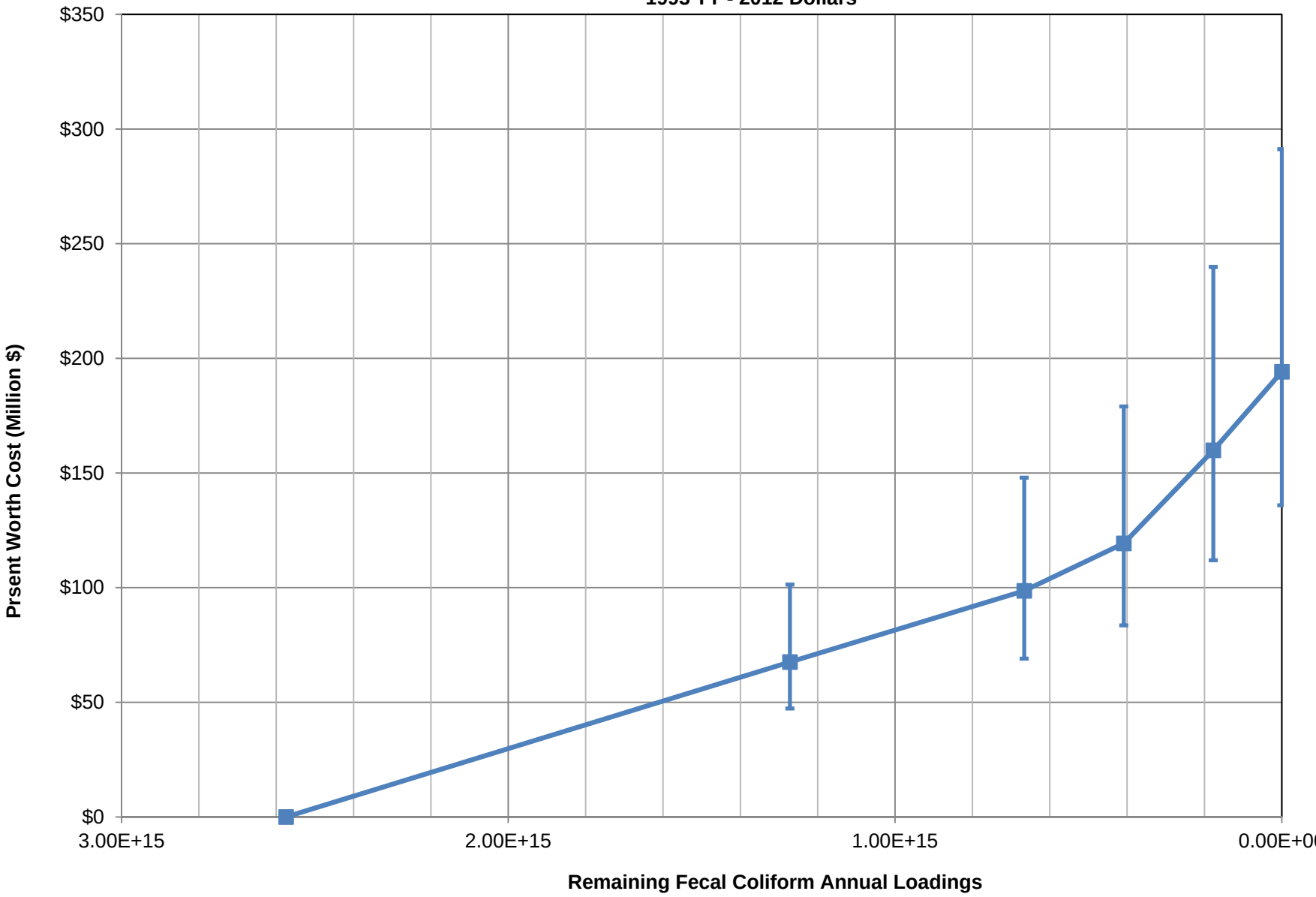


Figure U: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Erie Basin
(System-wide Alternative UA1)
1993 TY - 2012 Dollars

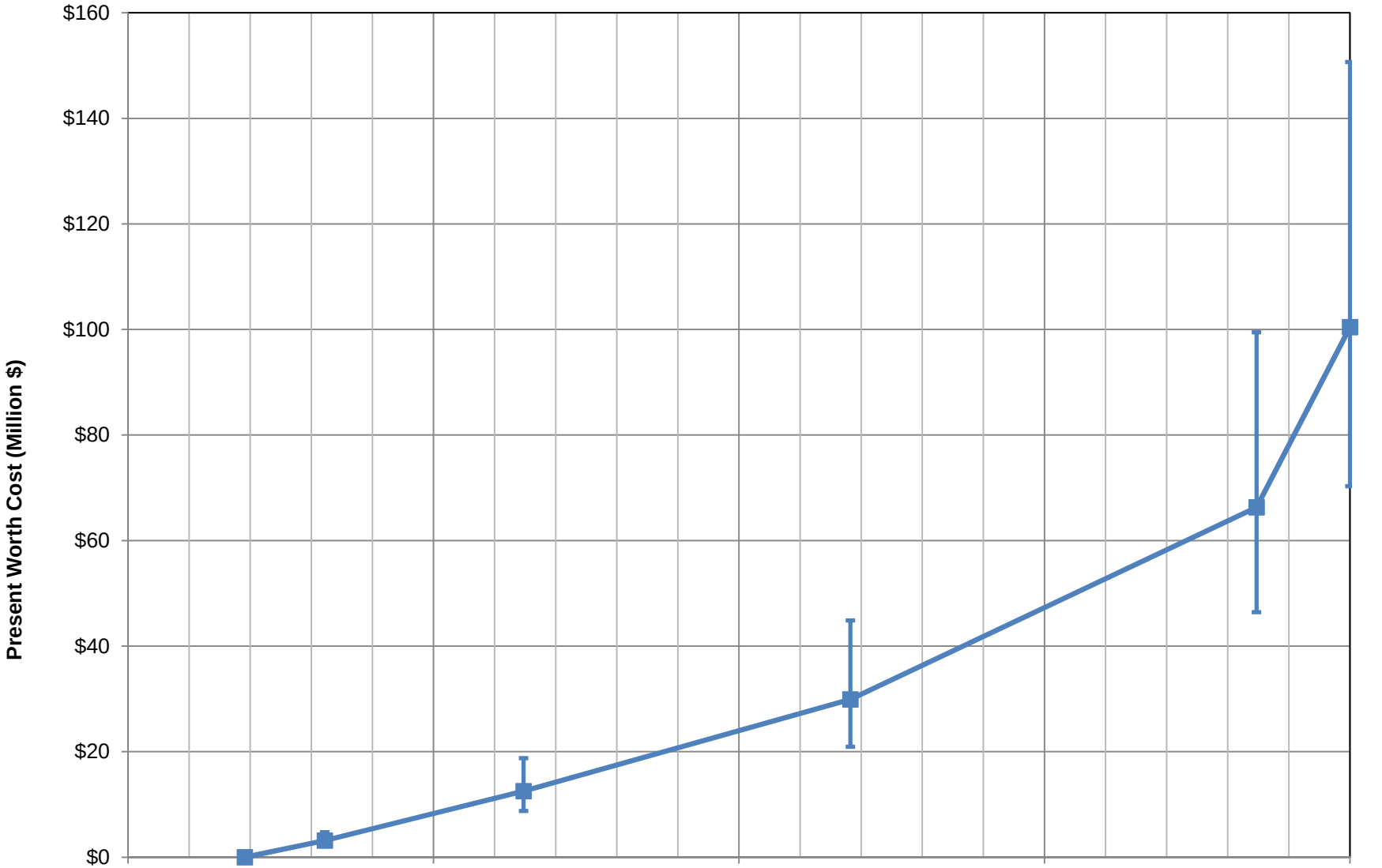
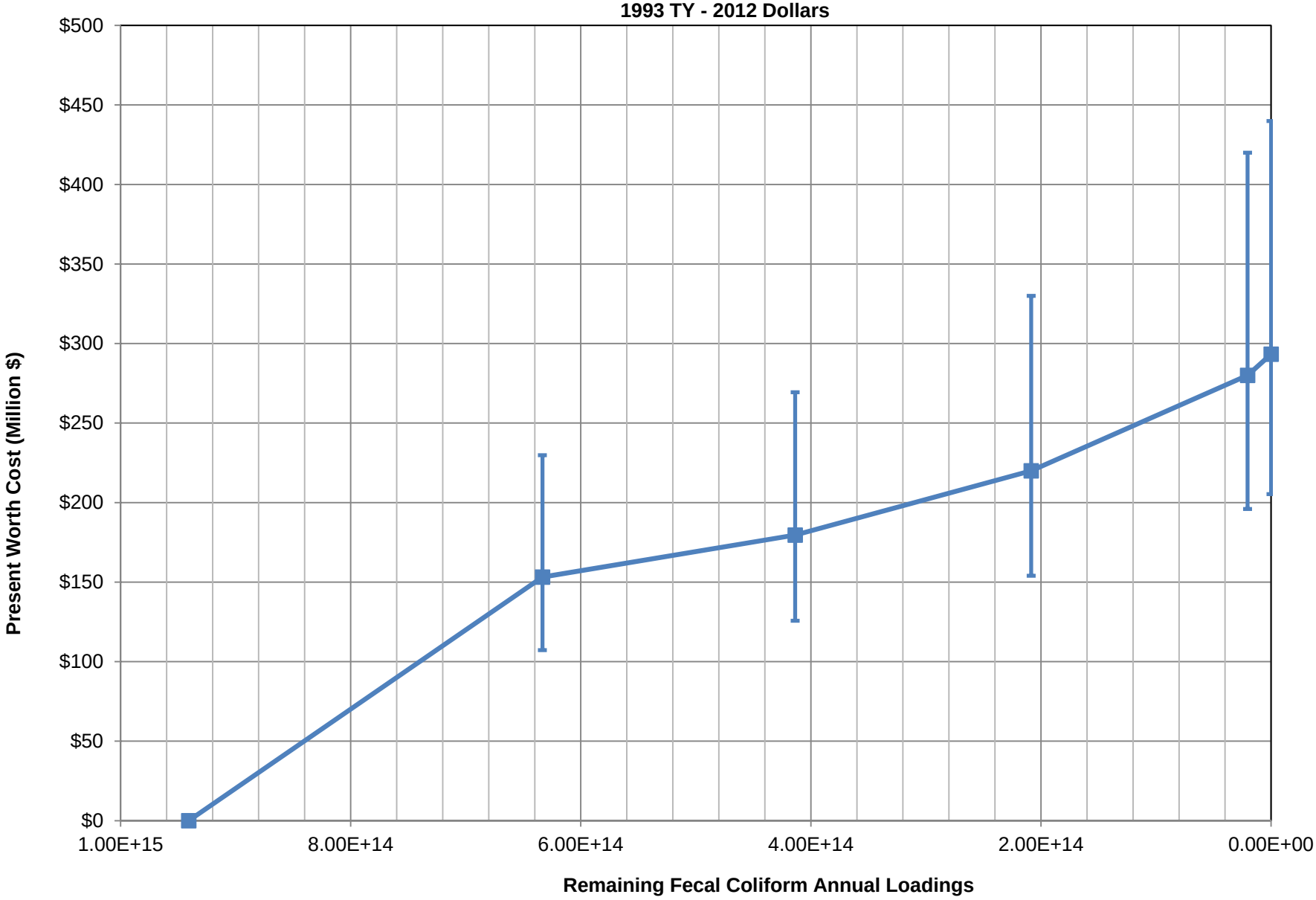


Figure V: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Scajaquada Creek
(System-wide Alternative UA1)
1993 TY - 2012 Dollars



Alternative UA1 Overflow Volume Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	Revised Baseline 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA1 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA1 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA1 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA1 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)
004	Scajaquada	Black Rock Canal	16.2	11.2	0.0	0.0	0.0	0.0
005	Scajaquada	Black Rock Canal	0.1	0.1	0.1	0.1	0.1	0.1
006	Scajaquada	Black Rock Canal	201.4	198.9	To Tunnel	To Tunnel	To Tunnel	To Tunnel
008	Scajaquada	Black Rock Canal	8.2	6.1	Closed	Closed	Closed	Closed
010	Scajaquada	Black Rock Canal	11.8	11.9	To Tunnel	To Tunnel	To Tunnel	To Tunnel
012	Albany	Black Rock Canal	52.0	52.5	0.0	0.0	0.0	0.0
013	South Central	Black Rock Canal	13.6	6.8	6.7	6.7	4.6	0.8
061	Scajaquada	Black Rock Canal	33.8	31.2	0.0	0.0	0.0	0.0
063	South Central	Black Rock Canal	1.5	0.6	0.2	To storage	To storage	To storage
017	South Central	Buffalo River	101.6	71.3	46.2	41.3	13.8	5.4
022	South Central	Buffalo River	42.7	29.8	0.1	0.1	0.3	0.1
025	South Central	Buffalo River	1.4	1.4	0.6	0.6	0.2	0.1
026	South Central	Buffalo River	146.5	124.2	44.3	24.9	13.0	2.2
027	South Central	Buffalo River	19.4	31.7	16.1	14.6	12.9	7.2
028	South Central	Buffalo River	44.4	45.5	16.3	10.0	3.6	0.4
029	South Central	Buffalo River	0.0	0.0	To storage	To storage	To storage	To storage
032	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
033	South Central	Buffalo River	35.7	37.8	18.7	15.8	9.5	0.7
034	South Central	Buffalo River	0.1	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
050	South Central	Buffalo River	4.1	3.2	0.0	0.0	0.0	0.0
051	South Central	Buffalo River	3.7	1.2	0.2	0.2	0.2	0.1
052	South Central	Buffalo River	13.6	10.9	6.3	6.2	2.9	0.1
064	South Central	Buffalo River	27.2	21.1	0.0	0.0	2.5	0.7
066	South Central	Buffalo River	2.5	1.7	7.9	3.7	1.5	0.6
035	South Central	Cazenovia Creek - B	4.8	0.9	0.0	0.0	0.0	0.0
037	South Central	Cazenovia Creek - C	21.2	23.3	0.0	0.0	0.0	0.0
039	South Central	Cazenovia Creek - C	0.0	0.0	0.0	0.0	0.0	0.0
044	South Central	Cazenovia Creek - C	6.5	2.3	0.0	0.0	0.0	0.0
046	South Central	Cazenovia Creek - C	1.1	1.3	0.0	0.0	0.0	0.0
047	South Central	Cazenovia Creek - C	10.4	8.7	0.0	0.0	0.0	0.0
048	South Central	Cazenovia Creek - C	1.5	0.0	0.0	0.0	0.0	0.0
055	Hertel	Cornelius Creek	613.6	601.1	194.5	97.2	60.2	23.1
014	South Central	Erie Basin	25.9	4.2	3.6	3.6	3.6	0.4
015	South Central	Erie Basin	5.7	6.1	6.0	4.2	1.1	0.5
016	South Central	Erie Basin	0.0	0.0	0.0	0.0	0.0	0.0
003	Parish	Niagara River	4.5	0.0	0.0	0.0	0.0	0.0
011	Albany	Niagara River	125.7	134.3	To Tunnel	To Tunnel	To Tunnel	To Tunnel
054	Ontario	Niagara River	0.1	0.0	0.0	0.0	0.0	0.0
053	Scajaquada	Scajaquada Creek	275.0	268.0	To Tunnel	To Tunnel	To Tunnel	To Tunnel
056	Hertel	Scajaquada Creek	0.0	0.0	0.0	0.0	0.0	0.0
057	Parish	Scajaquada Creek	0.3	0.0	0.0	0.0	0.0	0.0
058	Parish	Scajaquada Creek	0.0	0.0	0.0	0.0	0.0	0.0
059	Scajaquada	Scajaquada Creek	5.1	0.0	0.0	0.0	0.0	0.0
060	Scajaquada	Scajaquada Creek	2.9	0.7	0.7	0.7	0.6	0.1
ScNSTof	-	Niagara River	Closed	NA	168.7	93.1	56.5	27.5
ScEWTof	-	Scajaquada Creek	Closed	NA	180.2	117.4	58.9	5.7
Totals			1886	1750	368	230	131	42

Total CSO Combined Only Volume by District (MG)	Albany		177.7	186.8	0.0	0.0	0.0	0.0
	Hertel		613.7	601.1	194.6	97.2	60.2	23.1
	Ontario		0.1	0.0	0.0	0.0	0.0	0.0
	Parish		4.7	0.0	0.0	0.0	0.0	0.0
	Scajaquada		554.7	528.1	0.7	0.7	0.7	0.2
	South Central		535.2	434.0	173.2	132.0	69.9	19.1
Total CSO Combined Only Volume by Receiving Water (MG)		Black Rock Canal	338.7	319.3	7.0	6.8	4.7	0.9
		Buffalo River	442.9	379.7	156.6	117.5	60.6	17.4
		Cazenovia Creek - B	4.8	0.9	0.0	0.0	0.0	0.0
		Cazenovia Creek - C	40.7	35.6	0.0	0.0	0.0	0.0
		Cornelius Creek	613.6	601.1	194.5	97.2	60.2	23.1
		Erie Basin	31.6	10.3	9.6	7.7	4.7	0.9
		Niagara River	130.2	134.3	168.7	93.1	56.5	27.5
		Scajaquada Creek	283.4	268.7	180.9	118.1	59.6	5.8

Alternative UA1 Overflow Frequency Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA1 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA1 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA1 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA1 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency
004	Scajaquada	Black Rock Canal	7	5	0	0	0	0
005	Scajaquada	Black Rock Canal	0	4	4	4	4	2
006	Scajaquada	Black Rock Canal	65	65	To Tunnel	To Tunnel	To Tunnel	To Tunnel
008	Scajaquada	Black Rock Canal	42	39	Closed	Closed	Closed	Closed
010	Scajaquada	Black Rock Canal	44	44	To Tunnel	To Tunnel	To Tunnel	To Tunnel
012	Albany	Black Rock Canal	42	42	0	0	0	0
013	South Central	Black Rock Canal	14	7	7	7	4	2
061	Scajaquada	Black Rock Canal	10	10	0	0	0	0
063	South Central	Black Rock Canal	50	13	6	To storage	To storage	To storage
017	South Central	Buffalo River	55	49	7	4	3	2
022	South Central	Buffalo River	55	49	1	1	1	1
025	South Central	Buffalo River	11	11	5	5	4	2
026	South Central	Buffalo River	61	63	12	5	4	1
027	South Central	Buffalo River	36	36	11	5	3	2
028	South Central	Buffalo River	69	69	10	6	4	2
029	South Central	Buffalo River	0	0	To storage	To storage	To storage	To storage
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	8	9	11	5	4	2
034	South Central	Buffalo River	5	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0	0	0	0	0	0
050	South Central	Buffalo River	22	14	1	1	1	1
051	South Central	Buffalo River	16	4	3	3	3	1
052	South Central	Buffalo River	11	10	4	4	4	2
064	South Central	Buffalo River	55	56	0	0	3	1
066	South Central	Buffalo River	16	10	11	4	4	2
035	South Central	Cazenovia Creek - B	29	5	0	0	0	0
037	South Central	Cazenovia Creek - C	14	13	0	0	0	0
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	15	7	0	0	0	0
046	South Central	Cazenovia Creek - C	9	1	0	0	0	0
047	South Central	Cazenovia Creek - C	47	44	0	0	0	0
048	South Central	Cazenovia Creek - C	12	0	0	0	0	0
055	Hertel	Cornelius Creek	40	41	10	6	4	2
014	South Central	Erie Basin	17	4	4	4	4	2
015	South Central	Erie Basin	12	12	9	6	4	2
016	South Central	Erie Basin	3	0	0	0	0	0
003	Parish	Niagara River	27	0	0	0	0	0
011	Albany	Niagara River	41	41	To Tunnel	To Tunnel	To Tunnel	To Tunnel
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	65	65	To Tunnel	To Tunnel	To Tunnel	To Tunnel
056	Hertel	Scajaquada Creek	5	5	5	5	0	0
057	Parish	Scajaquada Creek	11	0	0.0	0.0	0.0	0.0
058	Parish	Scajaquada Creek	2	7	0.0	0.0	0.0	0.0
059	Scajaquada	Scajaquada Creek	17	11	0.0	0.0	0.0	0.0
060	Scajaquada	Scajaquada Creek	11	5	5	5	2	2
ScNSTof	-	Niagara River	Closed	Closed	12.0	6.0	2.0	2.0
ScEWTof	-	Scajaquada Creek	Closed	Closed	11.0	6.0	3.0	1.0

Max Events	Albany		42	42	0	0	0	0
	Hertel		40	41	10	6	4	2
	Ontario		4	0	0	0	0	0
	Parish		27	7	0	0	0	0
	Scajaquada		65	65	5	5	2	2
	South Central		69	69	12	7	4	2
Max Events		Black Rock Canal	65	65	7	7	4	2
		Buffalo River	69	69	12	6	4	2
		Cazenovia Creek - B	29	5	0	0	0	0
		Cazenovia Creek - C	47	44	0	0	0	0
		Cornelius Creek	40	41	10	6	4	2
		Erie Basin	17	12	9	6	4	2
		Niagara River	41	41	12	6	2	2
		Scajaquada Creek	65	65	5	5	2	2

Alternative UA1 Overflow Duration Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA1 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA1 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA1 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA1 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)
004	Scajaquada	Black Rock Canal	12	8	0	0	0	0
005	Scajaquada	Black Rock Canal	5	5	5	5	5	5
006	Scajaquada	Black Rock Canal	322	344	To Tunnel	To Tunnel	To Tunnel	To Tunnel
008	Scajaquada	Black Rock Canal	105	90	Closed	Closed	Closed	Closed
010	Scajaquada	Black Rock Canal	103	103	To Tunnel	To Tunnel	To Tunnel	To Tunnel
012	Albany	Black Rock Canal	111	111	0	0	0	0
013	South Central	Black Rock Canal	58	25	40	40	38	21
061	Scajaquada	Black Rock Canal	31	29	0	0	0	0
063	South Central	Black Rock Canal	110	19	9	To storage	To storage	To storage
017	South Central	Buffalo River	166	124	23	16	9	3
022	South Central	Buffalo River	166	124	2	2	3	2
025	South Central	Buffalo River	17	17	9	9	8	2
026	South Central	Buffalo River	232	247	35	17	10	2
027	South Central	Buffalo River	127	131	31	16	13	7
028	South Central	Buffalo River	328	328	24	17	8	3
029	South Central	Buffalo River	0	0	To storage	To storage	To storage	To storage
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	20	21	28	14	11	3
034	South Central	Buffalo River	8	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0	0	0	0	0	0
050	South Central	Buffalo River	47	22	1	1	1	1
051	South Central	Buffalo River	56	14	5	5	5	1
052	South Central	Buffalo River	112	70	47	47	36	2
064	South Central	Buffalo River	166	181	0	0	9	1
066	South Central	Buffalo River	26	17	25	7	6	2
035	South Central	Cazenovia Creek - B	55	9	0	0	0	0
037	South Central	Cazenovia Creek - C	42	40	0	0	0	0
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	37	12	0	0	0	0
046	South Central	Cazenovia Creek - C	37	1	0	0	0	0
047	South Central	Cazenovia Creek - C	108	94	0	0	0	0
048	South Central	Cazenovia Creek - C	42	0	0	0	0	0
055	Hertel	Cornelius Creek	184	174	63	24	18	8
014	South Central	Erie Basin	61	15	14	14	14	2
015	South Central	Erie Basin	43	43	18	8	5	2
016	South Central	Erie Basin	4	0	0	0	0	0
003	Parish	Niagara River	224	32	32	32	31	22
011	Albany	Niagara River	240	243	To Tunnel	To Tunnel	To Tunnel	To Tunnel
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	322	344	To Tunnel	To Tunnel	To Tunnel	To Tunnel
056	Hertel	Scajaquada Creek	8	8	8	8	0	0
057	Parish	Scajaquada Creek	15	0	To Tunnel	To Tunnel	To Tunnel	To Tunnel
058	Parish	Scajaquada Creek	2	10	To Tunnel	To Tunnel	To Tunnel	To Tunnel
059	Scajaquada	Scajaquada Creek	45	26	To Tunnel	To Tunnel	To Tunnel	To Tunnel
060	Scajaquada	Scajaquada Creek	25	11	11	11	8	2
ScNSTof	-	-	Closed	Closed	126.0	55.0	29.0	26.0
ScEWTof	-	-	Closed	Closed	76.0	46.0	22.0	4.0

APPENDIX 11-4

ALTERNATIVE UA2 - Real Time Control/Green Infrastructure, HRT at Plant, and Revised Foundation

FINANCIAL ASSUMPTIONS

Current ENR CCI:	9,011	i (interest rate):	5.00%
2004 BSA LTCP ENR CCI:	6,695	j (discount rate):	2.50%
Project Contingency Percentage:	25%	t (time horizon for plan):	20
Engineering Percentage:	15%	Present Worth Factor:	15.30
O/M Contingency Percentage:	10%	Assumed Escalation (for O&M) per year:	3.50%

REVISED 4/14/2012 AT 12:35 PM TO ADD HRT DISINFECTION

Storage (data provided by collection system modeling)

BSA 2004 COST CURVE (unit cost per gal stored) $Cost = 220 * V^{-0.27}$

ALCOSAN COST CURVE (Dec 2008) $Cost = 3.4 \times V^{0.826}$

EPA CSO Cost Manual (using costs for sed basins) - 1995 $Cost_{O\&M} = 15.174 \times Capacity^{[illegible]}$

(Calculated using ALCOSAN cost curve (Dec 2008))

	Receiving Basin	Volume (MG)					Construction Cost ($ millions) - Updated BSA Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-013	Black Rock Canal	2.25	1.20	0.27	0	0	$12.85	$8.11	$2.73	$0.00	$0.00
CSO-028/044/047	Buffalo River	0.0	0	0	2.32	0.62	$0.00	$0.00	$0.00	$13.13	$5.01
CSO-052	Buffalo River	0.0	0	0	0.6	0	$0.00	$0.00	$0.00	$4.89	$0.00
CSO-064	Buffalo River	0.0	0	0	0.1	0	$0.00	$0.00	$0.00	$1.32	$0.00
CSO-055	Cornelius Creek	71.16	36.00	25.00	17.50	5.00	$159.80	$97.17	$74.46	$57.39	$23.00
CSO-014/015	Erie Basin	3.55	0.83	0.25	0	0	$17.92	$6.20	$2.58	$0.00	$0.00
CSO-060	Scajaquada Creek	0.42	0	0	0	0	$3.75	$0.00	$0.00	$0.00	$0.00
SPP337	Scajaquada Creek	0.0	0	0.70	0.45	0	$0.00	$0.00	$5.48	$3.97	$0.00
Jefferson & Florida (SPP170B)	Scajaquada Creek	0.0	0	2.60	1.70	0.83	$0.00	$0.00	$14.27	$10.46	$6.20
SPP165A, SPP165B, SPP336A, SPP336B	Scajaquada Creek	0.0	0	4.10	2.55	0.77	$0.00	$0.00	$19.90	$14.07	$5.87
Total		**77.38**	**38.03**	**32.92**	**25.22**	**7.22**	***$194.32***	***$111.49***	***$119.42***	***$105.24***	***$40.08***

	Construction Cost ($ millions) - ALCOSAN Curve					O/M Cost Present Worth ($ millions)					Total Present Worth Cost ($)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-013	$7.01	$4.17	$1.22	$0	$0	$0.63	$0.45	$0.19	$0.00	$0.00	$7.64	$4.61	$1.41	$0.00	$0.00
CSO-028/044/047	$0	$0	$0	$7.18	$2.41	$0.00	$0.00	$0.00	$0.65	$0.31	$0.00	$0.00	$0.00	$7.83	$2.72
CSO-052	$0	$0	$0	$2.35	$0	$0.00	$0.00	$0.00	$0.30	$0.00	$0.00	$0.00	$0.00	$2.65	$0.00
CSO-064	$0	$0	$0	$0.54	$0	$0.00	$0.00	$0.00	$0.11	$0.00	$0.00	$0.00	$0.00	$0.65	$0.00
CSO-055	$121.39	$69.14	$51.16	$38.11	$13.54	$4.38	$2.99	$2.44	$2.00	$0.99	$125.77	$72.13	$53.60	$40.10	$14.53
CSO-014/015	$10.21	$3.07	$1.14	$0	$0	$0.82	$0.36	$0.19	$0.00	$0.00	$11.02	$3.44	$1.33	$0.00	$0.00
CSO-060	$1.74	$0	$0	$0	$0	$0.25	$0.00	$0.00	$0.00	$0.00	$1.99	$0.00	$0.00	$0.00	$0.00
SPP337	$0	$0	$2.67	$1.85	$0	$0.00	$0.00	$0.33	$0.26	$0.00	$0.00	$0.00	$3.00	$2.11	$0.00
Jefferson & Florida (SPP170B)	$0	$0	$7.89	$5.55	$3.07	$0.00	$0.00	$0.69	$0.54	$0.36	$0.00	$0.00	$8.58	$6.10	$3.44
SPP165A, SPP165B, SPP336A, SPP336B	$0	$0	$11.49	$7.76	$2.89	$0.00	$0.00	$0.89	$0.68	$0.35	$0.00	$0.00	$12.38	$8.44	$3.24
Total	***$140.34***	***$76.38***	***$75.57***	***$63.34***	***$21.91***	***$6.08***	***$3.80***	***$4.72***	***$4.53***	***$2.01***	***$146.42***	***$80.18***	***$80.28***	***$67.87***	***$23.92***

Storage Consolidation Piping (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length	Diameter (ft)	Unit Cost ($/ft)	Construction Cost ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
SPP336a	Scajaquada Creek	44	2.5	$289	$0.00	$0.00	$0.01	$0.01	$0.01
SPP336b	Scajaquada Creek	107	5	$645	$0.00	$0.00	$0.07	$0.07	$0.07
SPP336a&b	Scajaquada Creek	1,547	5	$645	$0.00	$0.00	$1.00	$1.00	$1.00
SPP170b	Scajaquada Creek	1,036	5	$645	$0.00	$0.00	$0.67	$0.67	$0.67
SPP165a&b	Scajaquada Creek	123	3	$362	$0.00	$0.00	$0.04	$0.04	$0.04
SPP 178	Scajaquada Creek	1,385	3.5	$420	$0.00	$0.00	$0.58	$0.00	$0.00
SPP337	Scajaquada Creek	28	4.5	$559	$0.00	$0.00	$0.02	$0.02	$0.00
CSO 013	Black Rock Canal	94	4	$478	$0.05	$0.05	$0.05	$0.00	$0.00
CSO 015	Erie Basin	51	3.5	$420	$0.02	$0.02	$0.02	$0.00	$0.00
CSO 014	Erie Basin	1,180	4.5	$559	$0.66	$0.66	$0.00	$0.00	$0.00
CSO 028	Buffalo River	268	6.5	$953	$0.00	$0.00	$0.00	$0.26	$0.26
CSO 047	Buffalo River	3,061	3.5	$420	$0.00	$0.00	$0.00	$1.29	$1.29
CSO 052	Buffalo River	176	2.5	$289	$0.00	$0.00	$0.00	$0.05	$0.00
CSO 055	Cornelius Creek	1,282	9	$1,633	$2.09	$2.09	$2.09	$2.09	$2.09
CSO 060	Scajaquada Creek	80	2.5	$289	$0.02	$0.00	$0.00	$0.00	$0.00
CSO 064	Buffalo River	30	3.5	$420	$0.00	$0.00	$0.00	$0.01	$0.00
Total		**10,492**			***$2.84***	***$2.82***	***$4.55***	***$5.50***	***$5.42***

Storage Dewatering Force Main (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter) (O&M costs assumed to be zero)

	Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Construction Cost ($ millions)				
			0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-013	Black Rock Canal	368	12	8	4	0	0	$68	$46	$32	$0	$0	$0.03	$0.02	$0.01	$0.00	$0.00
CSO-028/044/047	Buffalo River	597	0	0	0	12	6	$0	$0	$0	$68	$40	$0.00	$0.00	$0.00	$0.04	$0.02
CSO-052	Buffalo River	1336	0	0	0	6	0	$0	$0	$0	$40	$0	$0.00	$0.00	$0.00	$0.05	$0.00
CSO-064	Buffalo River	1997	0	0	0	4	0	$0	$0	$0	$32	$0	$0.00	$0.00	$0.00	$0.06	$0.00
CSO-055	Cornelius Creek	707	60	42	36	30	16	$553	$299	$240	$193	$102	$0.39	$0.21	$0.17	$0.14	$0.07
CSO-014/015	Erie Basin	525	14	8	4	0	0	$84	$46	$32	$0	$0	$0.04	$0.02	$0.02	$0.00	$0.00
CSO-060	Scajaquada Creek	598	6	0	0	0	0	$40	$0	$0	$0	$0	$0.02	$0.00	$0.00	$0.00	$0.00
SPP337	Scajaquada Creek	119	0	0	6	6	0	$0	$0	$40	$40	$0	$0.00	$0.00	$0.01	$0.01	$0.00
Jefferson & Florida (SPP170B)	Scajaquada Creek	230	0	0	12	10	8	$0	$0	$68	$54	$46	$0.00	$0.00	$0.02	$0.01	$0.01
SPP165A, SPP165B, SPP336A, SPP336B	Scajaquada Creek	86	0	0	14	12	6	$0	$0	$84	$68	$40	$0.00	$0.00	$0.01	$0.01	$0.00
Total		**6,562**											***$0.48***	***$0.25***	***$0.23***	***$0.32***	***$0.11***

High Rate Treatment (data provided by collection system modeling)

ALCOSAN COST CURVE (DEC 2008) $Price = 640{,}000 \times Capacity^{[illegible]}$

ALCOSAN COST CURVE (DEC 2008) $Cost_{O\&M} = 98.251Q^{[illegible]}$

BSA O&M $O/MCost = 4347.2 \times Flow + 18228$

ALCOSAN COST CURVE (DEC 2008) - Intermed. Cost $Cost = 385002 \times Flow(inMGD)^{0.8941}$

ALCOSAN COST CURVE (DEC 2008) - Source 1 $Cost = (770.4 + 925.8) \times Flow + (536.98 + 18536)$

(Addition of O/M Cost for HRT and for PS)

(Using AlCOSAN cost curves)

	Receiving Basin	Peak Flow (mgd)					Construction Cost ($ millions) - Alcosan Curve					Present Worth O/M Cost ($ millions) - Alcosan Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-017	Buffalo River	75.0	40.8	0.0	0.0	0.0	$14.34	$9.32	$0.00	$0.00	$0.00	$20.75	$14.46	$0.00	$0.00	$0.00
CSO-022	Buffalo River	11.3	5.7	4.0	0.0	0.0	$3.75	$2.31	$1.80	$0.00	$0.00	$6.76	$4.51	$3.66	$0.00	$0.00
CSO-025	Buffalo River	9.1	4.2	1.0	0.0	0.0	$3.21	$1.86	$0.67	$0.00	$0.00	$5.94	$3.77	$1.61	$0.00	$0.00
CSO-026	Buffalo River	118.7	27.2	0.0	0.0	0.0	$19.84	$6.99	$0.00	$0.00	$0.00	$27.21	$11.37	$0.00	$0.00	$0.00
CSO-027	Buffalo River	88.2	36.6	10.0	0.0	0.0	$16.08	$8.63	$3.44	$0.00	$0.00	$22.83	$13.56	$6.29	$0.00	$0.00
CSO-028/044/047	Buffalo River	100.1	71.2	46.5	0.0	0.0	$17.59	$13.81	$10.22	$0.00	$0.00	$24.61	$20.11	$15.63	$0.00	$0.00
CSO-033	Buffalo River	85.9	66.1	26.0	0.0	0.0	$15.79	$13.11	$6.77	$0.00	$0.00	$22.48	$19.25	$11.08	$0.00	$0.00
CSO-050	Buffalo River	12.1	7.2	3.3	0.0	0.0	$3.94	$2.73	$1.57	$0.00	$0.00	$7.05	$5.18	$3.27	$0.00	$0.00
CSO-051/052/066	Buffalo River	44.6	20.0	4.8	0.0	0.0	$9.92	$5.62	$2.05	$0.00	$0.00	$15.24	$9.49	$4.08	$0.00	$0.00
CSO-064	Buffalo River	14.2	4.5	4.0	0.0	0.0	$4.40	$1.96	$1.80	$0.00	$0.00	$7.73	$3.92	$3.66	$0.00	$0.00
CSO-037	Cazenovia Creek - C	46.3	29.2	16.1	0.0	0.0	$10.19	$7.35	$4.83	$0.00	$0.00	$15.59	$11.86	$8.35	$0.00	$0.00
Bird Island	Black Rock Canal	370.0	260.0	0.0	0.0	0.0	$44.38	$34.57	$0.00	$0.00	$0.00	$53.36	$43.30	$0.00	$0.00	$0.00
Total		**975**	**573**	**116**	**0**	**0**	***$163.44***	***$108.26***	***$33.16***	***$0.00***	***$0.00***	***$229.55***	***$160.78***	***$57.62***	***$0.00***	***$0.00***

	Present Worth O/M Cost ($ millions) - BSA Curve					HRT PS Const Cost ($ millions) - ALCOSAN Curve					PW HRT PS O/M Cost ($ millions) - ALCOSAN Curve				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-017	$6.70	$3.81	$0.00	$0.00	$0.00	$19.27	$11.17	$0.00	$0.00	$0.00	$2.48	$1.50	$0.00	$0.00	$0.00
CSO-022	$1.31	$0.84	$0.69	$0.00	$0.00	$3.55	$1.92	$1.40	$0.00	$0.00	$0.65	$0.49	$0.44	$0.00	$0.00
CSO-025	$1.12	$0.71	$0.44	$0.00	$0.00	$2.91	$1.46	$0.41	$0.00	$0.00	$0.58	$0.44	$0.35	$0.00	$0.00
CSO-026	$10.39	$2.65	$0.00	$0.00	$0.00	$29.03	$7.77	$0.00	$0.00	$0.00	$3.74	$1.11	$0.00	$0.00	$0.00
CSO-027	$7.82	$3.45	$1.20	$0.00	$0.00	$22.27	$10.14	$3.18	$0.00	$0.00	$2.86	$1.38	$0.61	$0.00	$0.00
CSO-028/044/047	$8.82	$6.37	$4.29	$0.00	$0.00	$24.93	$18.38	$12.56	$0.00	$0.00	$3.20	$2.37	$1.66	$0.00	$0.00
CSO-033	$7.63	$5.95	$2.55	$0.00	$0.00	$21.76	$17.21	$7.47	$0.00	$0.00	$2.80	$2.23	$1.07	$0.00	$0.00
CSO-050	$1.38	$0.96	$0.64	$0.00	$0.00	$3.78	$2.37	$1.18	$0.00	$0.00	$0.67	$0.53	$0.42	$0.00	$0.00
CSO-051/052/066	$4.12	$2.05	$0.76	$0.00	$0.00	$12.09	$5.91	$1.65	$0.00	$0.00	$1.61	$0.90	$0.46	$0.00	$0.00
CSO-064	$1.55	$0.74	$0.69	$0.00	$0.00	$4.34	$1.56	$1.40	$0.00	$0.00	$0.73	$0.45	$0.44	$0.00	$0.00
CSO-037	$4.27	$2.82	$1.72	$0.00	$0.00	$12.52	$8.29	$4.88	$0.00	$0.00	$1.66	$1.16	$0.79	$0.00	$0.00
Bird Island	$31.66	$22.35	$0.00	$0.00	$0.00	$80.25	$58.54	$0.00	$0.00	$0.00	$10.97	$7.80	$0.00	$0.00	$0.00
Total	***$86.78***	***$52.70***	***$12.98***	***$0.00***	***$0.00***	***$236.68***	***$144.71***	***$34.13***	***$0.00***	***$0.00***	***$31.94***	***$20.35***	***$6.24***	***$0.00***	***$0.00***

	Total Present Worth O/M Cost ($ millions)					Total Construction Cost ($ millions)					Total Present Worth Cost ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-017	$23.23	$15.96	$0.00	$0.00	$0.00	$33.61	$20.49	$0.00	$0.00	$0.00	$56.83	$36.45	$0.00	$0.00	$0.00
CSO-022	$7.41	$5.00	$4.10	$0.00	$0.00	$7.30	$4.24	$3.20	$0.00	$0.00	$14.71	$9.23	$7.30	$0.00	$0.00
CSO-025	$6.52	$4.21	$1.96	$0.00	$0.00	$6.13	$3.33	$1.08	$0.00	$0.00	$12.65	$7.54	$3.04	$0.00	$0.00
CSO-026	$30.95	$12.48	$0.00	$0.00	$0.00	$48.87	$14.76	$0.00	$0.00	$0.00	$79.82	$27.23	$0.00	$0.00	$0.00
CSO-027	$25.69	$14.94	$6.90	$0.00	$0.00	$38.35	$18.77	$6.62	$0.00	$0.00	$64.04	$33.71	$13.53	$0.00	$0.00
CSO-028/044/047	$27.81	$22.48	$17.29	$0.00	$0.00	$42.52	$32.19	$22.78	$0.00	$0.00	$70.33	$54.66	$40.06	$0.00	$0.00
CSO-033	$25.28	$21.47	$12.15	$0.00	$0.00	$37.55	$30.32	$14.24	$0.00	$0.00	$62.82	$51.79	$26.39	$0.00	$0.00
CSO-050	$7.72	$5.71	$3.69	$0.00	$0.00	$7.72	$5.10	$2.76	$0.00	$0.00	$15.44	$10.81	$6.45	$0.00	$0.00
CSO-051/052/066	$16.84	$10.38	$4.54	$0.00	$0.00	$22.01	$11.53	$3.70	$0.00	$0.00	$38.85	$21.92	$8.23	$0.00	$0.00
CSO-064	$8.46	$4.38	$4.10	$0.00	$0.00	$8.74	$3.51	$3.20	$0.00	$0.00	$17.20	$7.89	$7.30	$0.00	$0.00
CSO-037	$17.25	$13.03	$9.14	$0.00	$0.00	$22.71	$15.64	$9.71	$0.00	$0.00	$39.95	$28.66	$18.85	$0.00	$0.00
Bird Island	$64.32	$51.10	$0.00	$0.00	$0.00	$124.64	$93.11	$0.00	$0.00	$0.00	$188.96	$144.21	$0.00	$0.00	$0.00
Total	***$261.48***	***$181.13***	***$63.86***	***$0.00***	***$0.00***	***$400.12***	***$252.98***	***$67.29***	***$0.00***	***$0.00***	***$661.60***	***$434.11***	***$131.15***	***$0.00***	***$0.00***

High Rate Treatment Disinfection (data provided by collection system modeling)

EPA Cost Curve (1993) $Cost = 0.121Q^{0.464}$

EPA Cost Curve (1993) $Cost = 0.1144Q^{0.479}$

	Receiving Basin	Peak Flow (mgd)					Construction Cost ($ millions) - EPA Curve					Present Worth O&M Cost ($ millions) - EPA Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-017	Buffalo River	75.0	40.8	0.0	0.0	0.0	$1.68	$1.27	$0.00	$0.00	$0.00	$0.03	$0.02	$0.00	$0.00	$0.00
CSO-022	Buffalo River	11.3	5.7	4.0	0.0	0.0	$0.70	$0.51	$0.43	$0.00	$0.00	$0.01	$0.01	$0.01	$0.00	$0.00
CSO-025	Buffalo River	9.1	4.2	1.0	0.0	0.0	$0.63	$0.44	$0.23	$0.00	$0.00	$0.01	$0.01	$0.00	$0.00	$0.00
CSO-026	Buffalo River	118.7	27.2	0.0	0.0	0.0	$2.08	$1.05	$0.00	$0.00	$0.00	$0.03	$0.02	$0.00	$0.00	$0.00
CSO-027	Buffalo River	88.2	36.6	10.0	0.0	0.0	$1.82	$1.21	$0.66	$0.00	$0.00	$0.03	$0.02	$0.01	$0.00	$0.00
CSO-028/044/047	Buffalo River	100.1	71.2	46.5	0.0	0.0	$1.93	$1.64	$1.35	$0.00	$0.00	$0.03	$0.03	$0.02	$0.00	$0.00
CSO-033	Buffalo River	85.9	66.1	26.0	0.0	0.0	$1.79	$1.59	$1.03	$0.00	$0.00	$0.03	$0.02	$0.02	$0.00	$0.00
CSO-050	Buffalo River	12.1	7.2	3.3	0.0	0.0	$0.72	$0.57	$0.40	$0.00	$0.00	$0.01	$0.01	$0.01	$0.00	$0.00
CSO-051/052/066	Buffalo River	44.6	20.0	4.8	0.0	0.0	$1.32	$0.91	$0.47	$0.00	$0.00	$0.02	$0.01	$0.01	$0.00	$0.00
CSO-064	Buffalo River	14.2	4.5	4.0	0.0	0.0	$0.78	$0.46	$0.43	$0.00	$0.00	$0.01	$0.01	$0.01	$0.00	$0.00
CSO-037	Cazenovia Creek - C	46.3	29.2	16.1	0.0	0.0	$1.35	$1.09	$0.83	$0.00	$0.00	$0.02	$0.02	$0.01	$0.00	$0.00
Bird Island	Black Rock Canal	370.0	260.0	0.0	0.0	0.0	$3.53	$3.00	$0.00	$0.00	$0.00	$0.06	$0.05	$0.00	$0.00	$0.00
Total		**975**	**573**	**116**	**0**	**0**	**$18.33**	**$13.73**	**$5.82**	**$0.00**	**$0.00**	**$0.28**	**$0.21**	**$0.09**	**$0.00**	**$0.00**

High Rate CCT (data provided by collection system modeling)

ALCOSAN COST CURVE (DEC 2008)

$$Cost = 3.4 \times V^{0.8526}$$

	Receiving Basin	CCT Volume (MG)					Construction Cost ($ millions) - ALCOSAN Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-017	Buffalo River	0.26	0.14	0.00	0.00	0.00	*$0.88*	*$0.53*	*$0.00*	*$0.00*	*$0.00*
CSO-022	Buffalo River	0.04	0.02	0.01	0.00	0.00	*$0.18*	*$0.10*	*$0.08*	*$0.00*	*$0.00*
CSO-025	Buffalo River	0.03	0.01	0.00	0.00	0.00	*$0.15*	*$0.08*	*$0.02*	*$0.00*	*$0.00*
CSO-026	Buffalo River	0.41	0.09	0.00	0.00	0.00	*$1.28*	*$0.38*	*$0.00*	*$0.00*	*$0.00*
CSO-027	Buffalo River	0.31	0.13	0.03	0.00	0.00	*$1.00*	*$0.48*	*$0.17*	*$0.00*	*$0.00*
CSO-028/044/047	Buffalo River	0.35	0.25	0.16	0.00	0.00	*$1.11*	*$0.84*	*$0.59*	*$0.00*	*$0.00*
CSO-033	Buffalo River	0.30	0.23	0.09	0.00	0.00	*$0.98*	*$0.79*	*$0.37*	*$0.00*	*$0.00*
CSO-050	Buffalo River	0.04	0.03	0.01	0.00	0.00	*$0.19*	*$0.13*	*$0.07*	*$0.00*	*$0.00*
CSO-051/052/066	Buffalo River	0.15	0.07	0.02	0.00	0.00	*$0.57*	*$0.29*	*$0.09*	*$0.00*	*$0.00*
CSO-064	Buffalo River	0.05	0.02	0.01	0.00	0.00	*$0.22*	*$0.09*	*$0.08*	*$0.00*	*$0.00*
CSO-037	Cazenovia Creek - C	0.16	0.10	0.06	0.00	0.00	*$0.59*	*$0.40*	*$0.25*	*$0.00*	*$0.00*
Bird Island	Black Rock Canal	1.28	0.90	0.00	0.00	0.00	*$3.27*	*$2.45*	*$0.00*	*$0.00*	*$0.00*
Total		**3.39**	**1.99**	**0.40**	**0.00**	**0.00**	**$10.43**	**$6.56**	**$1.70**	**$0.00**	**$0.00**

HRT Piping (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length	Diameter (ft)	Unit Cost ($/ft)	Capital Cost ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CSO 028 (IN)	Buffalo River	268	6.5	$953	*$0.26*	*$0.26*	*$0.26*	*$0.00*	*$0.00*
CSO 044 (IN)	Buffalo River	1,374	3.0	$362	*$0.50*	*$0.50*	*$0.50*	*$0.00*	*$0.00*
CSO 047 (IN)	Buffalo River	3,061	5.0	$645	*$1.97*	*$1.97*	*$1.97*	*$0.00*	*$0.00*
CSO 052 (IN)	Buffalo River	176	2.5	$289	*$0.05*	*$0.05*	*$0.05*	*$0.00*	*$0.00*
CSO 064 (IN)	Buffalo River	30	3.5	$420	*$0.01*	*$0.01*	*$0.01*	*$0.00*	*$0.00*
CSO 017 (IN)	Buffalo River	171	5.0	$645	*$0.11*	*$0.11*	*$0.00*	*$0.00*	*$0.00*
CSO 022 (IN)	Buffalo River	787	2.5	$289	*$0.23*	*$0.23*	*$0.23*	*$0.00*	*$0.00*
CSO 025 (IN)	Buffalo River	228	2.5	$289	*$0.07*	*$0.07*	*$0.07*	*$0.00*	*$0.00*
CSO 026 (IN)	Buffalo River	652	5.5	$739	*$0.48*	*$0.48*	*$0.00*	*$0.00*	*$0.00*
CSO 027 (IN)	Buffalo River	429	4.5	$559	*$0.24*	*$0.24*	*$0.24*	*$0.00*	*$0.00*
CSO 033 (IN)	Buffalo River	381	5.0	$645	*$0.25*	*$0.25*	*$0.25*	*$0.00*	*$0.00*
CSO 050 (IN)	Buffalo River	212	2.5	$289	*$0.06*	*$0.06*	*$0.06*	*$0.00*	*$0.00*
CSO 066 (IN)	Buffalo River	597	3.5	$420	*$0.25*	*$0.25*	*$0.00*	*$0.00*	*$0.00*
CSO 051 (IN)	Buffalo River	2,136	3.0	$362	*$0.77*	*$0.77*	*$0.00*	*$0.00*	*$0.00*
CSO 037 (IN)	Cazenovia Creek - C	773	4.0	$478	*$0.37*	*$0.37*	*$0.37*	*$0.00*	*$0.00*
CSO 028/044/047 (OUT)	Buffalo River	178	5.5	$739	*$0.13*	*$0.13*	*$0.13*	*$0.00*	*$0.00*
CSO 051/052/066 (OUT)	Buffalo River	192	4.5	$559	*$0.11*	*$0.11*	*$0.11*	*$0.00*	*$0.00*
CSO 064 (OUT)	Buffalo River	272	3.5	$420	*$0.11*	*$0.11*	*$0.11*	*$0.00*	*$0.00*
CSO 017 (OUT)	Buffalo River	108	5.0	$645	*$0.07*	*$0.07*	*$0.00*	*$0.00*	*$0.00*
CSO 022 (OUT)	Buffalo River	125	2.5	$289	*$0.04*	*$0.04*	*$0.04*	*$0.00*	*$0.00*
CSO 026 (OUT)	Buffalo River	280	5.5	$739	*$0.21*	*$0.21*	*$0.00*	*$0.00*	*$0.00*
CSO 027 (OUT)	Buffalo River	280	4.5	$559	*$0.16*	*$0.16*	*$0.16*	*$0.00*	*$0.00*
CSO 033 (OUT)	Buffalo River	219	5.0	$645	*$0.14*	*$0.14*	*$0.14*	*$0.00*	*$0.00*
CSO 025 (OUT)	Buffalo River	140	2.5	$289	*$0.04*	*$0.04*	*$0.04*	*$0.00*	*$0.00*
CSO 050 (OUT)	Buffalo River	175	2.5	$289	*$0.05*	*$0.05*	*$0.05*	*$0.00*	*$0.00*
CSO 037 (OUT)	Cazenovia Creek - C	169	4.0	$478	*$0.08*	*$0.08*	*$0.08*	*$0.00*	*$0.00*
Total		**13,414**			***$6.75***	***$6.75***	***$4.85***	***$0.00***	***$0.00***

HRT Force Main (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

			114.5	*96.0*	*0.0*	*0.0*	*0.0*										
	Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Construction Cost ($ millions)				
			0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
Bird Island	Black Rock Canal	3,500	120	96	0	0	0	$4,403	$1,920	$0	$0	$0	*$15.41*	*$6.72*	*$0.00*	*$0.00*	*$0.00*
Total		**3,500**											***$15.41***	***$6.72***	***$0.00***	***$0.00***	***$0.00***

Tunnel Storage (data provided by collection system model)

BSA 2004 Curve

$$ScajCost = 2846725.52 \times dia.$$

ALCOSAN cost curve (deep tunnel dewatering, Fig D-3)

$$Cost = 910439 \times Flow^{0.9421}$$

Calculation Based on per Gal Pumped

ALCOSAN COST CURVE (DEC 2008) - Source 2

$$Cost = 749.43 \times VOL + 17816$$

ALCOSAN COST CURVE (DEC 2008) - Source 1

$$Cost = 959.78 * VOL + 22246$$

BSA 2004 LTCP Equation

	Receiving Basin	Volume (MG) or Dewatering (MGD) or Diameter (ft)					Length (ft)	Tunnel Construction Cost ($ millions) - linear curve					Dewatering PS Const Cost ($ millions) - Alcosan Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
East-West Volume	Scajaquada Creek	44.14	18.77	0.00	0.00	0.00	14,200	*$88.12*	*$57.47*	*$0.00*	*$0.00*	*$0.00*	$36.63	$16.37	$0.00	$0.00	$0.00
East-West Diameter		23.00	15.00	0.00	0.00	0.00											
Total		**44.14**	**18.77**	**0.00**	**0.00**	**0.00**	**14,200**	***$88.12***	***$57.47***	***$0.00***	***$0.00***	***$0.00***	***$36.63***	***$16.37***	***$0.00***	***$0.00***	***$0.00***

	Total Construction Cost ($)					Annual Volume Pumped (MG)					Present Worth O/M Costs - Energy ($ millions)					PW O/M Costs - Materials ($ millions)					PW O/M Costs - Labor ($ millions)					PW O/M Costs - Tunnel ($ millions)					PW O/M Costs - Total ($ millions)					Present Worth Costs - Total ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
$124.76	$73.84	$0.00	$0.00	$0.00	165.60	136.80	0.00	0.00	0.00	$0.15	$0.12	$0.00	$0.00	$0.00	$0.86	$0.54	$0.00	$0.00	$0.00	$1.10	$0.69	$0.00	$0.00	$0.00	$6.10	$5.71	$0.00	$0.00	$0.00	$8.21	$7.06	$0.00	$0.00	$0.00	$132.97	$80.90	$0.00	$0.00	$0.00
$124.76	***$73.84***	***$0.00***	***$0.00***	***$0.00***	***165.60***	***136.80***	***0.00***	***0.00***	***0.00***	***$0.15***	***$0.12***	***$0.00***	***$0.00***	***$0.00***	***$0.86***	***$0.54***	***$0.00***	***$0.00***	***$0.00***	***$1.10***	***$0.69***	***$0.00***	***$0.00***	***$0.00***	***$6.10***	***$5.71***	***$0.00***	***$0.00***	***$0.00***	***$8.21***	***$7.06***	***$0.00***	***$0.00***	***$0.00***	***$132.97***	***$80.90***	***$0.00***	***$0.00***	***$0.00***

Tunnel Collectors (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length	Diameter (ft)	Unit Cost ($/ft)	Construction Cost ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
SPP341a	Scajaquada Creek	957	3.0	$362	*$0.35*	*$0.35*	*$0.00*	*$0.00*	*$0.00*
SPP340	Scajaquada Creek	1,164	5.5	$739	*$0.86*	*$0.86*	*$0.00*	*$0.00*	*$0.00*
SPP339	Scajaquada Creek	1,285	3.5	$420	*$0.54*	*$0.54*	*$0.00*	*$0.00*	*$0.00*
SPP157	Scajaquada Creek	772	1.5	$183	*$0.14*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP338	Scajaquada Creek	1,905	4.0	$478	*$0.91*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP200a&b	Scajaquada Creek	130	2.0	$247	*$0.03*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP337	Scajaquada Creek	1,418	5.0	$645	*$0.91*	*$0.91*	*$0.00*	*$0.00*	*$0.00*
SPP202	Scajaquada Creek	774	3.0	$362	*$0.28*	*$0.28*	*$0.00*	*$0.00*	*$0.00*
SPP201	Scajaquada Creek	1,123	3.0	$362	*$0.41*	*$0.41*	*$0.00*	*$0.00*	*$0.00*
SPP203	Scajaquada Creek	39	2.5	$289	*$0.01*	*$0.01*	*$0.00*	*$0.00*	*$0.00*
SPP163	Scajaquada Creek	837	4.0	$478	*$0.40*	*$0.40*	*$0.00*	*$0.00*	*$0.00*
SPP204	Scajaquada Creek	1,752	6.0	$842	*$1.48*	*$1.48*	*$0.00*	*$0.00*	*$0.00*
SPP336a	Scajaquada Creek	144	2.5	$289	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.00*
SPP336b	Scajaquada Creek	2,324	5.0	$645	*$1.50*	*$1.50*	*$0.00*	*$0.00*	*$0.00*
SPP166	Scajaquada Creek	247	1.5	$183	*$0.05*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP335	Scajaquada Creek	1,706	2.5	$289	*$0.49*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP229a	Scajaquada Creek	92	2.5	$289	*$0.03*	*$0.03*	*$0.00*	*$0.00*	*$0.00*
SPP345	Scajaquada Creek	1,735	2.0	$247	*$0.43*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP170b	Scajaquada Creek	1,036	5.0	$645	*$0.67*	*$0.67*	*$0.00*	*$0.00*	*$0.00*
SPP178	Scajaquada Creek	1,385	3.5	$420	*$0.58*	*$0.58*	*$0.00*	*$0.00*	*$0.00*
SPP331	Black Rock Canal	2,587	3.0	$362	*$0.94*	*$0.94*	*$0.00*	*$0.00*	*$0.00*
SPP180	Black Rock Canal	1,395	4.0	$478	*$0.67*	*$0.67*	*$0.00*	*$0.00*	*$0.00*
SPP179	Black Rock Canal	2,721	4.5	$559	*$1.52*	*$1.52*	*$0.00*	*$0.00*	*$0.00*
SPP335a	Scajaquada Creek	24	1.5	$183	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP165a&b	Scajaquada Creek	123	3.0	$362	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.00*
SPP342a&b	Scajaquada Creek	1,628	1.5	$183	*$0.30*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Total		**29,301**			***$13.57***	***$11.22***	***$0.00***	***$0.00***	***$0.00***

Electricity Cost ($/kWhr):	0.1
Efficiency (%):	67%
Dynamic Head (ft)	125

Tunnel Dewatering Force Main (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
Scajaquada Creek	231	60	36	0	0	0	$553	$240	$0	$0	$0	*$0.13*	*$0.06*	*$0.00*	*$0.00*	*$0.00*
Total	**231**											***$0.13***	***$0.06***	***$0.00***	***$0.00***	***$0.00***

Existing CSO Underflow Capacity Increase (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length	Outlet Diameter (ft)					Unit Cost ($/ft)					Construction Cost ($ millions)				
			0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO 010	Black Rock Canal	67	4.5	4.0	4.0	4.0	4.0	$559	$478	$478	$478	$478	*$0.04*	*$0.03*	*$0.03*	*$0.03*	*$0.03*
CSO 008/010	Black Rock Canal	84	5.5	5.0	5.0	5.0	5.0	$739	$645	$645	$645	$645	*$0.06*	*$0.05*	*$0.05*	*$0.05*	*$0.05*
CSO 008	Black Rock Canal	1,646	3.0	3.0	3.0	3.0	3.0	$362	$362	$362	$362	$362	*$0.60*	*$0.60*	*$0.60*	*$0.60*	*$0.60*
CSO 061	Black Rock Canal	46	6.5	5.0	6.0	5.0	0.0	$953	$645	$842	$645	$0	*$0.04*	*$0.03*	*$0.04*	*$0.03*	*$0.00*
CSO 004	Black Rock Canal	112	8.0	7.0	6.0	0.0	0.0	$1,336	$1,072	$842	$0	$0	*$0.15*	*$0.12*	*$0.09*	*$0.00*	*$0.00*
Total		**1,955**											***$0.89***	***$0.83***	***$0.82***	***$0.71***	***$0.68***

Gravity Sewer Conveyance Improvem (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

Receiving Basin	Length	Diameter (ft)					Unit Cost ($/ft)					Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	2,045	8.0	5.5	7.5	4.0	2.5	$1,336	$739	$1,200	$478	$289	*$2.73*	*$1.51*	*$2.45*	*$0.98*	*$0.59*
Black Rock Canal	571	10.0	8.0	10.0	5.0	2.5	$1,963	$1,336	$1,963	$645	$289	*$1.12*	*$0.76*	*$1.12*	*$0.37*	*$0.17*
Black Rock Canal	3,265	8.0	5.5	8.0	0.0	0.0	$1,336	$739	$1,336	$0	$0	*$4.36*	*$2.41*	*$4.36*	*$0.00*	*$0.00*
Black Rock Canal	1,185	0.0	0.0	0.0	3.0	0.0	$0	$0	$0	$362	$0	*$0.00*	*$0.00*	*$0.00*	*$0.43*	*$0.00*
Total	**7,065**											***$8.21***	***$4.69***	***$7.94***	***$1.35***	***$0.76***

Green Infrastructure (Average cost determined from costs observed on other municipalities' projects)

Receiving Water	Area Managed by GI (ac)	Const Cost ($ millions)
Black Rock Canal	168	*$9.58*
Buffalo River	418	*$23.83*
Cazenovia Creek - B	3	*$0.17*
Cazenovia Creek - C	60	*$3.42*
Erie Basin	49	*$2.79*
Niagara River	412	*$23.48*
Scajaquada Creek	510	*$29.07*
Total	**1,620**	***$92.34***

Includes Quarry Area

Green Infrastructure Unit Cost ($/ac):	*$57,000*

Total - Construction Cost ($ millions) - Gray Infrastructure

Receiving Basin	Alternative UA2				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$166.15*	*$118.14*	*$10.02*	*$2.49*	*$1.44*
Buffalo River	*$279.10*	*$163.88*	*$68.44*	*$11.83*	*$3.98*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$25.09*	*$17.58*	*$11.23*	*$0.00*	*$0.00*
Cornelius Creek	*$123.88*	*$71.45*	*$53.42*	*$40.33*	*$15.70*
Erie Basin	*$10.93*	*$3.78*	*$1.18*	*$0.00*	*$0.00*
Niagara River	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$137.12*	*$82.00*	*$24.47*	*$17.00*	*$7.76*
Sub-Total	***$742.26***	***$456.82***	***$168.76***	***$71.65***	***$28.88***

Sub-Total - Present Worth O/M ($ millions)

Receiving Basin	Alternative UA2				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$65.01*	*$51.59*	*$0.19*	*$0.00*	*$0.00*
Buffalo River	*$180.12*	*$117.15*	*$54.80*	*$1.06*	*$0.31*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$17.27*	*$13.04*	*$9.15*	*$0.00*	*$0.00*
Cornelius Creek	*$4.38*	*$2.99*	*$2.44*	*$2.00*	*$0.99*
Erie Basin	*$0.82*	*$0.36*	*$0.19*	*$0.00*	*$0.00*
Niagara River	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$8.46*	*$7.06*	*$1.90*	*$1.48*	*$0.71*
Sub-Total	***$276.05***	***$192.19***	***$68.67***	***$4.53***	***$2.01***

Sub-Total - Engineering ($ millions)

Receiving Basin	Alternative UA2				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$24.92*	*$17.72*	*$1.50*	*$0.37*	*$0.22*
Buffalo River	*$41.87*	*$24.58*	*$10.27*	*$1.77*	*$0.60*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$3.76*	*$2.64*	*$1.68*	*$0.00*	*$0.00*
Cornelius Creek	*$18.58*	*$10.72*	*$8.01*	*$6.05*	*$2.36*
Erie Basin	*$1.64*	*$0.57*	*$0.18*	*$0.00*	*$0.00*
Niagara River	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$20.57*	*$12.30*	*$3.67*	*$2.55*	*$1.16*
Sub-Total	***$111.34***	***$68.52***	***$25.31***	***$10.75***	***$4.33***

Sub-Total - Present Worth O/M Contigency ($ millions)

Receiving Basin	Alternative UA2				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$6.50*	*$5.16*	*$0.02*	*$0.00*	*$0.00*
Buffalo River	*$18.01*	*$11.71*	*$5.48*	*$0.11*	*$0.03*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$1.73*	*$1.30*	*$0.92*	*$0.00*	*$0.00*
Cornelius Creek	*$0.44*	*$0.30*	*$0.24*	*$0.20*	*$0.10*
Erie Basin	*$0.08*	*$0.04*	*$0.02*	*$0.00*	*$0.00*
Niagara River	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$0.85*	*$0.71*	*$0.19*	*$0.15*	*$0.07*
Sub-Total	***$27.61***	***$19.22***	***$6.87***	***$0.45***	***$0.20***

Sub-Total - Project Contingency ($ millions)

Receiving Basin	Alternative UA2				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$47.8*	*$34.0*	*$2.9*	*$0.7*	*$0.4*
Buffalo River	*$80.2*	*$47.1*	*$19.7*	*$3.4*	*$1.1*
Cazenovia Creek - B	*$0.0*	*$0.0*	*$0.0*	*$0.0*	*$0.0*
Cazenovia Creek - C	*$7.2*	*$5.1*	*$3.2*	*$0.0*	*$0.0*
Cornelius Creek	*$35.6*	*$20.5*	*$15.4*	*$11.6*	*$4.5*
Erie Basin	*$3.1*	*$1.1*	*$0.3*	*$0.0*	*$0.0*
Niagara River	*$0.0*	*$0.0*	*$0.0*	*$0.0*	*$0.0*
Scajaquada Creek	*$39.4*	*$23.6*	*$7.0*	*$4.9*	*$2.2*
Sub-Total	***$213.40***	***$131.34***	***$48.52***	***$20.60***	***$8.30***

Sub-Total - Present Worth O/M with Contingency ($ millions)

Receiving Basin	Alternative UA2				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$71.51*	*$56.75*	*$0.21*	*$0.00*	*$0.00*
Buffalo River	*$198.13*	*$128.86*	*$60.27*	*$1.16*	*$0.34*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$18.99*	*$14.35*	*$10.07*	*$0.00*	*$0.00*
Cornelius Creek	*$4.81*	*$3.29*	*$2.68*	*$2.20*	*$1.09*
Erie Basin	*$0.90*	*$0.40*	*$0.20*	*$0.00*	*$0.00*
Niagara River	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$9.30*	*$7.76*	*$2.09*	*$1.63*	*$0.78*
Sub-Total	***$303.66***	***$211.41***	***$75.53***	***$4.99***	***$2.21***

Total - Project Cost with Contingencies ($ millions) with green infrastructure

Receiving Basin	Foundation Alternative ($ millions)	Alternative UA2				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$6.89*	*$248.42*	*$179.41*	*$23.98*	*$13.15*	*$11.64*
Buffalo River	*$41.13*	*$425.03*	*$259.41*	*$122.20*	*$40.83*	*$29.54*
Cazenovia Creek - B	*$0.00*	*$0.17*	*$0.17*	*$0.17*	*$0.17*	*$0.17*
Cazenovia Creek - C	*$0.02*	*$39.49*	*$28.69*	*$19.57*	*$3.42*	*$3.42*
Cornelius Creek	*$8.70*	*$178.07*	*$102.70*	*$76.80*	*$57.98*	*$22.57*
Erie Basin	*$0.00*	*$18.50*	*$8.22*	*$4.49*	*$2.79*	*$2.79*
Niagara River	*$0.00*	*$23.48*	*$23.48*	*$23.48*	*$23.48*	*$23.48*
Scajaquada Creek	*$27.75*	*$226.17*	*$146.94*	*$64.24*	*$53.51*	*$40.23*
Sub-Total	***$84.48***	***$1,159.34***	***$749.02***	***$334.93***	***$195.33***	***$133.86***
Total (with Foundation Alternative)		***$1,243.83***	***$833.50***	***$419.41***	***$279.81***	***$218.34***

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Receiving Basin	Foundation Alternative ($ millions)	Alternative UA2				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$6.89	$248.42	$179.41	$23.98	$13.15	$11.64
Buffalo River	$41.13	$425.03	$259.41	$122.20	$40.83	$29.54
Cazenovia Creek - B	$0.00	$0.17	$0.17	$0.17	$0.17	$0.17
Cazenovia Creek - C	$0.02	$39.49	$28.69	$19.57	$3.42	$3.42
Erie Basin	$0.00	$18.50	$8.22	$4.49	$2.79	$2.79
Niagara River (including CSO 055)	$8.70	$201.55	$126.19	$100.28	$81.46	$46.06
Scajaquada Creek	$27.75	$226.17	$146.94	$64.24	$53.51	$40.23
Sub-Total		**$1,159.34**	**$749.02**	**$334.93**	**$195.33**	**$133.86**
Total (with Foundation Alternative)	**$84.48**	**$1,243.83**	**$833.50**	**$419.41**	**$279.81**	**$218.34**

Total - Project Cost and Present Worth O/M with Contingencies

Receiving Basin	Foundation Alternative	Alternative UA2				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$6.89*	*$319.93*	*$236.16*	*$24.20*	*$13.15*	*$11.64*
Buffalo River	*$41.13*	*$623.16*	*$388.27*	*$182.48*	*$41.99*	*$29.88*
Cazenovia Creek - B	*$0.00*	*$0.17*	*$0.17*	*$0.17*	*$0.17*	*$0.17*
Cazenovia Creek - C	*$0.02*	*$58.48*	*$43.03*	*$29.64*	*$3.42*	*$3.42*
Cornelius Creek	*$8.70*	*$182.88*	*$105.99*	*$79.48*	*$60.18*	*$23.66*
Erie Basin	*$0.00*	*$19.40*	*$8.62*	*$4.69*	*$2.79*	*$2.79*
Niagara River	*$0.00*	*$23.48*	*$23.48*	*$23.48*	*$23.48*	*$23.48*
Scajaquada Creek	*$27.75*	*$235.48*	*$154.70*	*$66.33*	*$55.13*	*$41.01*
Sub-Total	***$84.48***	***$1,463.00***	***$960.43***	***$410.46***	***$200.32***	***$136.07***
Total (with Foundation Alternative)		***$1,547.48***	***$1,044.91***	***$494.95***	***$284.80***	***$220.55***

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Receiving Basin	Foundation Alternative ($	Alternative UA2				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$6.89	$319.93	$236.16	$24.20	$13.15	$11.64
Buffalo River	$41.13	$623.16	$388.27	$182.48	$41.99	$29.88
Cazenovia Creek - B	$0.00	$0.17	$0.17	$0.17	$0.17	$0.17
Cazenovia Creek - C	$0.02	$58.48	$43.03	$29.64	$3.42	$3.42
Erie Basin	$0.00	$19.40	$8.62	$4.69	$2.79	$2.79
Niagara River (including CSO 055)	$8.70	$206.37	$129.48	$102.96	$83.66	$47.15
Scajaquada Creek	$27.75	$235.48	$154.70	$66.33	$55.13	$41.01
Sub-Total		**$1,463.00**	**$960.43**	**$410.46**	**$200.32**	**$136.07**
Total (with Foundation Alternative)	**$84.48**	**$1,547.48**	**$1,044.91**	**$494.95**	**$284.80**	**$220.55**

Fecal 92500

Figure A: Present Worth Costs vs. Frequency of Activation for Black Rock Canal
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

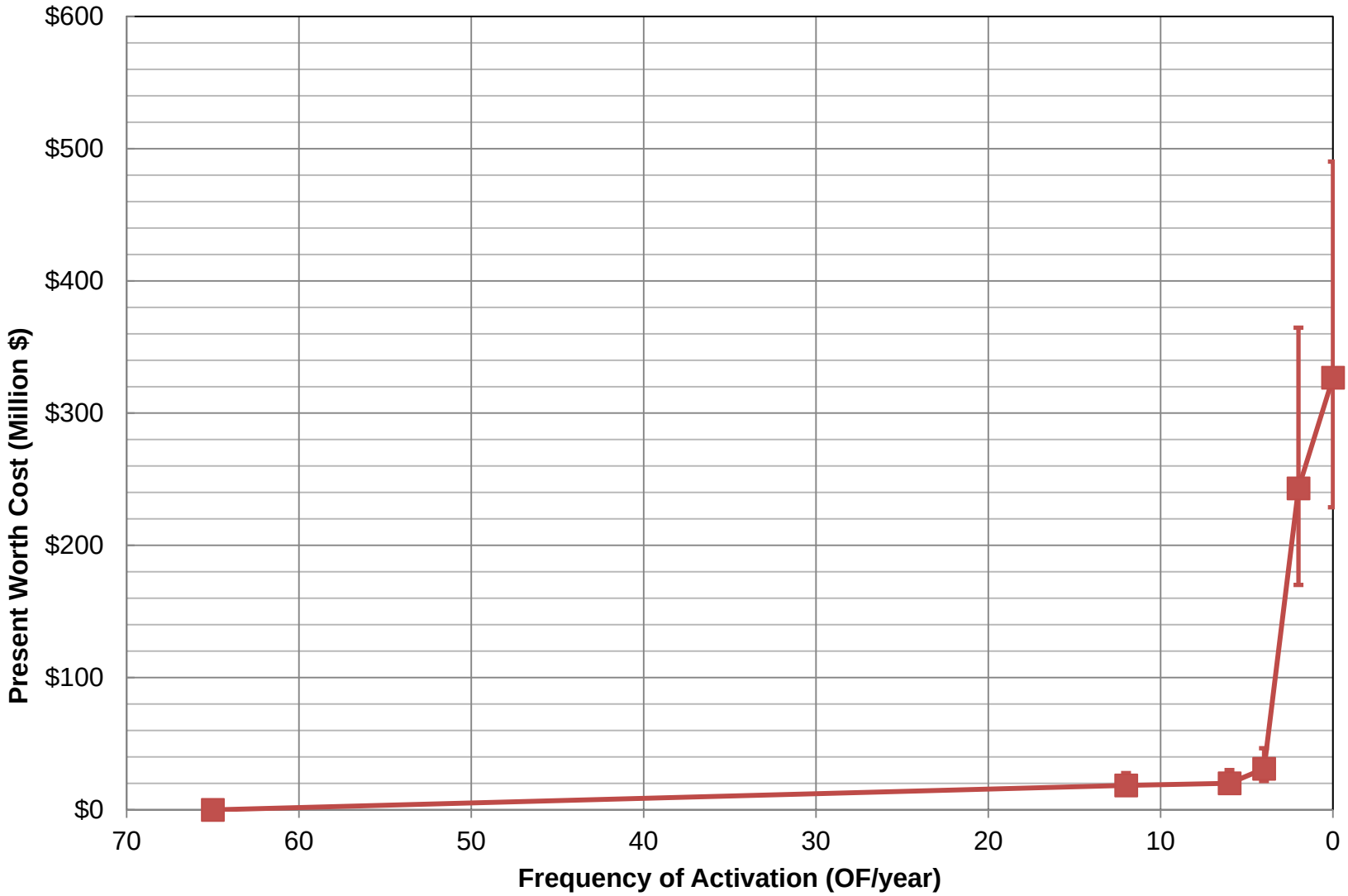


Figure B: Present Worth Costs vs. Frequency of Activation for Buffalo River
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

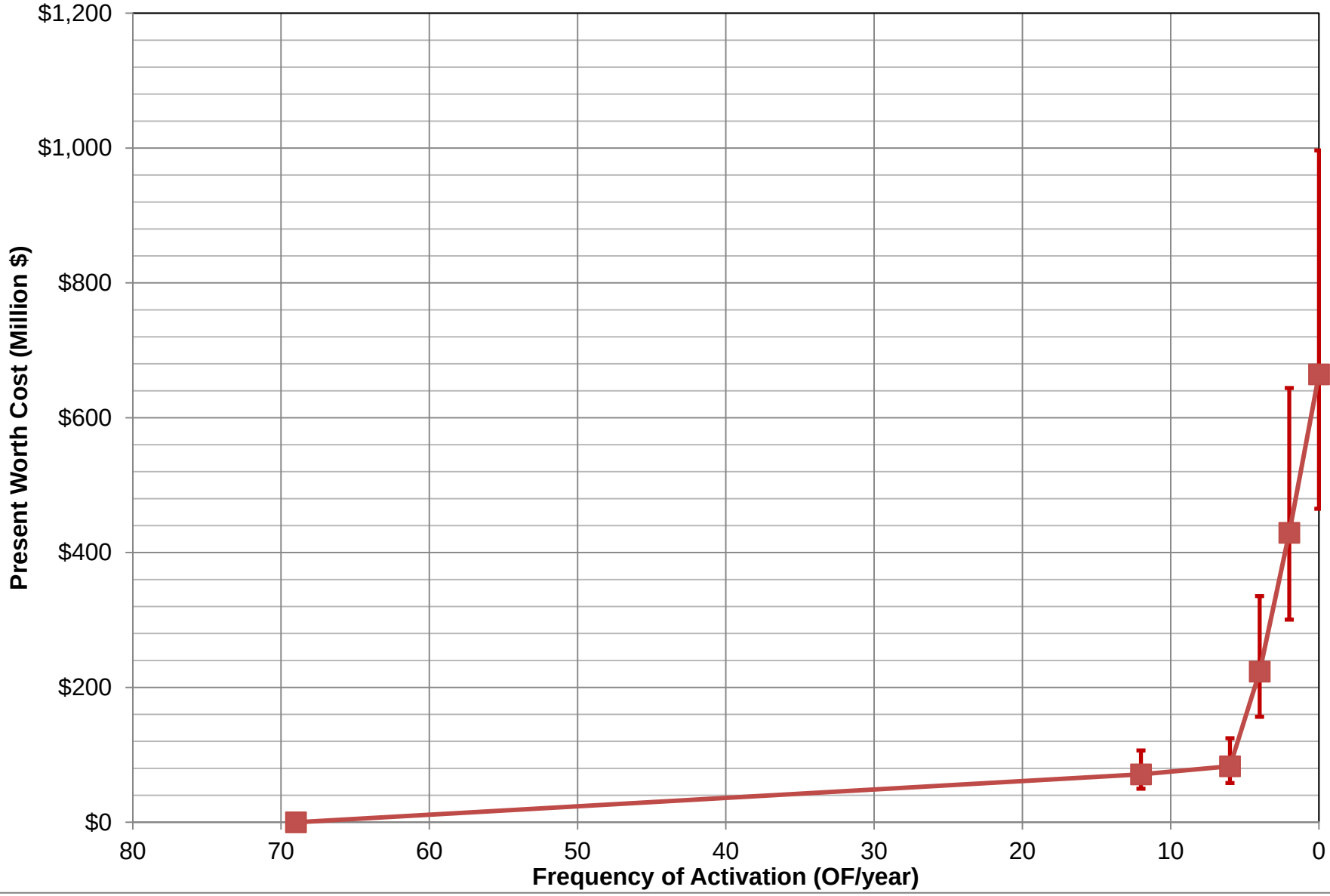


Figure C: Present Worth Costs vs. Frequency of Activation for Cazenovia Creek (C)
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

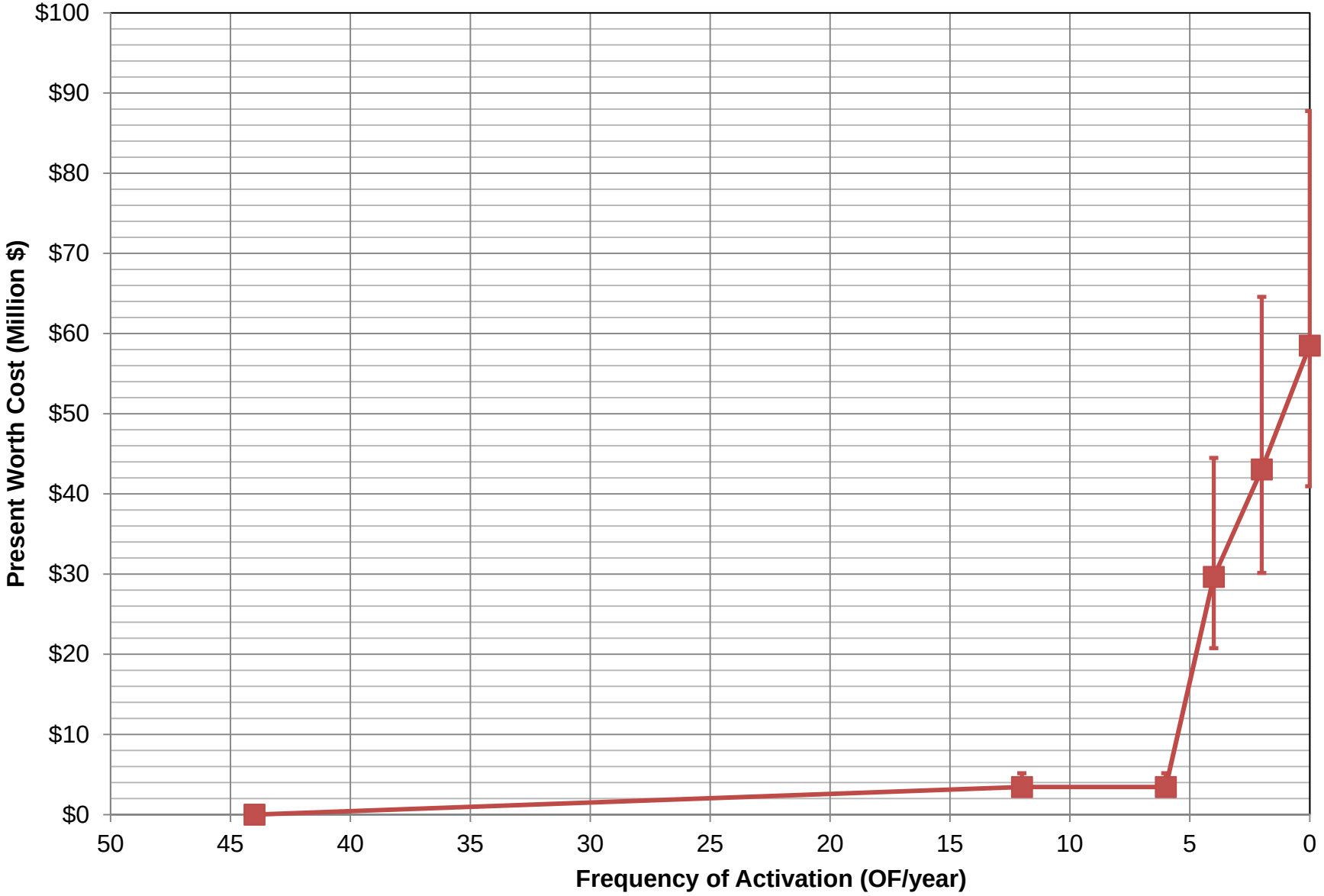


Figure D: Present Worth Costs vs. Frequency of Activation for Cazenovia Creek (B)
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

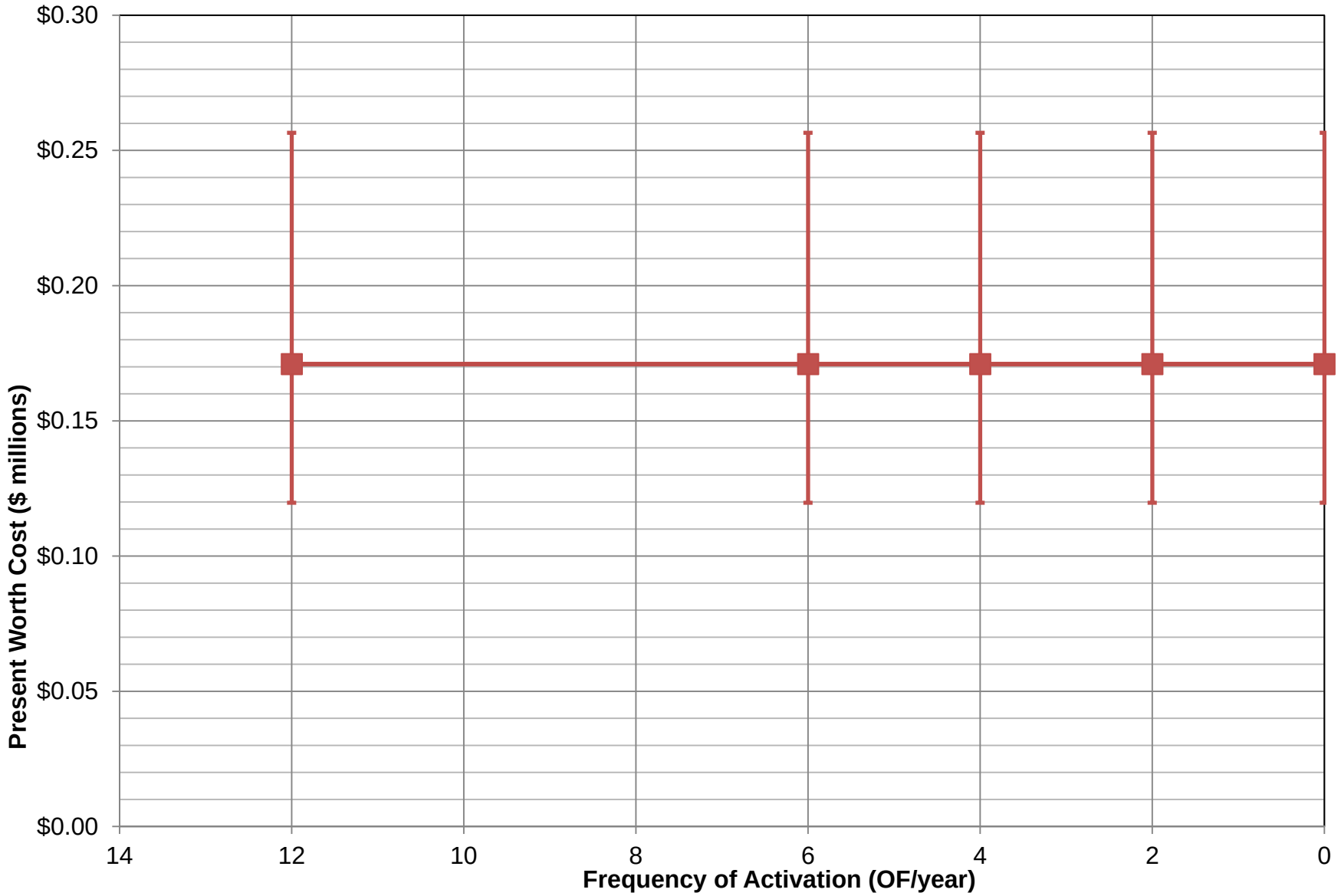


Figure E: Present Worth Costs vs. Frequency of Activation for Niagara River and CSO-055
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

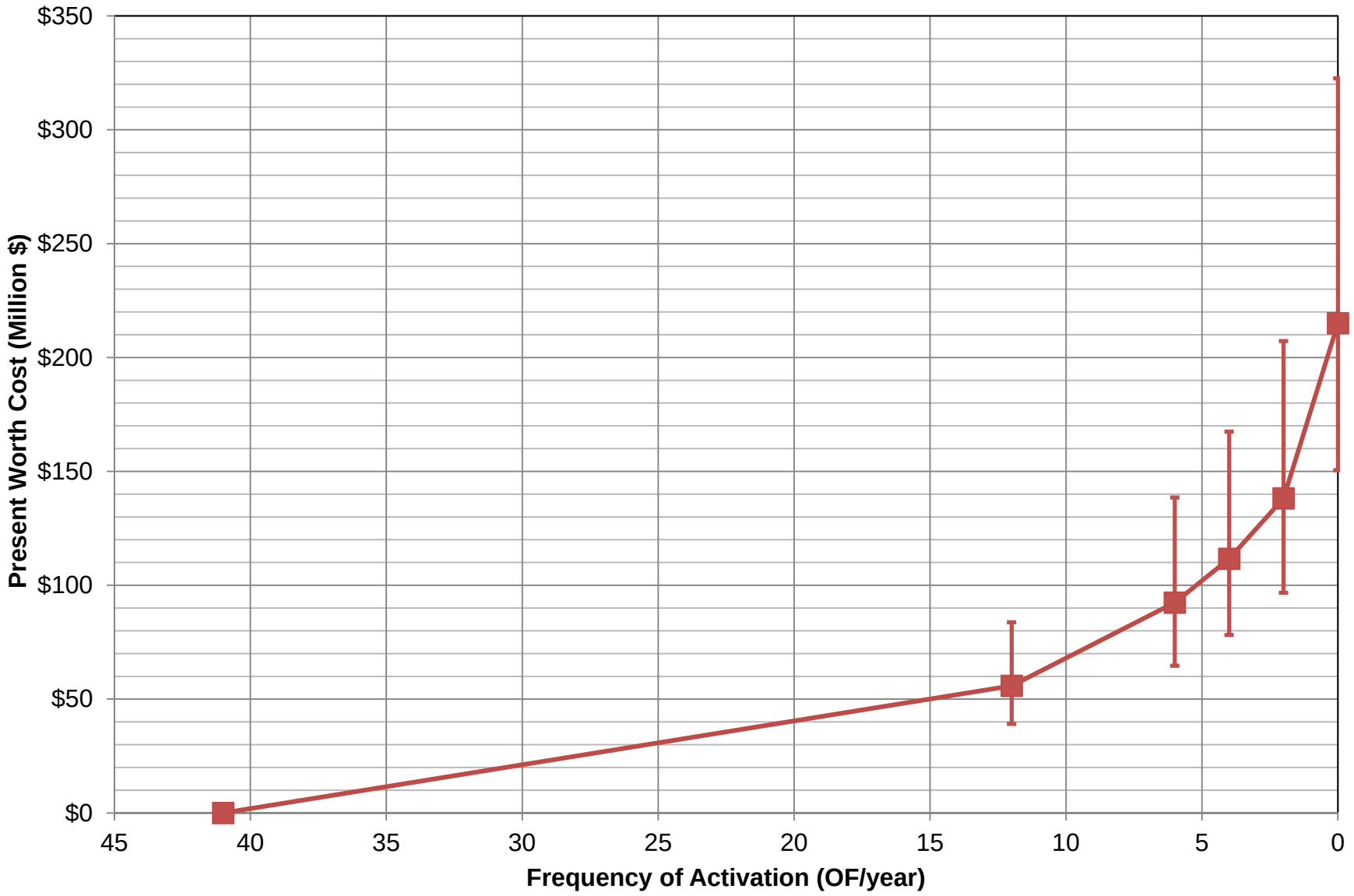


Figure F: Present Worth Costs vs. Frequency of Activation for Erie Basin
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

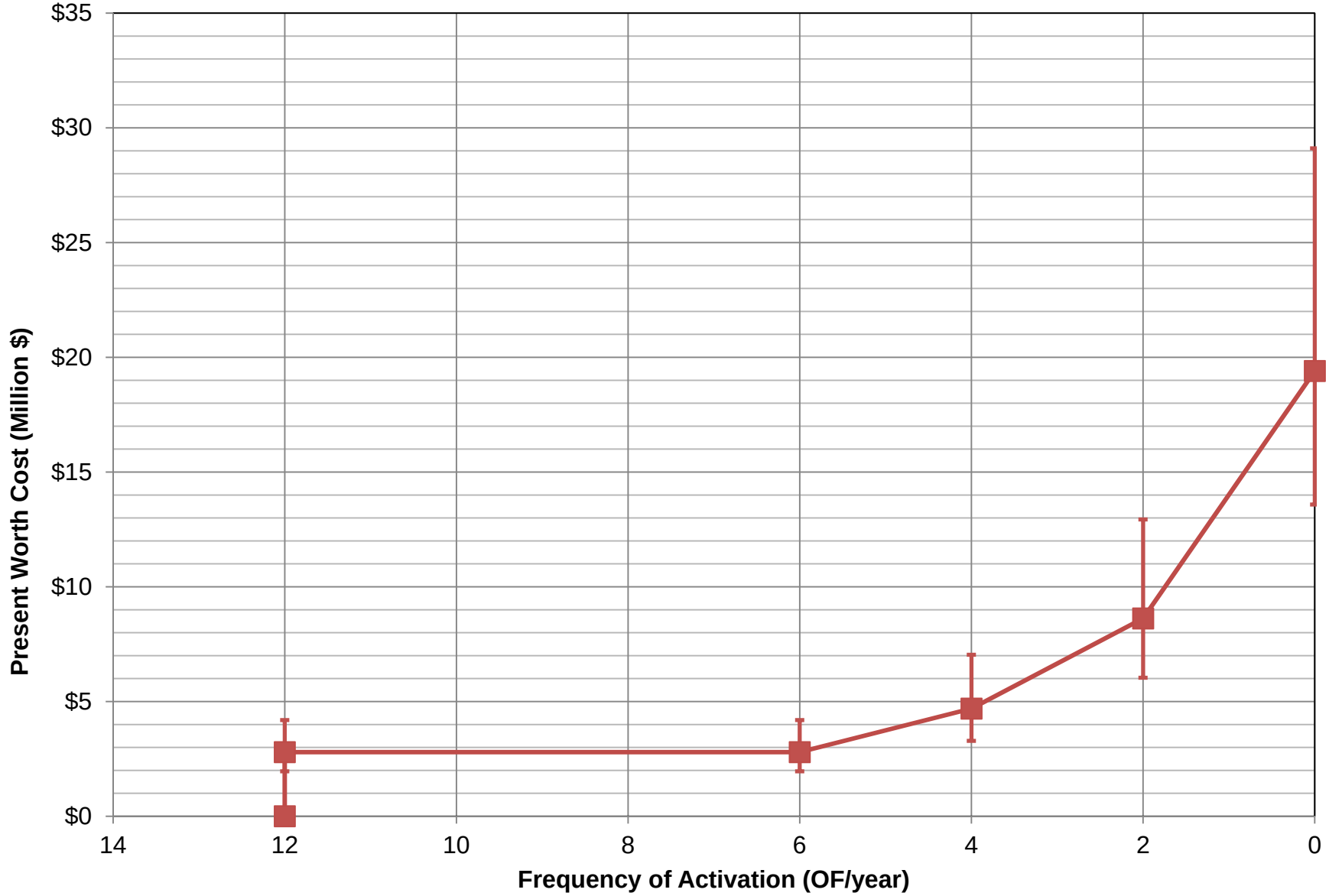


Figure G: Present Worth Costs vs. Frequency of Activation for Scajaquada Creek (System-wide Alternative UA2)
1993 TY - 2012 Dollars

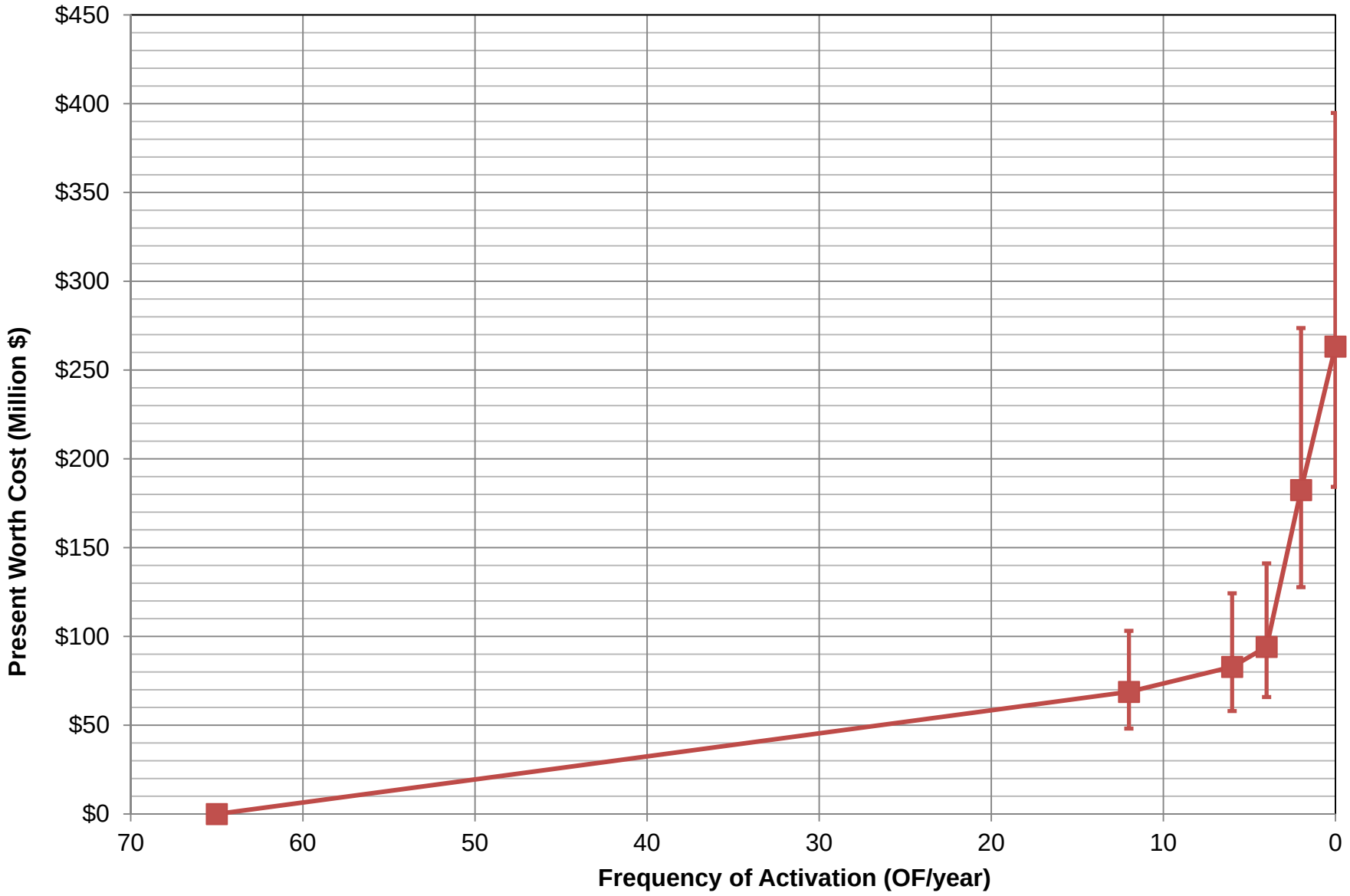


Figure H: Present Worth Costs vs. Remaining CSO Volumes for Black Rock Canal (System-wide Alternative UA2)
1993 TY - 2012 Dollars

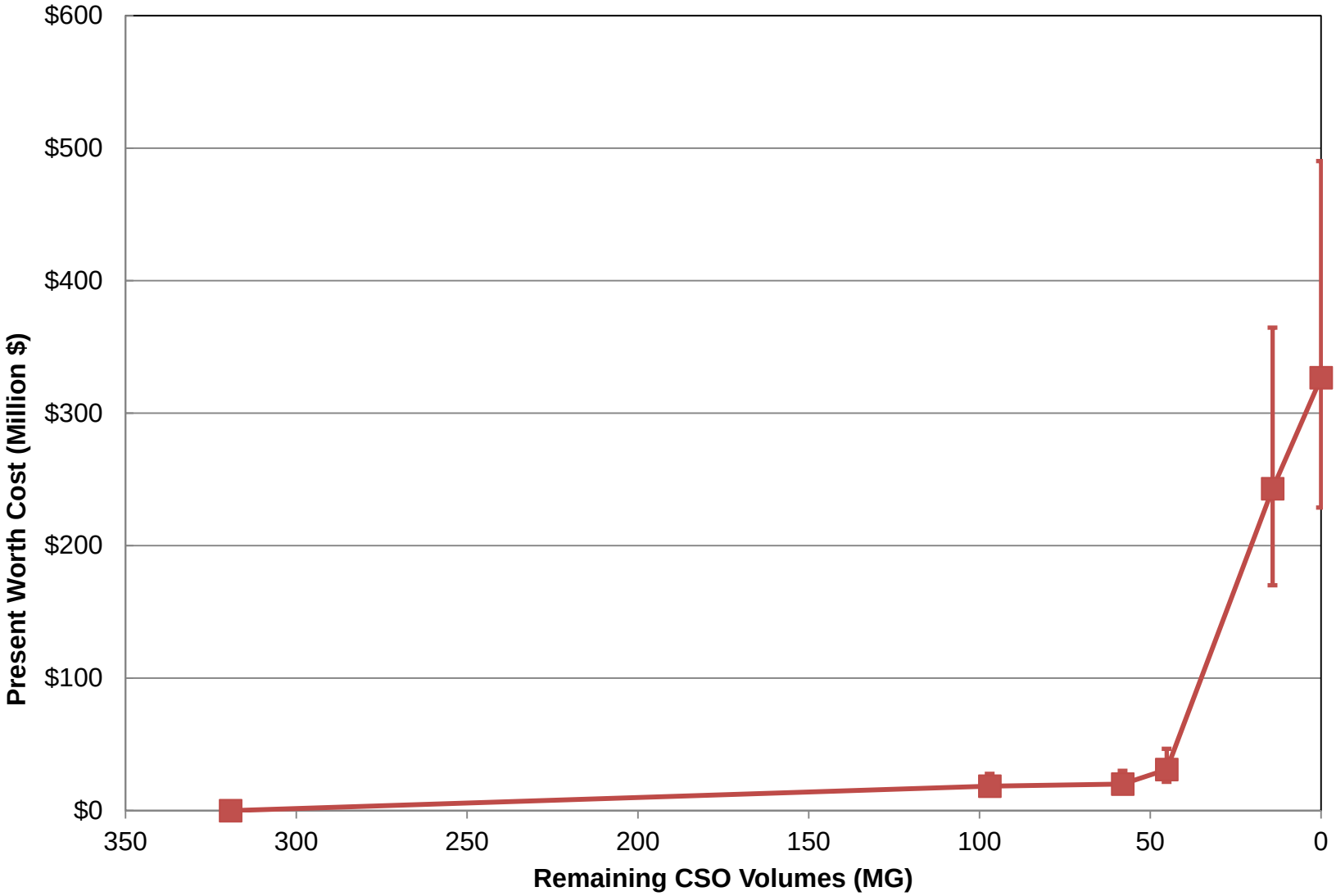
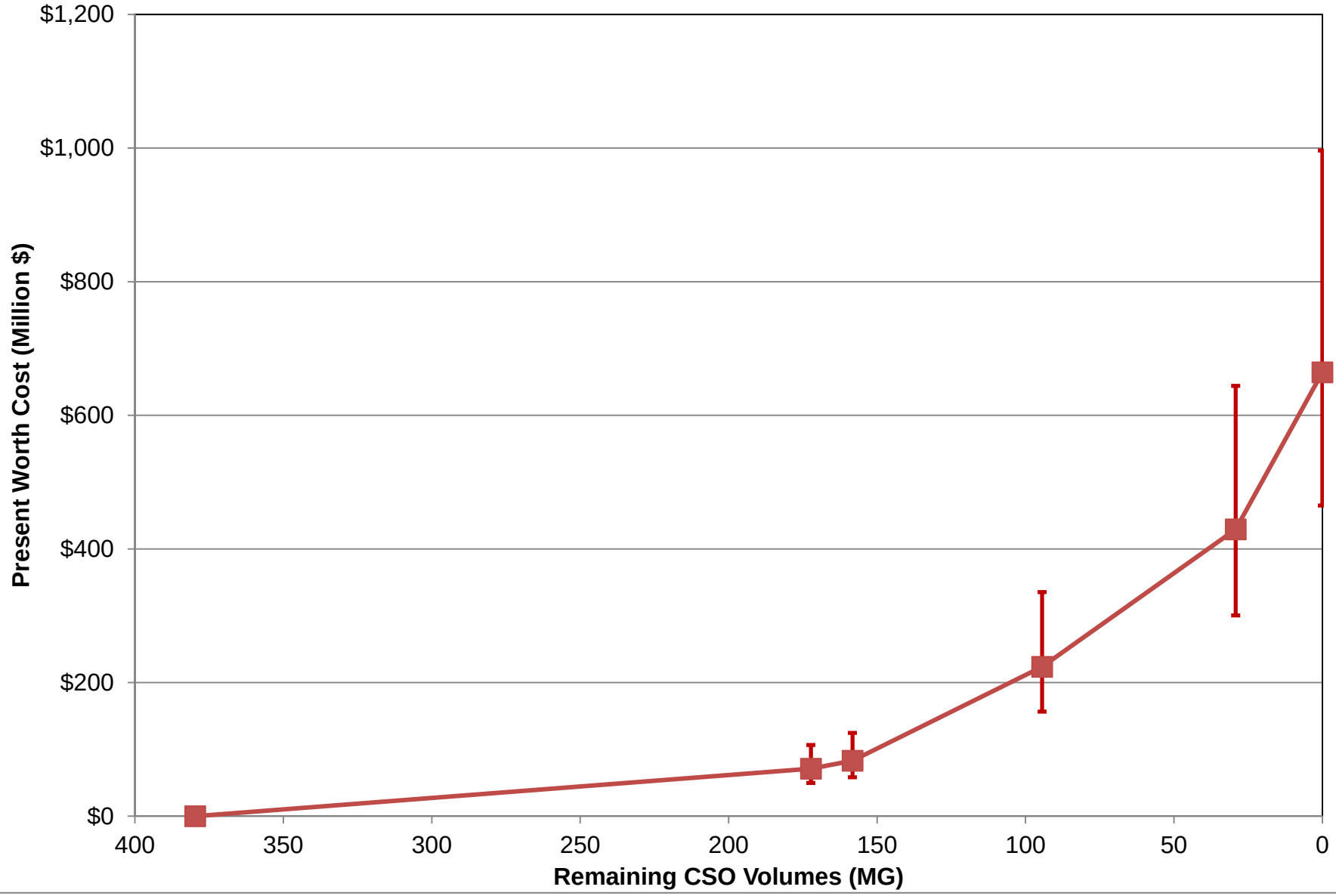


Figure I: Present Worth Costs vs. Remaining CSO Volumes for Buffalo River
(System-wide Alternative UA2)
1993 TY - 2012 Dollars



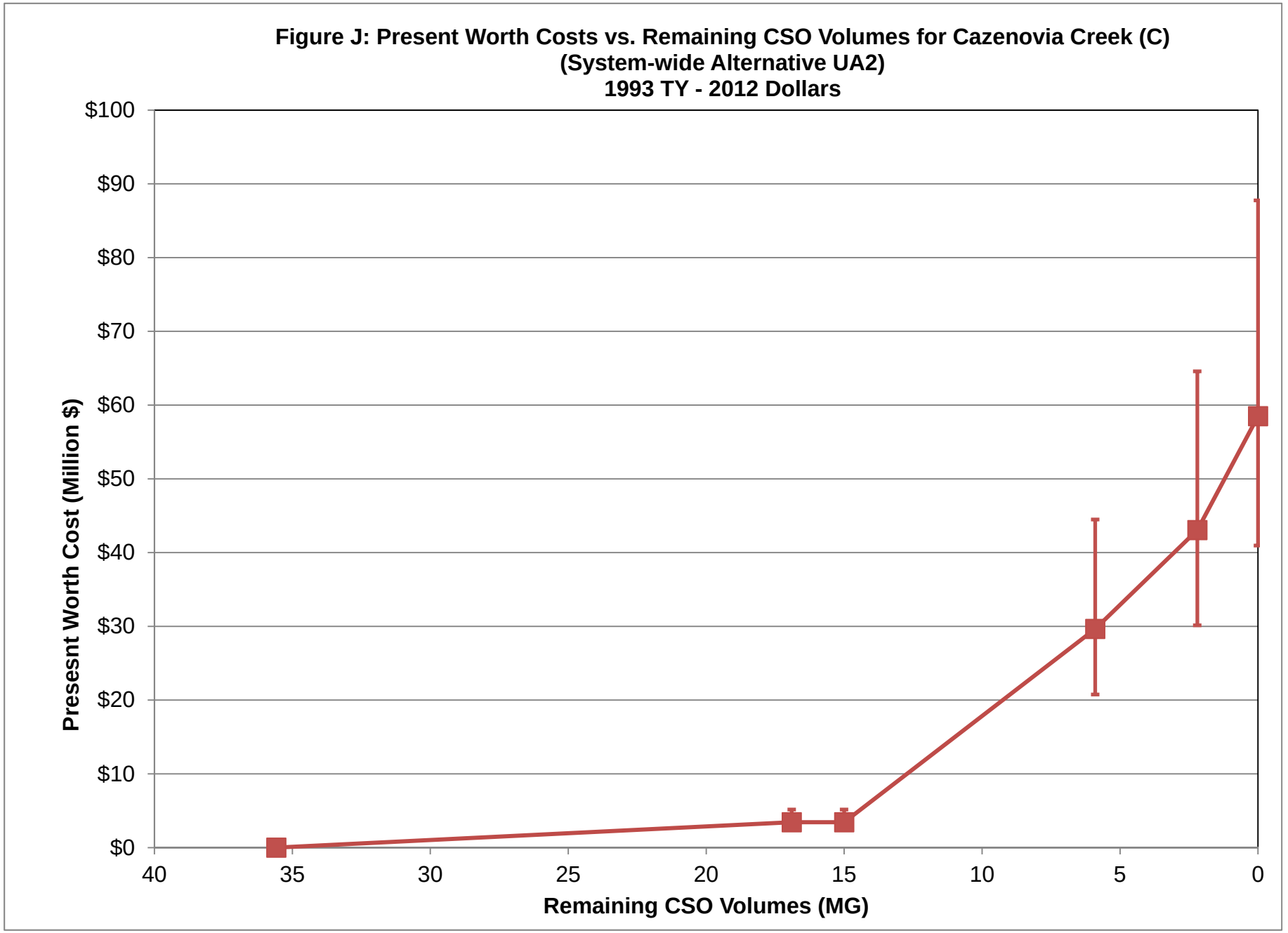


Figure J: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (C)
(System-wide Alternative UA2)
1993 TY - 2012 Dollars
Presesnt Worth Cost (Million $)
$100
$90
$80
$70
$60
$50
$40
$30
$20
$10
$0
40
35
30
25
20
15
10
5
0
Remaining CSO Volumes (MG)

Figure K: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (B)
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

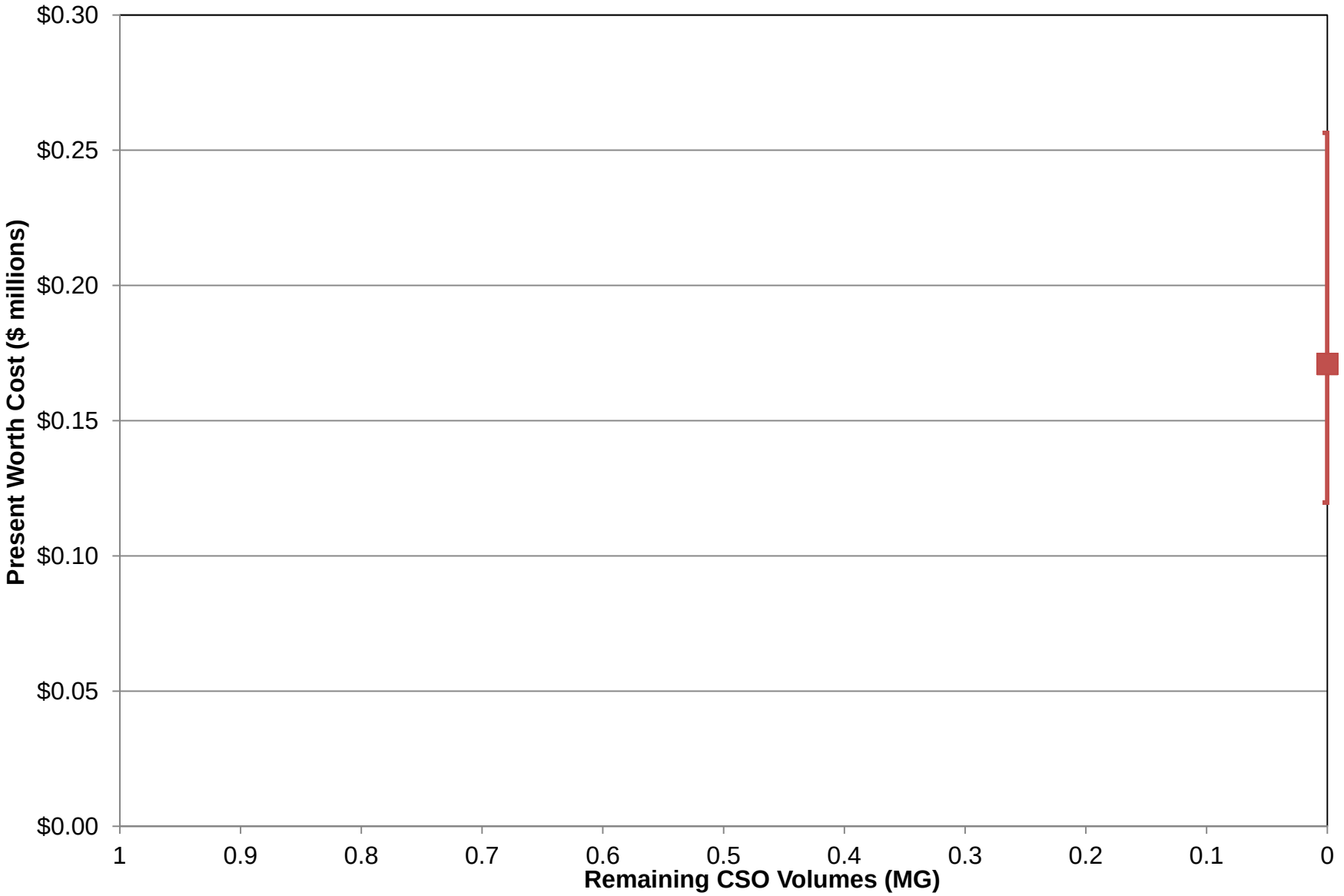


Figure L: Present Worth Costs vs. Remaining CSO Volumes for Niagara River and CSO-055
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

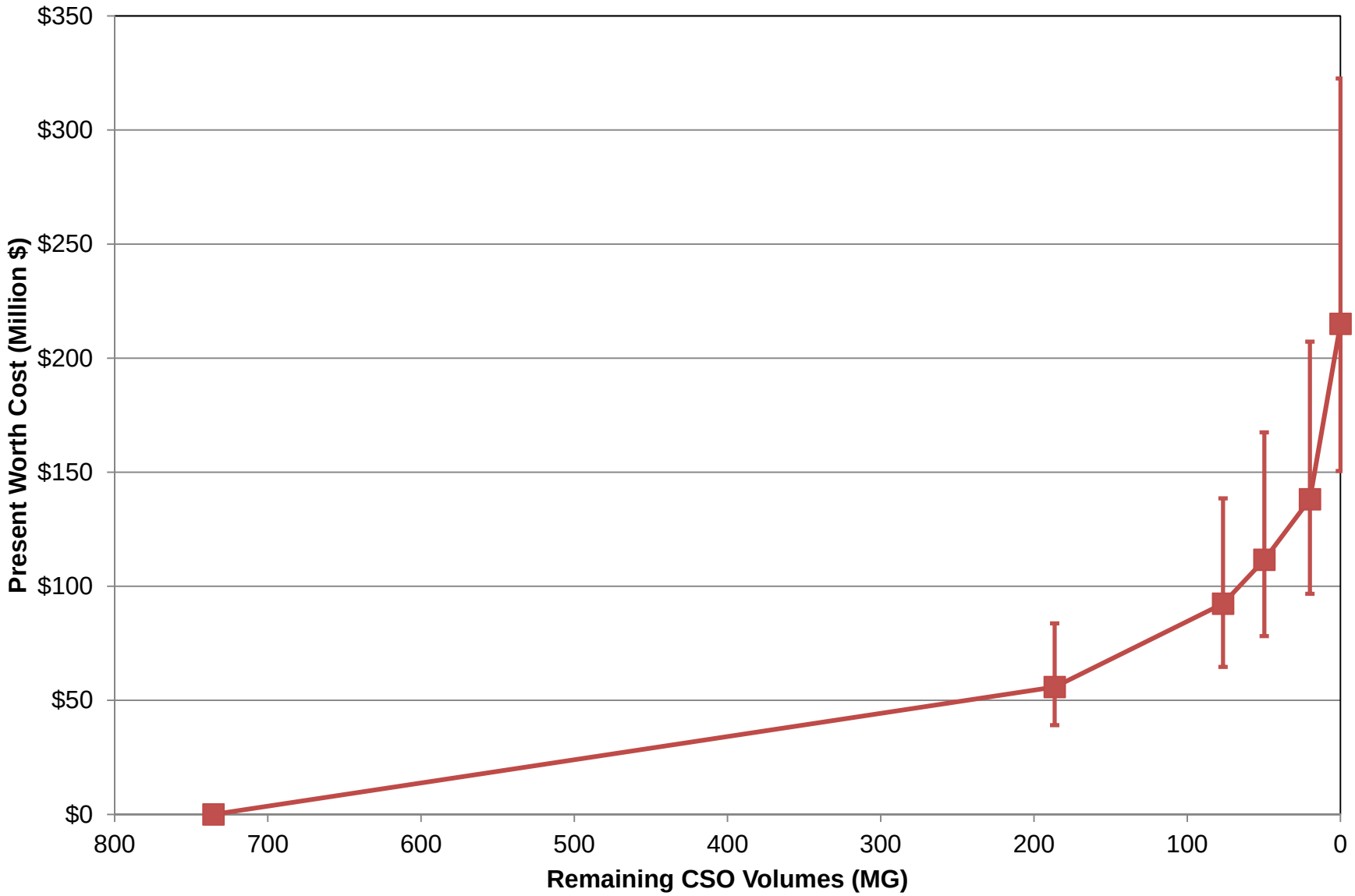


Figure M: Present Worth Costs vs. Remaining CSO Volumes for Erie Basin
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

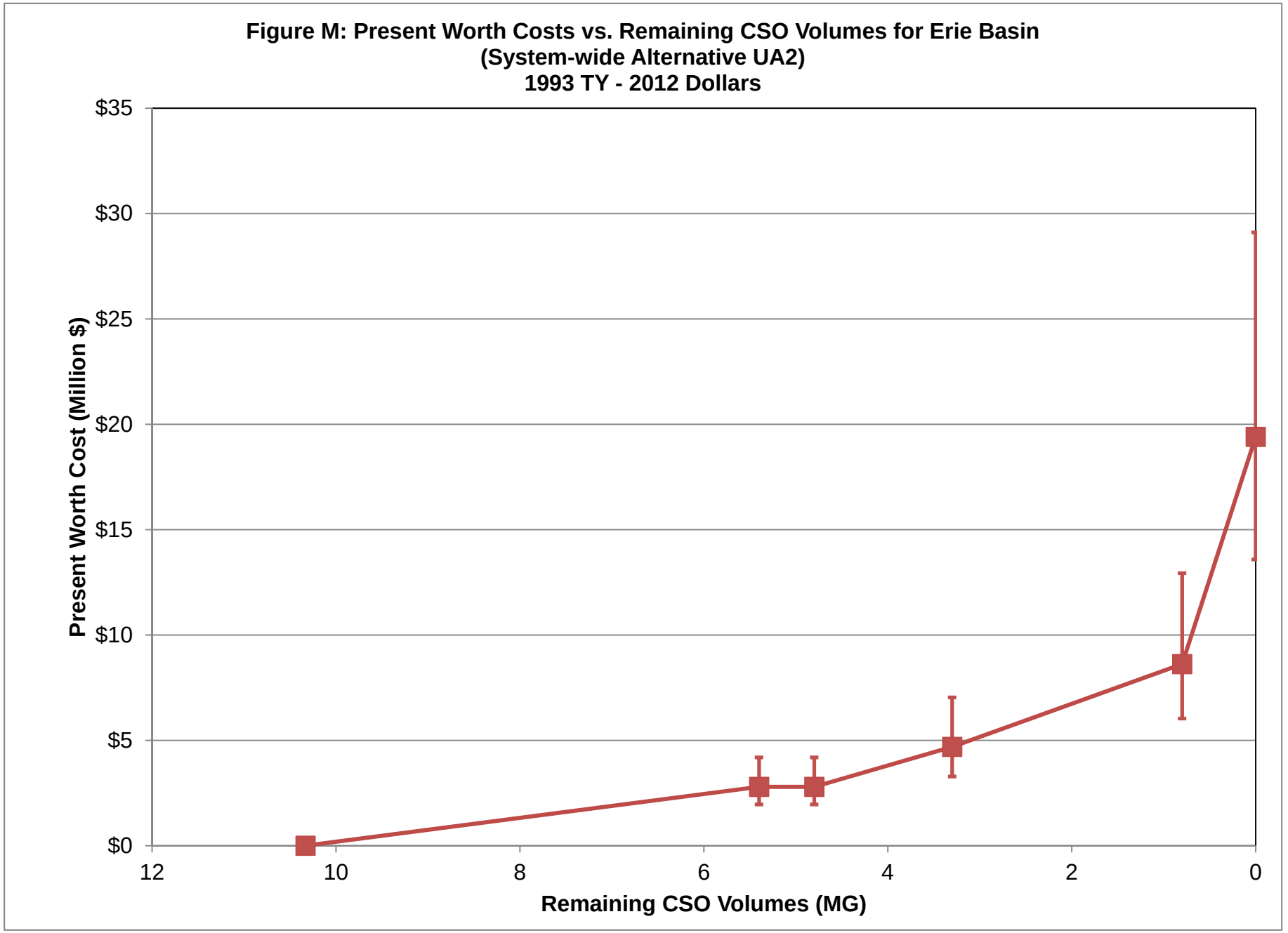


Figure N: Present Worth Costs vs. Remaining CSO Volumes for Scajaquada Creek (System-wide Alternative UA2)
1993 TY - 2012 Dollars

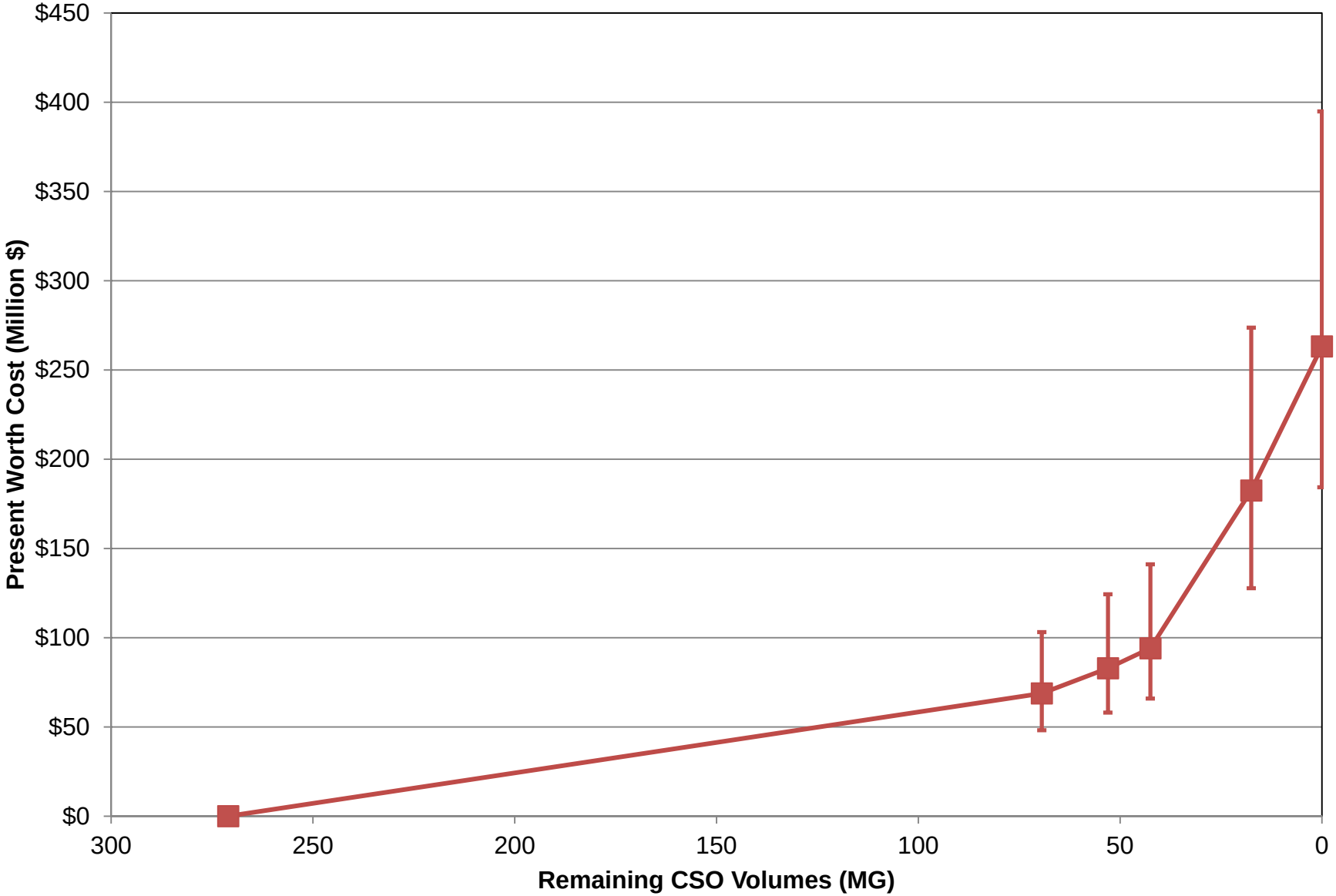


Figure O: Present Worth Costsvs Remaining Fecal Coliform Annual Loadings for System-wide Alternative UA2 1993 TY - 2012 Dollars

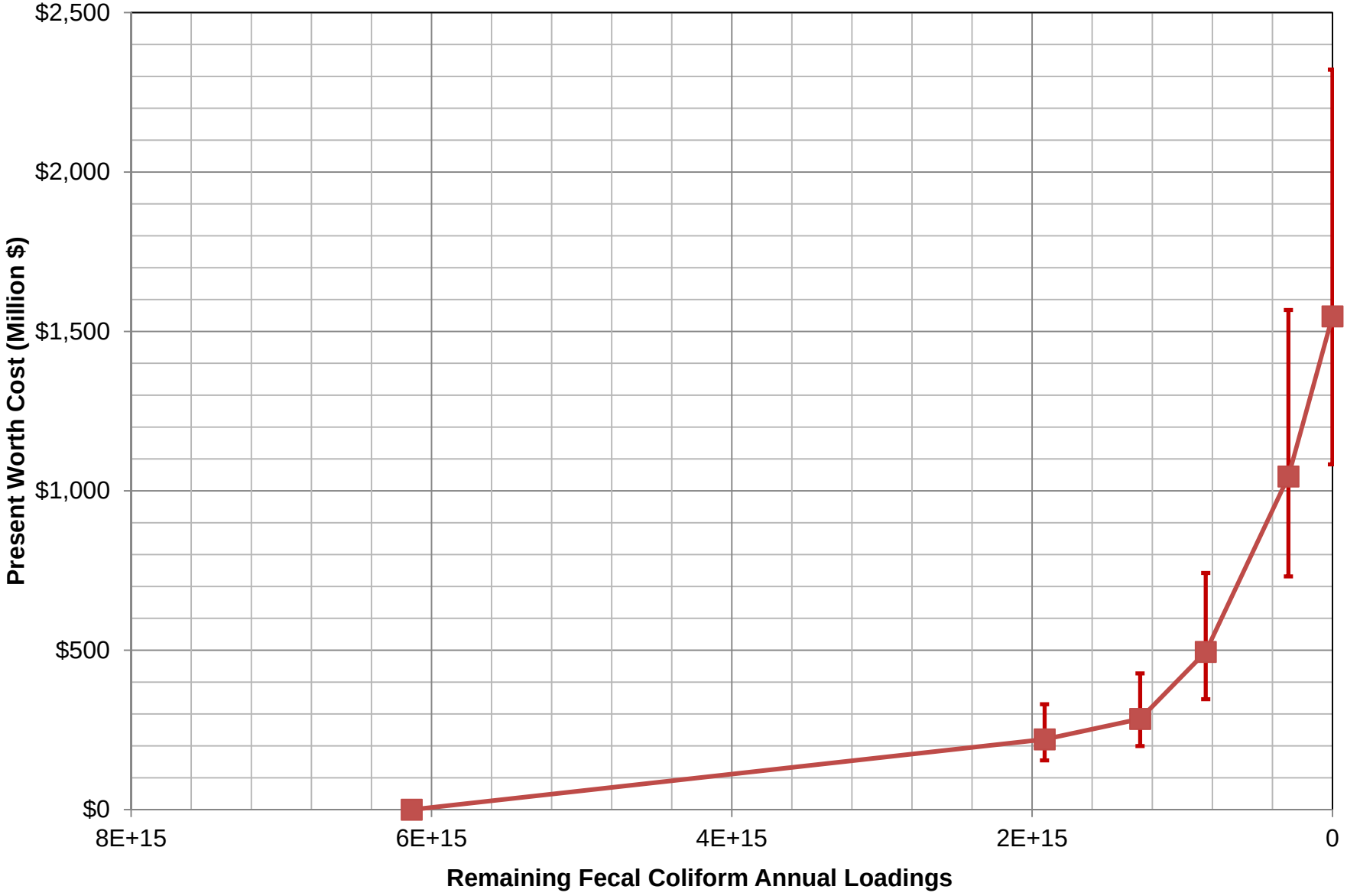


Figure P: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Black Rock Canal (System-wide Alternative UA2)
1993 TY - 2012 Dollars

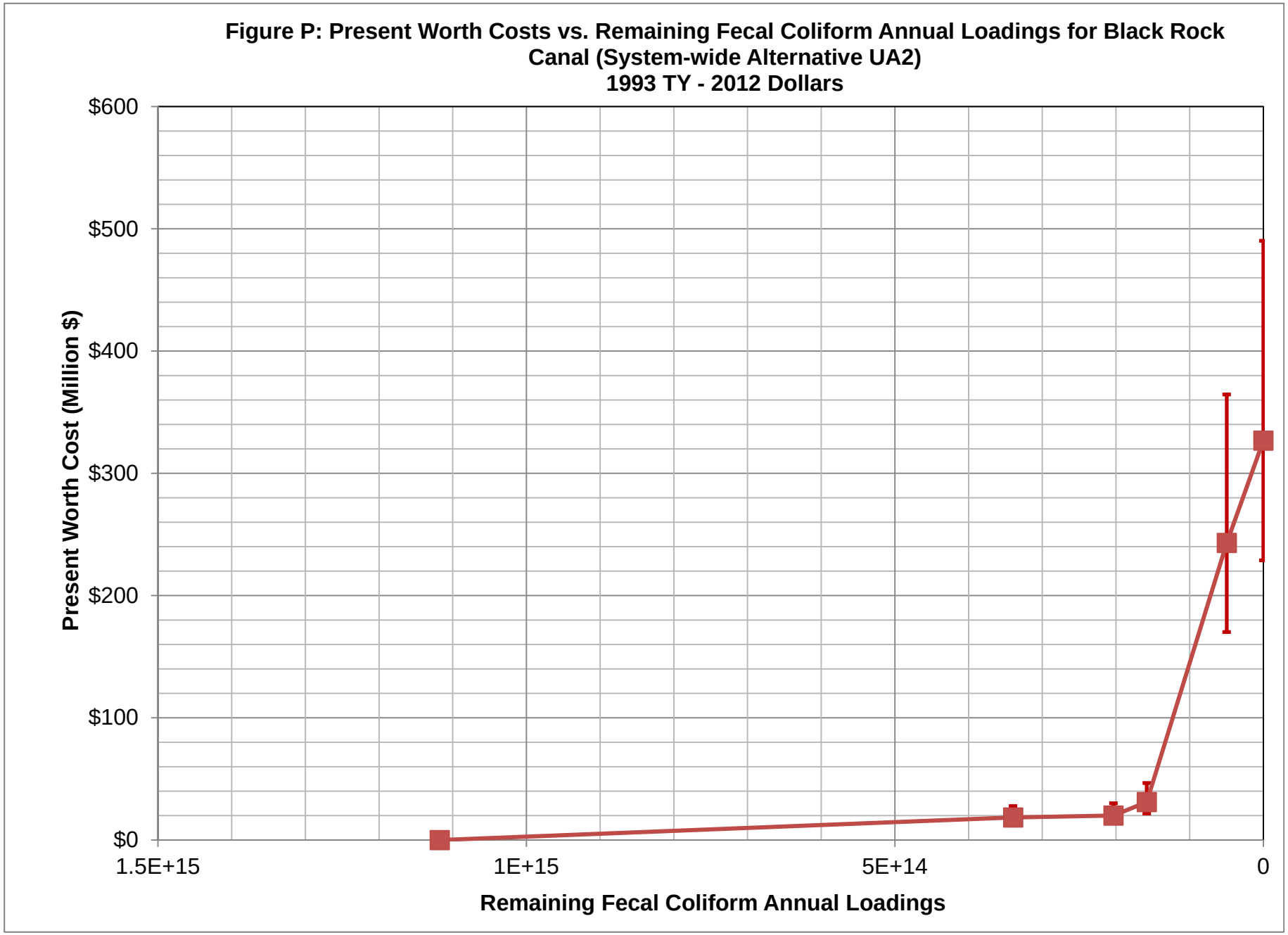


Figure Q: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Buffalo River (System-wide Alternative UA2)
1993 TY - 2012 Dollars

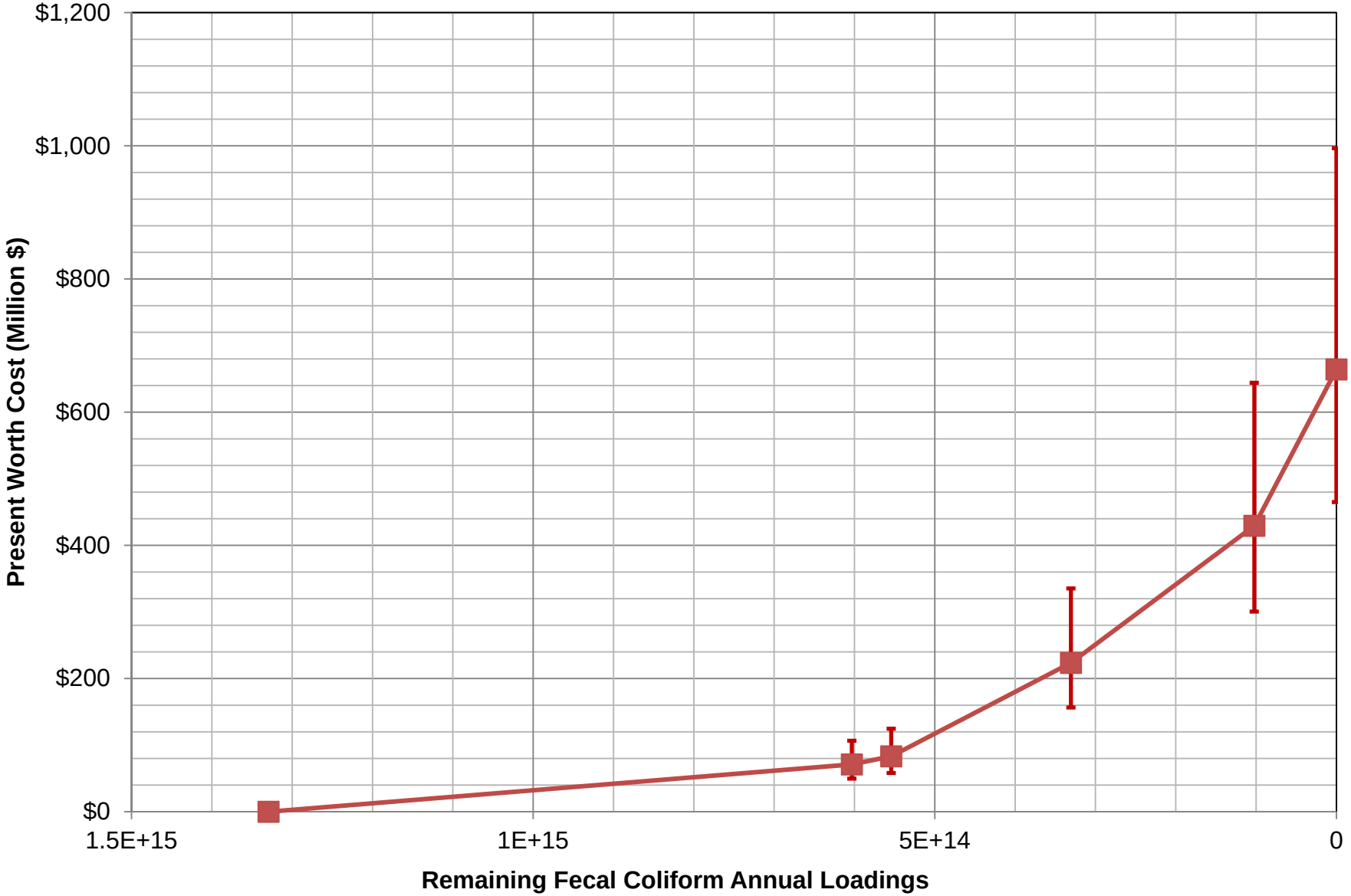


Figure R: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Cazenovia Creek (B) (System-wide Alternative UA2)
1993 TY - 2012 Dollars

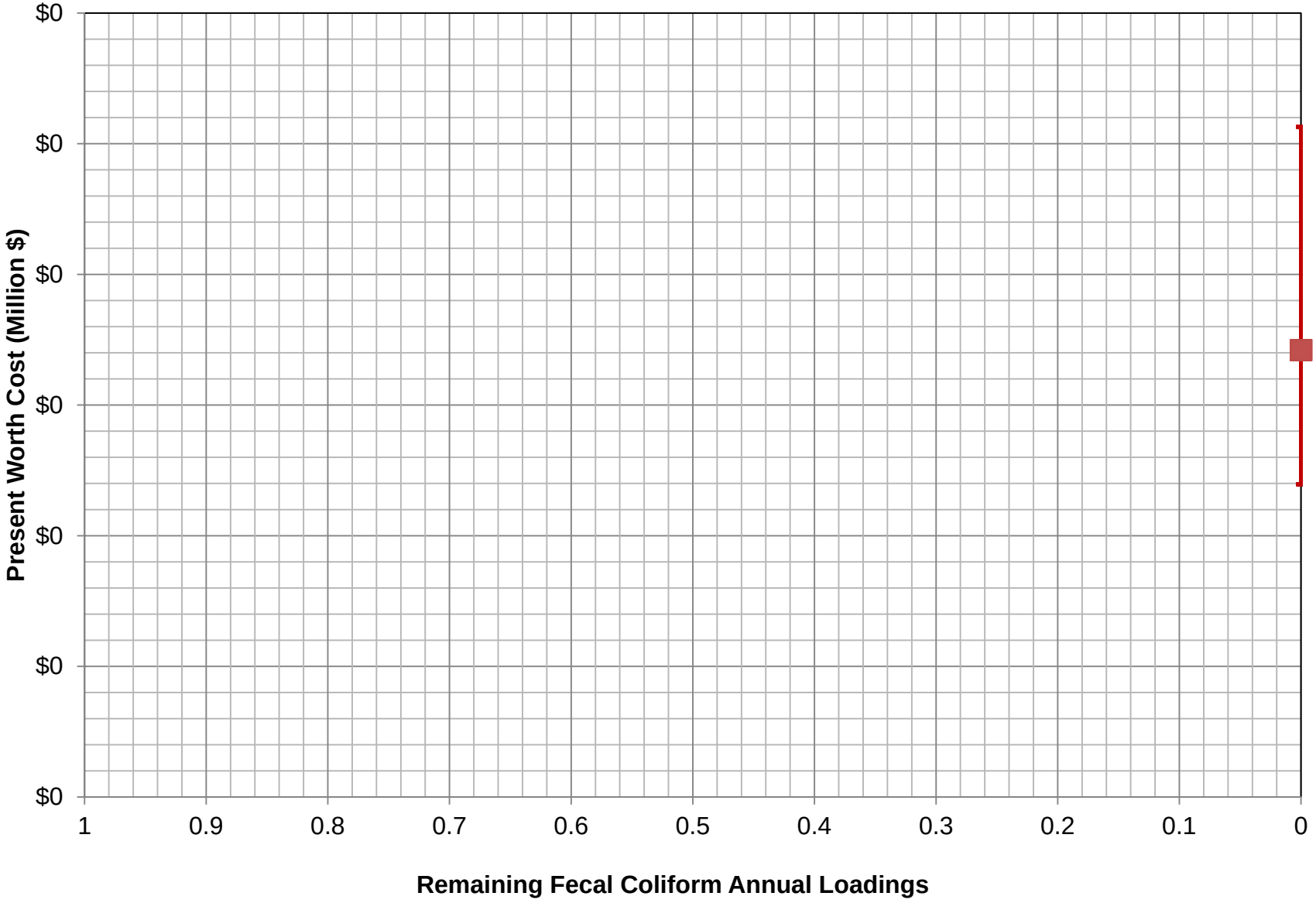


Figure S: Present Worth Costs vs. Remaining Fecal Coliform Loadings for Cazenovia Creek (C)
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

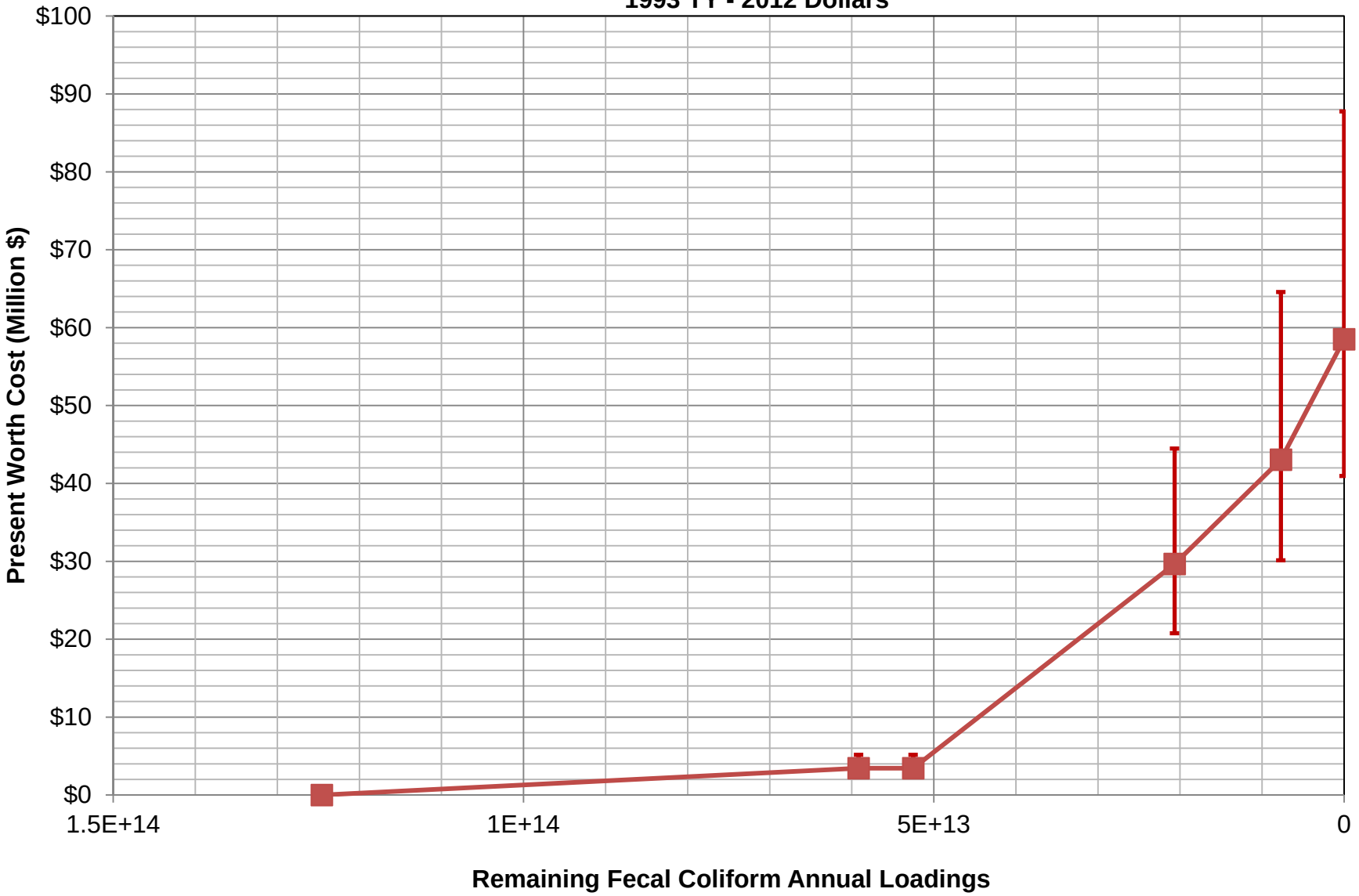


Figure T: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Niagara River CSO-055
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

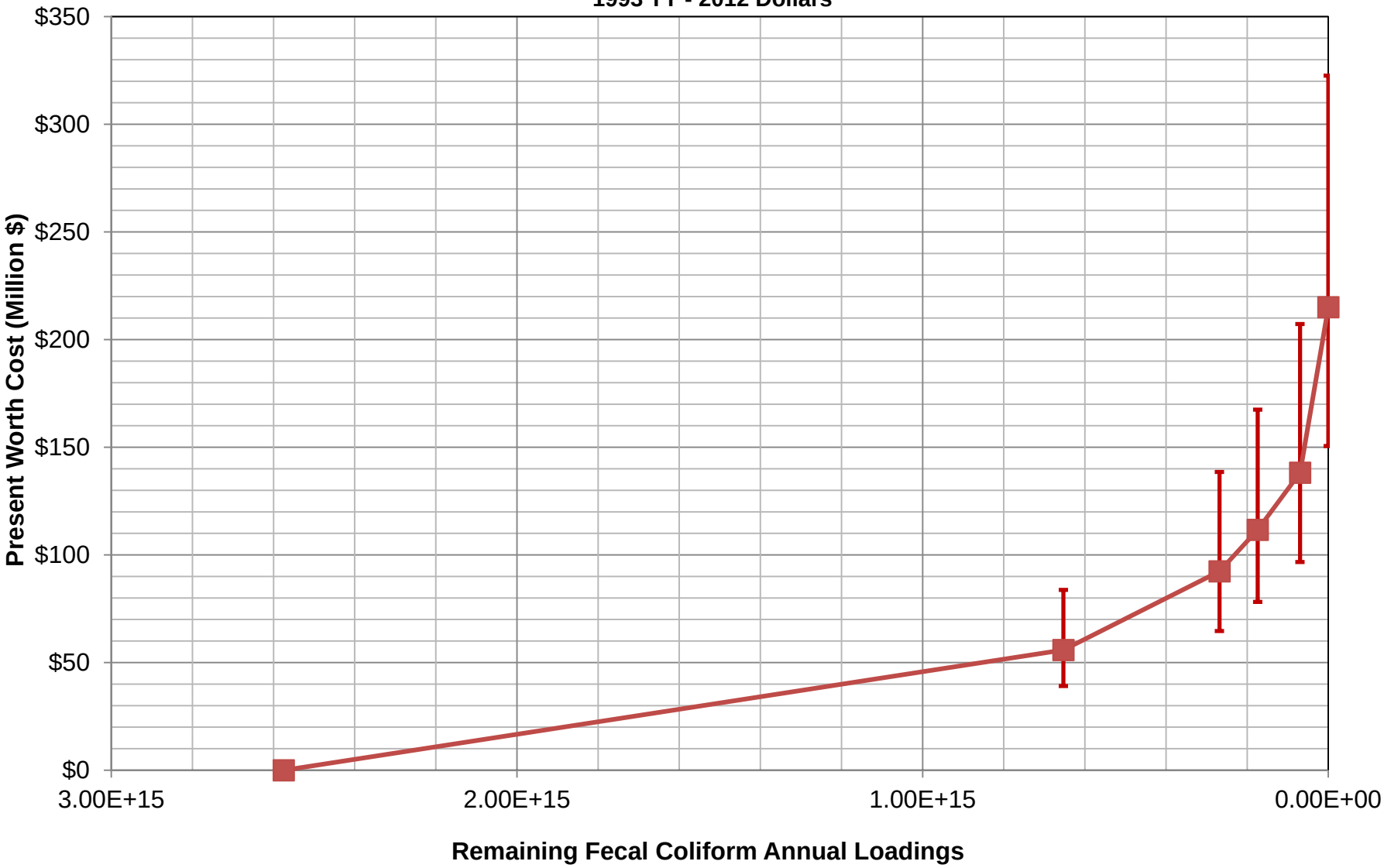


Figure U: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Erie Basin
(System-wide Alternative UA2)
1993 TY - 2012 Dollars

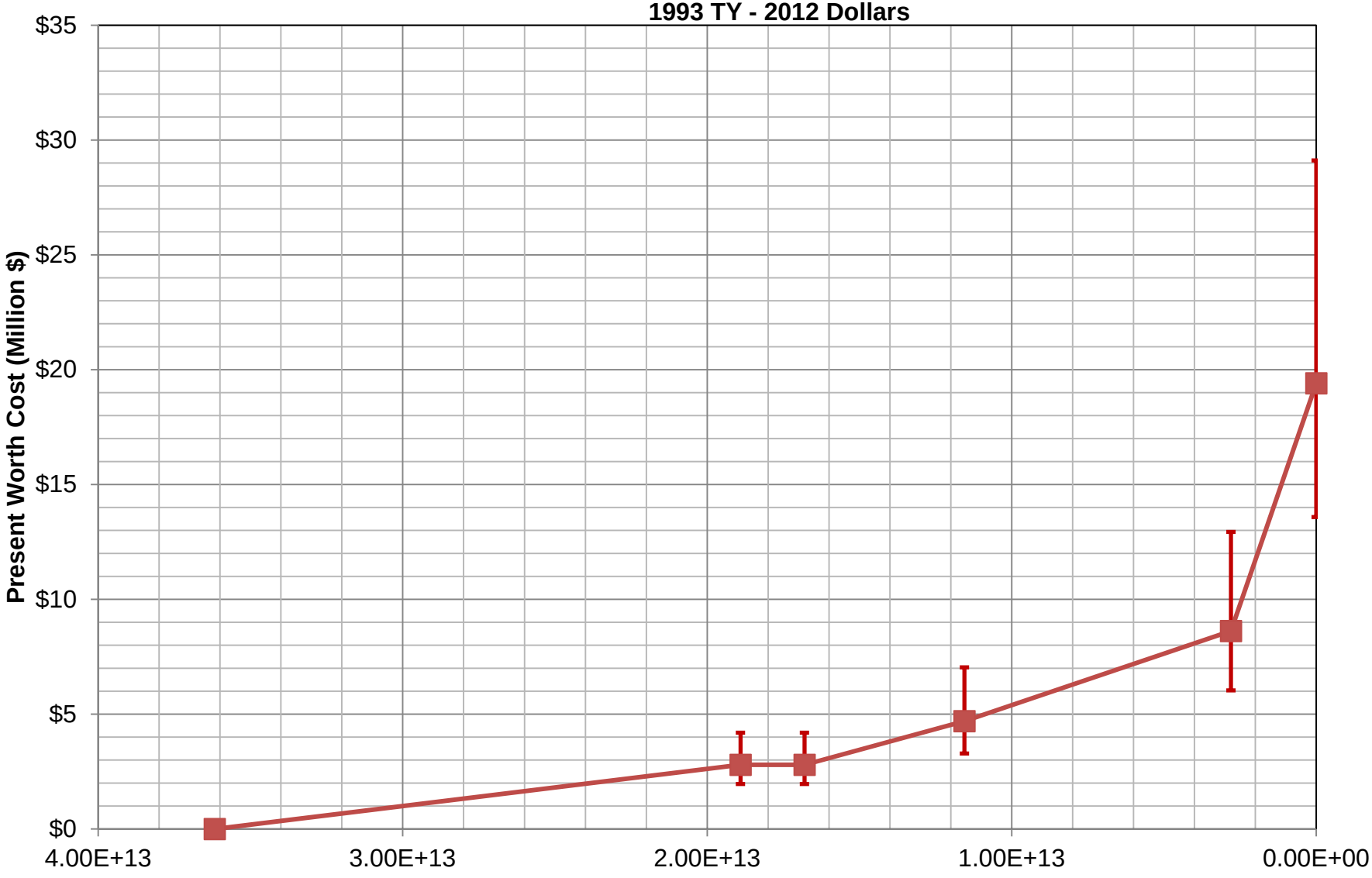
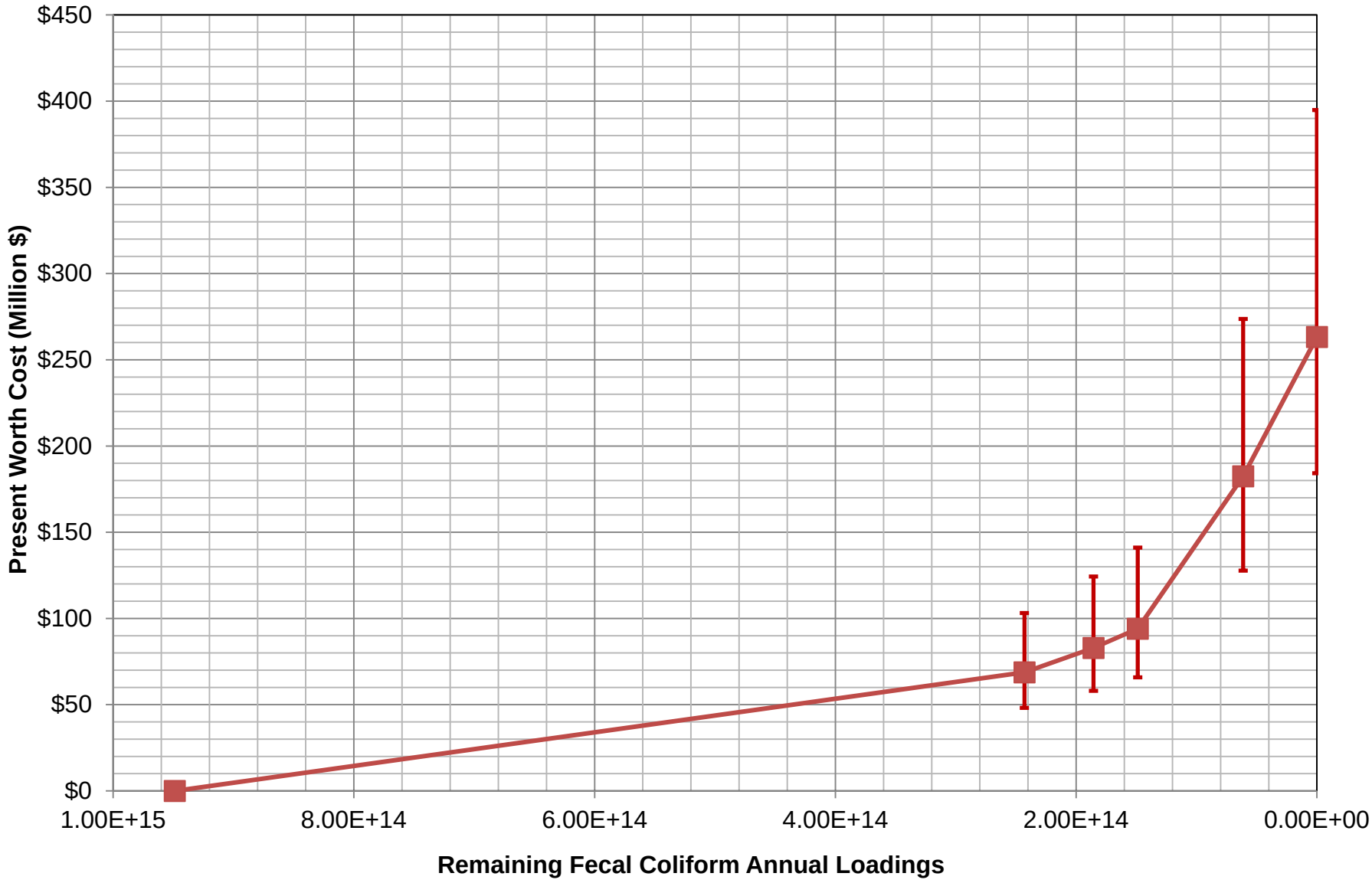


Figure V: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Scajaquada Creek (System-wide Alternative UA2)
1993 TY - 2012 Dollars



Alternative UA2 Overflow Volume Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	Revised Baseline 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA2 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA2 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA2 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA2 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)
004	Scajaquada	Black Rock Canal	16.2	11.2	15.5	15.2	7.8	0.0
005	Scajaquada	Black Rock Canal	0.1	0.1	0.1	0.1	0.1	0.1
006	Scajaquada	Black Rock Canal	201.4	198.9	41.3	33.7	30.1	11.8
008	Scajaquada	Black Rock Canal	8.2	6.1	0.0	0.0	0.0	0.0
010	Scajaquada	Black Rock Canal	11.8	11.9	0.0	0.0	0.0	0.0
012	Albany	Black Rock Canal	52.0	52.5	10.5	1.3	0.2	0.0
013	South Central	Black Rock Canal	13.6	6.8	5.1	5.0	3.7	0.6
061	Scajaquada	Black Rock Canal	33.8	31.2	24.1	2.5	2.8	1.4
063	South Central	Black Rock Canal	1.5	0.6	0.3	0.3	0.3	0.3
017	South Central	Buffalo River	101.6	71.3	35.0	34.7	34.6	4.4
022	South Central	Buffalo River	42.7	29.8	1.7	1.7	0.2	0.0
025	South Central	Buffalo River	1.4	1.4	1.2	1.2	0.6	0.1
026	South Central	Buffalo River	146.5	124.2	25.6	25.7	25.8	11.4
027	South Central	Buffalo River	19.4	31.7	23.9	24.7	17.4	7.0
028	South Central	Buffalo River	44.4	45.5	33.5	20.6	2.5	0.6
029	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
032	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
033	South Central	Buffalo River	35.7	37.8	32.4	32.8	9.6	2.9
034	South Central	Buffalo River	0.1	Closed	Closed	Closed	0.0	0.0
049	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
050	South Central	Buffalo River	4.1	3.2	2.5	2.5	0.8	0.1
051	South Central	Buffalo River	3.7	1.2	1.0	1.0	1.0	0.1
052	South Central	Buffalo River	13.6	10.9	9.1	6.2	1.4	0.4
064	South Central	Buffalo River	27.2	21.1	5.9	6.9	0.1	0.1
066	South Central	Buffalo River	2.5	1.7	0.4	0.4	0.4	2.2
035	South Central	Cazenovia Creek - B	4.8	0.0	0.0	0.0	0.0	0.0
037	South Central	Cazenovia Creek - C	21.2	23.3	11.8	11.8	3.7	0.8
039	South Central	Cazenovia Creek - C	0.0	0.0	0.0	0.0	0.0	0.0
044	South Central	Cazenovia Creek - C	6.5	2.3	1.3	0.7	0.8	0.2
046	South Central	Cazenovia Creek - C	1.1	1.3	1.2	1.2	1.2	1.2
047	South Central	Cazenovia Creek - C	10.4	8.7	2.6	1.3	0.2	0.0
048	South Central	Cazenovia Creek - C	1.5	0.0	0.0	0.0	0.0	0.0
055	Hertel	Cornelius Creek	613.6	601.1	161.1	68.7	44.6	12.5
014	South Central	Erie Basin	25.9	4.2	2.5	1.9	1.7	0.6
015	South Central	Erie Basin	5.7	6.1	2.9	2.9	1.5	0.3
016	South Central	Erie Basin	0.0	0.0	0.0	0.0	0.0	0.0
003	Parish	Niagara River	4.5	0.1	0.1	0.1	0.1	0.1
011	Albany	Niagara River	125.7	134.3	25.3	7.8	5.0	0.8
054	Ontario	Niagara River	0.1	0.0	0.0	0.0	0.0	0.0
053	Scajaquada	Scajaquada Creek	275.0	268.0	68.9	52.5	42.0	17.0
056	Hertel	Scajaquada Creek	0.0	0.0	0.0	0.0	0.0	0.0
057	Parish	Scajaquada Creek	0.3	0.0	0.0	0.0	0.0	0.0
058	Parish	Scajaquada Creek	0.0	0.0	0.0	0.0	0.0	0.0
059	Scajaquada	Scajaquada Creek	5.1	0.0	0.0	0.0	0.0	0.0
060	Scajaquada	Scajaquada Creek	2.9	0.7	0.5	0.5	0.5	0.5
North HRT	-	Niagara River	Closed	Closed	0.0	0.0	0.0	6.5
Totals			1886	1749	547	365.8	241	84
Total CSO Combined Only Volume by District (MG)	Albany		177.7	186.8	35.9	9.1	5.3	0.9
	Hertel		613.7	601.1	161.1	68.7	44.6	12.5
	Ontario		0.1	0.0	0.0	0.0	0.0	0.0
	Parish		4.7	0.1	0.1	0.1	0.1	0.1
	Scajaquada		554.7	528.1	150.4	104.4	83.4	30.8
	South Central		535.2	433.0	200.0	183.5	107.6	33.1
Total CSO Combined Only Volume by Receiving Water (MG)		Black Rock Canal	338.7	319.3	97.0	58.1	45.2	14.2
		Buffalo River	442.9	379.7	172.3	158.3	94.4	29.2
		Cazenovia Creek - B	4.8	0.0	0.0	0.0	0.0	0.0
		Cazenovia Creek - C	40.7	35.6	16.9	15.0	5.9	2.2
		Cornelius Creek	613.6	601.1	161.1	68.7	44.6	12.5
		Erie Basin	31.6	10.3	5.4	4.8	3.3	0.8
		Niagara River	130.2	134.4	25.4	7.8	5.1	7.4
		Scajaquada Creek	283.4	268.7	69.4	53.0	42.5	17.5

Alternative UA2 Overflow Frequency Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA2 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA2 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA2 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA2 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency
004	Scajaquada	Black Rock Canal	7	5	4	4	4	0
005	Scajaquada	Black Rock Canal	0	4	4	4	4	4
006	Scajaquada	Black Rock Canal	65	65	12	6	4	2
008	Scajaquada	Black Rock Canal	42	39	0	0	0	0
010	Scajaquada	Black Rock Canal	44	44	1	1	1	1
012	Albany	Black Rock Canal	42	42	5	2	1	0
013	South Central	Black Rock Canal	14	7	6	6	4	2
061	Scajaquada	Black Rock Canal	10	10	9	4	4	2
063	South Central	Black Rock Canal	50	13	1	1	1	1
017	South Central	Buffalo River	55	49	3	3	3	2
022	South Central	Buffalo River	55	49	12	6	4	1
025	South Central	Buffalo River	11	11	6	6	4	1
026	South Central	Buffalo River	61	63	3	3	3	2
027	South Central	Buffalo River	36	36	12	6	4	2
028	South Central	Buffalo River	69	69	10	6	4	2
029	South Central	Buffalo River	0	0	0	0	0	0
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	8	9	7	7	4	2
034	South Central	Buffalo River	5	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0	0	0	0	0	0
050	South Central	Buffalo River	22	14	11	6	4	2
051	South Central	Buffalo River	16	4	4	4	4	1
052	South Central	Buffalo River	11	10	9	3	3	2
064	South Central	Buffalo River	55	56	10	2	1	1
066	South Central	Buffalo River	16	10	4	4	4	2
035	South Central	Cazenovia Creek - B	29	0	0	0	0	0
037	South Central	Cazenovia Creek - C	14	13	5	5	4	2
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	15	7	4	2	3	1
046	South Central	Cazenovia Creek - C	9	1	0	0	0	0
047	South Central	Cazenovia Creek - C	47	44	7	2	2	1
048	South Central	Cazenovia Creek - C	12	0	0	0	0	0
055	Hertel	Cornelius Creek	40	41	10	6	3	2
014	South Central	Erie Basin	17	4	4	4	4	1
015	South Central	Erie Basin	12	12	6	6	3	2
016	South Central	Erie Basin	3	0	0	0	0	0
003	Parish	Niagara River	27	6	4	4	4	2
011	Albany	Niagara River	41	41	10	4	3	2
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	65	65	12	6	4	2
056	Hertel	Scajaquada Creek	0	0	0	0	0	0
057	Parish	Scajaquada Creek	11	0	0	0	0	0
058	Parish	Scajaquada Creek	2	0	0	0	0	0
059	Scajaquada	Scajaquada Creek	17	0	0	0	0	0
060	Scajaquada	Scajaquada Creek	11	5	5	5	4	2
North HRT	-	Niagara River	Closed	Closed	12	6	4	2

Max Events	Albany		42	42	10	4	3	2
	Hertel		40	41	10	6	3	2
	Ontario		4	0	0	0	0	0
	Parish		27	6	4	4	4	2
	Scajaquada		65	65	12	6	4	2
	South Central		69	69	12	7	4	2
Max Events		Black Rock Canal	65	65	12	6	4	4
		Buffalo River	69	69	12	7	4	2
		Cazenovia Creek - B	29	0	0	0	0	0
		Cazenovia Creek - C	47	44	7	5	4	2
		Cornelius Creek	40	41	10	6	3	2
		Erie Basin	17	12	6	6	4	2
		Niagara River	41	41	12	6	4	2
		Scajaquada Creek	65	65	12	6	4	2

Alternative UA2 Overflow Duration Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA2 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA2 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA2 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA2 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)
004	Scajaquada	Black Rock Canal	12	8	9	9	9	0
005	Scajaquada	Black Rock Canal	5	5	4	4	4	4
006	Scajaquada	Black Rock Canal	322	344	111	57	18	20
008	Scajaquada	Black Rock Canal	105	90	0	0	0	0
010	Scajaquada	Black Rock Canal	103	103	1	1	1	1
012	Albany	Black Rock Canal	111	111	13	4	2	0
013	South Central	Black Rock Canal	58	25	36	36	38	19
061	Scajaquada	Black Rock Canal	31	29	26	10	11	4
063	South Central	Black Rock Canal	110	19	11	11	11	11
017	South Central	Buffalo River	166	124	47	47	48	5
022	South Central	Buffalo River	166	124	23	31	5	1
025	South Central	Buffalo River	17	17	14	12	7	1
026	South Central	Buffalo River	232	247	18	19	19	8
027	South Central	Buffalo River	127	131	50	32	13	6
028	South Central	Buffalo River	328	328	87	42	8	3
029	South Central	Buffalo River	0	0	0	0	0	0
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	20	21	18	18	10	6
034	South Central	Buffalo River	8	Closed	0	0	0	0
049	South Central	Buffalo River	0	0	0	0	0	0
050	South Central	Buffalo River	47	22	17	17	8	2
051	South Central	Buffalo River	56	14	23	22	23	1
052	South Central	Buffalo River	112	70	60	45	14	5
064	South Central	Buffalo River	166	181	130	31	1	1
066	South Central	Buffalo River	26	17	9	9	0	3
035	South Central	Cazenovia Creek - B	55	9	8	8	8	8
037	South Central	Cazenovia Creek - C	42	40	19	19	7	2
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	37	12	12	7	4	2
046	South Central	Cazenovia Creek - C	37	1	0	0	0	0
047	South Central	Cazenovia Creek - C	108	94	12	7	3	1
048	South Central	Cazenovia Creek - C	42	0	0	0	0	0
055	Hertel	Cornelius Creek	184	174	54	33	21	8
014	South Central	Erie Basin	61	15	24	22	22	6
015	South Central	Erie Basin	43	43	25	25	8	6
016	South Central	Erie Basin	4	0	8	0	0	0
003	Parish	Niagara River	224	32	23	23	23	23
011	Albany	Niagara River	240	243	36	7	6	2
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	322	344	111	57	18	20
056	Hertel	Scajaquada Creek	8	8	4	4	4	4
057	Parish	Scajaquada Creek	15	0	0	0	0	0
058	Parish	Scajaquada Creek	2	10	7	7	7	7
059	Scajaquada	Scajaquada Creek	45	26	20	20	20	20
060	Scajaquada	Scajaquada Creek	25	11	9	9	9	9
North HRT	-	Niagara River	Closed	Closed	46	15	7	4

ALTERNATIVE UA3 - System-wide Tunnel and Revised Foundation

FINANCIAL

Current ENR CCI:	9,011	i (interest rate):	5.00%
2004 BSA LTCP ENR CCI:	6,695	j (discount rate):	2.50%
Project Contingency Percentage:	25%	t (time horizon for plan):	20
Engineering Percentage:	15%	Present Worth Factor:	15.30
O/M Contingency Percentage:	10%	Assumed Escalation (for O&M) per year:	3.50%

Sewer Separation (Based on similar projects, partial separation is $25,000/ac and full separation is $50,000/ac)

Receiving Basin	Area (ac)					Cost ($ millions)		
	Partial Sewer Separation	Full Sewer Separation (ac)	Proposed Foundation Partial Separation	Full Separation	Total	Partial Sewer Separation	Full Sewer Separation	Total
Buffalo River	0.00	0.00	0.00	0.00	0.00	*0.00*	*0.00*	*0.00*
Cazenovia Creek - B	0.00	0.00	0.00	0.00	0.00	*0.00*	*0.00*	*0.00*
Cazenovia Creek - C	0.00	0.00	0.00	0.00	0.00	*0.00*	*0.00*	*0.00*
Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Storage (data provided by collection system modeling)

BSA 2004 COST CURVE (unit cost $Cost = 220 * V^{-0.27}$)

ALCOSAN COST CURVE (Dec 2008) $Cost = 3.4 \times V^{0.826}$

EPA CSO Cost Manual (using costs for sed basins) - 1995 $Cost = 8.19 * Capacity^{0.711}$

	Receiving Basin	Volume (MG)					Construction Cost ($ millions) - Updated BSA Curve					Construction Cost ($ millions) - ALCOSAN Curve					Present Worth O/M Cost ($ millions)					Total Present Worth Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO 003	Niagara River	0.12	0	0	0	0	*$1.51*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.62*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	$0.12	$0.00	$0.00	$0.00	$0.00	$0.75	$0.00	$0.00	$0.00	$0.00
CSO 051/052/066	Buffalo River	15	3.8	2.75	2.5	0	*$51.29*	*$18.82*	*$14.87*	*$13.87*	*$0.00*	*$33.55*	*$10.79*	*$8.26*	*$7.64*	*$0.00*	$1.83	$0.85	$0.71	$0.67	$0.00	$35.38	$11.64	$8.97	$8.31	$0.00
CSO 056/060	Scajaquada Creek	0.5	0.25	0.14	0	0	*$4.28*	*$2.58*	*$1.69*	*$0.00*	*$0.00*	*$2.02*	*$1.14*	*$0.71*	*$0.00*	*$0.00*	$0.27	$0.19	$0.13	$0.00	$0.00	$2.29	$1.33	$0.84	$0.00	$0.00
CSO 055	Cornelius Creek	76.2	54.1	37	28	13.3	*$167.99*	*$130.82*	*$99.14*	*$80.89*	*$46.97*	*$128.45*	*$96.80*	*$70.72*	*$56.18*	*$30.38*	$4.55	$3.75	$3.04	$2.60	$1.71	$133.00	$100.55	$73.76	$58.78	$32.09
Total		**91.82**	**58.15**	**39.89**	**30.50**	**13.30**	***$225.06***	***$152.23***	***$115.69***	***$94.75***	***$46.97***	***$164.64***	***$108.73***	***$79.69***	***$63.82***	***$30.38***	***$6.77***	***$4.79***	***$3.88***	***$3.27***	***$1.71***	***$171.42***	***$113.52***	***$83.57***	***$67.09***	***$32.09***

Storage Consolidation Piping (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length	Diameter (ft)	Unit Cost ($/ft)	Construction Cost ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CSO 055	Cornelius Creek	1,262	10	$1,963	*$2.48*	*$2.48*	*$2.48*	*$2.48*	*$2.48*
CSO 003	Niagara River	159	1.5	$183	*$0.03*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 060	Scajaquada Creek	234	2.5	$289	*$0.07*	*$0.07*	*$0.07*	*$0.00*	*$0.00*
CSO 056	Scajaquada Creek	355	1	$188	*$0.07*	*$0.07*	*$0.07*	*$0.00*	*$0.00*
CSO 051	Buffalo River	2,226	3	$362	*$0.81*	*$0.81*	*$0.81*	*$0.81*	*$0.00*
CSO 066	Buffalo River	591	3.5	$420	*$0.25*	*$0.25*	*$0.25*	*$0.25*	*$0.00*
CSO 052	Buffalo River	406	2.5	$289	*$0.12*	*$0.12*	*$0.12*	*$0.12*	*$0.00*
Total		**5,232**			**$3.81**	**$3.78**	**$3.78**	**$3.65**	**$2.48**

Storage Dewatering Force Main (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter) (O&M costs assumed to be zero)

	Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Cost ($ millions)				
			0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO 051/052/066	Buffalo River	1,336	24	16	14	14	0	$161	$102	$84	$84	$0	*$0.22*	*$0.14*	*$0.11*	*$0.11*	*$0.00*
CSO 055	Cornelius Creek	707	78	66	54	48	24	$1,030	$680	$449	$365	$161	*$0.73*	*$0.48*	*$0.32*	*$0.26*	*$0.11*
CSO 003	Niagara River	291	4	0	0	0	0	$32	$0	$0	$0	$0	*$0.01*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 056/060	Scajaquada Creek	2,496	8	4	4	0	0	$46	$32	$32	$0	$0	*$0.12*	*$0.08*	*$0.08*	*$0.00*	*$0.00*
Total		**4,830**											***$1.07***	***$0.70***	***$0.51***	***$0.37***	***$0.11***

Tunnel Storage (data provided by collection system model)

BSA 2004 Curve $BRC\ cost = 8194560 \times dia.$ $SC\ cost = 2846725.52 x dia$

ALCOSAN cost curve (deep tunnel dewatering, Fig D-3) $Cost = 910439 \times Flow^{0.9421}$

Calculation Based on per Gal Pumped

ALCOSAN COST CURVE (DEC 2008) - Source 2 $Cost = 749.43 \times VOL + 17816$

ALCOSAN COST CURVE (DEC 2008) - Source 2 $Cost = 959.78 * VOL + 22246$

BSA 2004 LTCP Equation [illegible]

	Receiving Basin	Volume (MG) or Dewatering (MGD) or Diameter (ft)					Length (ft)	Tunnel Cost ($ millions) - linear curve					Dewatering PS Cost ($ millions) - Alcosan Curve					Total Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South Volume	Black Rock Canal	157.2	70	36	29	7.9	36,600	*$297.79*	*$198.53*	*$143.38*	*$132.35*	*$77.21*	$121.22	$56.57	$30.23	$24.66	$7.24	$419.01	$255.09	$173.61	$157.01	$84.45
North-South Diameter		27	18	13	12	7																
East-West Volume	Scajaquada Creek	53.6	30	16	7.4	3.2	14,200	*$95.79*	*$72.80*	*$53.64*	*$34.48*	*$26.82*	$43.99	$25.46	$14.08	$6.81	$3.09	$139.78	$98.26	$67.72	$41.29	$29.91
East-West Diameter		25	19	14	9	7																
Total		**210.8**	**100.0**	**52.0**	**36.4**	**11.1**	**50,800**	***$393.58***	***$271.33***	***$197.02***	***$166.84***	***$104.03***	***$165.20***	***$82.03***	***$44.32***	***$31.47***	***$10.34***	***$558.78***	***$353.35***	***$241.34***	***$198.31***	***$114.36***

	Receiving Basin	Annual Volume Pumped (MG)					Annual Present Worth O/M Costs - Energy ($ millions)					Annual Present Worth O/M Costs - Materials ($ millions)					Annual Present Worth O/M Costs - Labor ($ millions)					Present Worth O/M Costs - Tunnel ($ millions)					Present Worth O/M Costs - Total ($ millions)					Costs - Total ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South Volume	Black Rock Canal	648.8	534.9	456.8	432.3	299	$0.58	$0.48	$0.41	$0.39	$0.27	$2.30	$1.19	$0.76	$0.67	$0.40	$2.94	$1.52	$0.97	$0.85	$0.51	$7.87	$6.51	$5.97	$5.87	$5.53	$13.69	$9.70	$8.11	$7.78	$6.71	$432.70	$264.79	$181.72	$164.79	$91.16
North-South Diameter																																				
East-West Volume	Scajaquada Creek	253	219.9	189.1	150.7	139.8	$0.23	$0.20	$0.17	$0.14	$0.13	$0.98	$0.68	$0.51	$0.40	$0.34	$1.25	$0.87	$0.64	$0.50	$0.43	$6.25	$5.88	$5.66	$5.53	$5.46	$8.71	$7.63	$6.98	$6.56	$6.36	$148.49	$105.89	$74.70	$47.85	$36.27
East-West Diameter																																				
Total		**901.8**	**754.8**	**645.9**	**583**	**438.8**	**$0.81**	**$0.68**	**$0.58**	**$0.52**	**$0.39**	**$3.28**	**$1.88**	**$1.27**	**$1.07**	**$0.75**	**$4.19**	**$2.39**	**$1.61**	**$1.35**	**$0.94**	**$14.12**	**$12.39**	**$11.64**	**$11.39**	**$11.00**	**$22.41**	**$17.33**	**$15.09**	**$14.33**	**$13.08**	**$581.19**	**$370.68**	**$256.42**	**$212.64**	**$127.44**

Dynamic Head (ft):	125
Efficiency (%):	67%
Electricity Cost ($/kWhr):	0.1

Tunnel Collectors (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length (ft)	Diameter (ft)	Unit Cost ($/ft)	Construction Costs - Total ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CazCrk1	Cazenovia Creek C	1,201	7.0	$1,072	*$1.29*	*$1.29*	*$1.29*	*$1.29*	*$1.29*
CazCrk2	Cazenovia Creek C	412	7.0	$1,072	*$0.44*	*$0.44*	*$0.44*	*$0.44*	*$0.44*
CazCrk3	Cazenovia Creek C	401	5.5	$739	*$0.30*	*$0.30*	*$0.30*	*$0.30*	*$0.30*
CazCrk4	Cazenovia Creek C	606	5.5	$739	*$0.45*	*$0.45*	*$0.45*	*$0.45*	*$0.45*
CSO 004	Black Rock Canal	977	6.0	$842	*$0.82*	*$0.82*	*$0.82*	*$0.82*	*$0.00*
CSO 008	Black Rock Canal	387	3.0	$362	*$0.14*	*$0.14*	*$0.14*	*$0.14*	*$0.14*
CSO 010	Black Rock Canal	1,496	3.5	$420	*$0.63*	*$0.63*	*$0.63*	*$0.63*	*$0.63*
CSO 011	Niagara River	1,512	9.0	$1,633	*$2.47*	*$2.47*	*$2.47*	*$2.47*	*$2.47*
CSO 012	Black Rock Canal	22	8.0	$1,336	*$0.03*	*$0.03*	*$0.03*	*$0.03*	*$0.03*
CSO 013	Black Rock Canal	3,643	5.0	$645	*$2.35*	*$2.35*	*$2.35*	*$2.35*	*$0.00*
CSO 014	Erie Basin	970	4.5	$559	*$0.54*	*$0.54*	*$0.00*	*$0.00*	*$0.00*
CSO 015	Erie Basin	176	4.0	$478	*$0.08*	*$0.08*	*$0.08*	*$0.08*	*$0.00*
CSO 017	Buffalo River	1,486	7.0	$1,072	*$1.59*	*$1.59*	*$0.00*	*$0.00*	*$0.00*
CSO 022	Buffalo River	870	3.0	$362	*$0.32*	*$0.32*	*$0.32*	*$0.32*	*$0.32*
CSO 025	Buffalo River	3,306	2.5	$289	*$0.96*	*$0.96*	*$0.96*	*$0.96*	*$0.00*
CSO 026	Buffalo River	1,869	6.5	$953	*$1.78*	*$1.78*	*$0.00*	*$0.00*	*$0.00*
CSO 027	Buffalo River	1,597	5.5	$739	*$1.18*	*$1.18*	*$1.18*	*$1.18*	*$0.00*
CSO 028	Buffalo River	25	7.0	$1,072	*$0.03*	*$0.03*	*$0.03*	*$0.03*	*$0.03*
CSO 029	Buffalo River	2,504	7.0	$1,072	*$2.69*	*$2.69*	*$2.69*	*$2.69*	*$2.69*
CSO 033	Buffalo River	573	6.0	$842	*$0.48*	*$0.48*	*$0.48*	*$0.48*	*$0.00*
CSO 035	Cazenovia Creek B	4,431	2.5	$289	*$1.28*	*$1.28*	*$1.28*	*$0.00*	*$0.00*
CSO 037	Cazenovia Creek C	597	4.5	$559	*$0.33*	*$0.33*	*$0.33*	*$0.33*	*$0.33*
CSO 039	Cazenovia Creek C	2,133	4.5	$559	*$1.19*	*$1.19*	*$1.19*	*$1.19*	*$1.19*
CSO 044	Cazenovia Creek C	1,366	5.0	$645	*$0.88*	*$0.88*	*$0.88*	*$0.88*	*$0.88*
CSO 046	Cazenovia Creek C	1,485	3.0	$362	*$0.54*	*$0.54*	*$0.54*	*$0.00*	*$0.00*
CSO 047	Cazenovia Creek C	36	3.0	$362	*$0.01*	*$0.01*	*$0.01*	*$0.01*	*$0.01*
CSO 047 (2)	Cazenovia Creek C	21	3.0	$362	*$0.01*	*$0.01*	*$0.01*	*$0.01*	*$0.01*
CSO 048	Cazenovia Creek C	70	0.8	$181	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 049	Buffalo River	390	3.5	$420	*$0.16*	*$0.16*	*$0.16*	*$0.16*	*$0.16*
CSO 050	Buffalo River	1,531	3.0	$362	*$0.55*	*$0.55*	*$0.55*	*$0.55*	*$0.55*
CSO 057	Scajaquada Creek	862	2.5	$289	*$0.25*	*$0.25*	*$0.25*	*$0.25*	*$0.00*
CSO 058	Scajaquada Creek	324	2.5	$289	*$0.09*	*$0.09*	*$0.09*	*$0.09*	*$0.00*
CSO 059	Scajaquada Creek	1,639	3.0	$362	*$0.59*	*$0.59*	*$0.59*	*$0.00*	*$0.00*
CSO 061	Black Rock Canal	239	5.0	$645	*$0.15*	*$0.15*	*$0.15*	*$0.15*	*$0.00*
CSO 063	Black Rock Canal	1,783	2.0	$247	*$0.44*	*$0.44*	*$0.44*	*$0.44*	*$0.00*
CSO 064	Buffalo River	1,121	6.5	$953	*$1.07*	*$1.07*	*$1.07*	*$1.07*	*$1.07*
SPP156	Scajaquada Creek	105	1.0	$188	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP157	Scajaquada Creek	772	2.5	$289	*$0.22*	*$0.22*	*$0.22*	*$0.00*	*$0.00*
SPP163	Scajaquada Creek	837	3.0	$362	*$0.30*	*$0.30*	*$0.30*	*$0.00*	*$0.00*
SPP165a&b	Scajaquada Creek	123	2.5	$289	*$0.04*	*$0.04*	*$0.04*	*$0.04*	*$0.04*
SPP166	Scajaquada Creek	247	2.0	$247	*$0.06*	*$0.06*	*$0.00*	*$0.00*	*$0.00*
SPP170b	Scajaquada Creek	1,036	5.5	$739	*$0.77*	*$0.77*	*$0.77*	*$0.77*	*$0.77*
SPP178	Scajaquada Creek	1,385	4.0	$478	*$0.66*	*$0.66*	*$0.66*	*$0.66*	*$0.66*
SPP179	Black Rock Canal	2,721	5.0	$645	*$1.75*	*$1.75*	*$1.75*	*$1.75*	*$0.00*
SPP180	Black Rock Canal	1,395	4.0	$478	*$0.67*	*$0.67*	*$0.67*	*$0.67*	*$0.00*
SPP200a&b	Scajaquada Creek	130	2.5	$289	*$0.04*	*$0.04*	*$0.04*	*$0.00*	*$0.00*
SPP201	Scajaquada Creek	1,123	3.5	$420	*$0.47*	*$0.47*	*$0.47*	*$0.00*	*$0.00*
SPP202	Scajaquada Creek	774	3.0	$362	*$0.28*	*$0.28*	*$0.28*	*$0.00*	*$0.00*
SPP203	Scajaquada Creek	39	3.0	$362	*$0.01*	*$0.01*	*$0.01*	*$0.01*	*$0.00*
SPP204	Scajaquada Creek	1,752	4.0	$478	*$0.84*	*$0.84*	*$0.84*	*$0.84*	*$0.00*
SPP229a	Scajaquada Creek	92	3.5	$420	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.00*
SPP331	Black Rock Canal	2,587	3.5	$420	*$1.09*	*$1.09*	*$1.09*	*$1.09*	*$0.00*
SPP335	Scajaquada Creek	1,706	3.0	$362	*$0.62*	*$0.62*	*$0.62*	*$0.00*	*$0.00*
SPP335a	Scajaquada Creek	24	1.5	$183	*$0.004*	*$0.004*	*$0.00*	*$0.00*	*$0.00*
SPP336a	Scajaquada Creek	144	2.5	$289	*$0.04*	*$0.04*	*$0.04*	*$0.04*	*$0.04*
SPP336b	Scajaquada Creek	2,324	5.0	$645	*$1.50*	*$1.50*	*$1.50*	*$1.50*	*$1.50*
SPP337	Scajaquada Creek	1,418	5.5	$739	*$1.05*	*$1.05*	*$1.05*	*$1.05*	*$1.05*
SPP338	Scajaquada Creek	1,905	5.0	$645	*$1.23*	*$1.23*	*$0.00*	*$0.00*	*$0.00*
SPP339	Scajaquada Creek	1,285	4.0	$478	*$0.61*	*$0.61*	*$0.00*	*$0.00*	*$0.00*
SPP340	Scajaquada Creek	1,164	5.5	$739	*$0.86*	*$0.86*	*$0.86*	*$0.86*	*$0.00*
SPP341a	Scajaquada Creek	957	3.0	$362	*$0.35*	*$0.35*	*$0.35*	*$0.35*	*$0.35*
SPP342a&b	Scajaquada Creek	1,628	2.0	$247	*$0.40*	*$0.40*	*$0.40*	*$0.00*	*$0.00*
SPP345	Scajaquada Creek	1,735	2.0	$247	*$0.43*	*$0.43*	*$0.43*	*$0.00*	*$0.00*
Total		**71,466**			***$40.45***	***$40.45***	***$34.58***	***$29.41***	***$17.38***

Tunnel Dewatering Force Main (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
Scajaquada Creek	231	90	72	54	18	10	$1,560	$837	$449	$121	$54	*$0.36*	*$0.19*	*$0.10*	*$0.03*	*$0.01*
Black Rock Canal	1,267	102	78	60	30	10	$2,363	$1,030	$553	$193	$54	*$2.99*	*$1.31*	*$0.70*	*$0.24*	*$0.07*
Total	**1,497**											***$3.35***	***$1.50***	***$0.80***	***$0.27***	***$0.08***

Total - Capital Cost

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$430.07	$264.47	$182.39	$165.33	$85.31
Buffalo River	$45.74	$22.91	$16.98	$16.35	$4.81
Cazenovia Creek - B	$1.28	$1.28	$1.28	$0.00	$0.00
Cazenovia Creek - C	$5.44	$5.44	$5.44	$4.90	$4.90
Cornelius Creek	$131.65	$99.75	$73.52	$58.92	$32.97
Erie Basin	$0.63	$0.63	$0.08	$0.08	$0.00
Niagara River	$3.13	$2.47	$2.47	$2.47	$2.47
Scajaquada Creek	$154.16	$111.43	$78.42	$47.77	$34.32
Sub-Total	***$772.10***	***$508.37***	***$360.58***	***$295.82***	***$164.79***

Sub-Total - Present Worth O/M

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$13.69	$9.70	$8.11	$7.78	$6.71
Buffalo River	$1.83	$0.85	$0.71	$0.67	$0.00
Cazenovia Creek - B	$0.00	$0.00	$0.00	$0.00	$0.00
Cazenovia Creek - C	$0.00	$0.00	$0.00	$0.00	$0.00
Cornelius Creek	$4.55	$3.75	$3.04	$2.60	$1.71
Erie Basin	$0.00	$0.00	$0.00	$0.00	$0.00
Niagara River	$0.12	$0.00	$0.00	$0.00	$0.00
Scajaquada Creek	$8.99	$7.81	$7.11	$6.56	$6.36
Sub-Total	***$29.18***	***$22.12***	***$18.96***	***$17.60***	***$14.79***

Sub-Total - Engineering

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$64.51	$39.67	$27.36	$24.80	$12.80
Buffalo River	$6.86	$3.44	$2.55	$2.45	$0.72
Cazenovia Creek - B	$0.19	$0.19	$0.19	$0.00	$0.00
Cazenovia Creek - C	$0.82	$0.82	$0.82	$0.74	$0.74
Cornelius Creek	$19.75	$14.96	$11.03	$8.84	$4.95
Erie Basin	$0.09	$0.09	$0.01	$0.01	$0.00
Niagara River	***$0.47***	***$0.37***	***$0.37***	***$0.37***	***$0.37***
Scajaquada Creek	$23.12	$16.71	$11.76	$7.17	$5.15
Sub-Total	***$115.82***	***$76.26***	***$54.09***	***$44.37***	***$24.72***

Sub-Total - Present Worth O/M Contingency

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$1.37	$0.97	$0.81	$0.78	$0.67
Buffalo River	$0.18	$0.08	$0.07	$0.07	$0.00
Cazenovia Creek - B	$0.00	$0.00	$0.00	$0.00	$0.00
Cazenovia Creek - C	$0.00	$0.00	$0.00	$0.00	$0.00
Cornelius Creek	$0.45	$0.38	$0.30	$0.26	$0.17
Erie Basin	$0.00	$0.00	$0.00	$0.00	$0.00
Niagara River	***$0.01***	***$0.00***	***$0.00***	***$0.00***	***$0.00***
Scajaquada Creek	$0.90	$0.78	$0.71	$0.66	$0.64
Sub-Total	***$2.92***	***$2.21***	***$1.90***	***$1.76***	***$1.48***

Sub-Total - Project Contingency

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$123.65	$76.03	$52.44	$47.53	$24.53
Buffalo River	$13.15	$6.59	$4.88	$4.70	$1.38
Cazenovia Creek - B	$0.37	$0.37	$0.37	$0.00	$0.00
Cazenovia Creek - C	$1.56	$1.56	$1.56	$1.41	$1.41
Cornelius Creek	$37.85	$28.68	$21.14	$16.94	$9.48
Erie Basin	$0.18	$0.18	$0.02	$0.02	$0.00
Niagara River	$0.90	$0.71	$0.71	$0.71	$0.71
Scajaquada Creek	$44.32	$32.04	$22.55	$13.74	$9.87
Sub-Total	***$221.98***	***$146.16***	***$103.67***	***$85.05***	***$47.38***

Sub-Total - Present Worth O/M with Contingency

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$15.06	$10.67	$8.92	$8.55	$7.39
Buffalo River	$2.01	$0.93	$0.78	$0.74	$0.00
Cazenovia Creek - B	$0.00	$0.00	$0.00	$0.00	$0.00
Cazenovia Creek - C	$0.00	$0.00	$0.00	$0.00	$0.00
Cornelius Creek	$5.00	$4.13	$3.34	$2.86	$1.88
Erie Basin	$0.00	$0.00	$0.00	$0.00	$0.00
Niagara River	$0.14	$0.00	$0.00	$0.00	$0.00
Scajaquada Creek	$9.88	$8.60	$7.82	$7.21	$7.00
Sub-Total	***$32.10***	***$24.33***	***$20.86***	***$19.36***	***$16.27***

Total - Project Cost with Contingencies

Receiving Basin	Foundation Alternative	Alternative UA3				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$6.89	$618.23	$380.17	$262.18	$237.66	$122.64
Buffalo River	$41.13	$65.75	$32.93	$24.40	$23.50	$6.92
Cazenovia Creek - B	$0.00	$1.84	$1.84	$1.84	$0.00	$0.00
Cazenovia Creek - C	$0.02	$7.82	$7.82	$7.82	$7.05	$7.05
Cornelius Creek	$8.70	$189.25	$143.40	$105.68	$84.69	$47.39
Erie Basin	$0.01	$0.90	$0.90	$0.12	$0.12	$0.00
Niagara River	$0.00	$4.50	$3.55	$3.55	$3.55	$3.55
Scajaquada Creek	$27.75	$221.61	$160.18	$112.73	$68.68	$49.34
Sub-Total		***$1,109.90***	***$730.78***	***$518.33***	***$425.24***	***$236.88***
Total (with Foundation Alternative)	***$84.49***	***$1,194.38***	***$815.27***	***$602.81***	***$509.73***	***$321.36***

Total - Project Cost and Present Worth O/M with Contingencies

Receiving Basin	Foundation Alternative	Alternative UA3				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$6.89	$633.29	$390.84	$271.10	$246.21	$130.02
Buffalo River	$41.13	$67.77	$33.86	$25.18	$24.24	$6.92
Cazenovia Creek - B	$0.00	$1.84	$1.84	$1.84	$0.00	$0.00
Cazenovia Creek - C	$0.02	$7.82	$7.82	$7.82	$7.05	$7.05
Cornelius Creek	$8.70	$194.25	$147.53	$109.02	$87.55	$49.27
Erie Basin	$0.01	$0.90	$0.90	$0.12	$0.12	$0.00
Niagara River	$0.00	$4.63	$3.55	$3.55	$3.55	$3.55
Scajaquada Creek	$27.75	$231.49	$168.77	$120.56	$75.89	$56.33
Sub-Total		***$1,142.00***	***$755.11***	***$539.19***	***$444.61***	***$253.14***
Total (with Foundation Alternative)	***$84.49***	***$1,226.48***	***$839.59***	***$623.67***	***$529.09***	***$337.63***

Receiving Basin	Foundation Alternative	Alternative UA3				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$6.89	$633.29	$390.84	$271.10	$246.21	$130.02
Buffalo River	$41.13	$67.77	$33.86	$25.18	$24.24	$6.92
Cazenovia Creek - B	$0.00	$1.84	$1.84	$1.84	$0.00	$0.00
Cazenovia Creek - C	$0.02	$7.82	$7.82	$7.82	$7.05	$7.05
Erie Basin	$0.01	$0.90	$0.90	$0.12	$0.12	$0.00
Niagara River (includes	$8.70	$198.89	$151.07	$112.57	$91.10	$52.82
Scajaquada Creek	$27.75	$231.49	$168.77	$120.56	$75.89	$56.33
	$84.49	#######	$755.11	$539.19	$444.61	$253.14

Fecal 92500

Figure A: Present Worth Costs vs. Frequency of Activation for Black Rock Canal
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

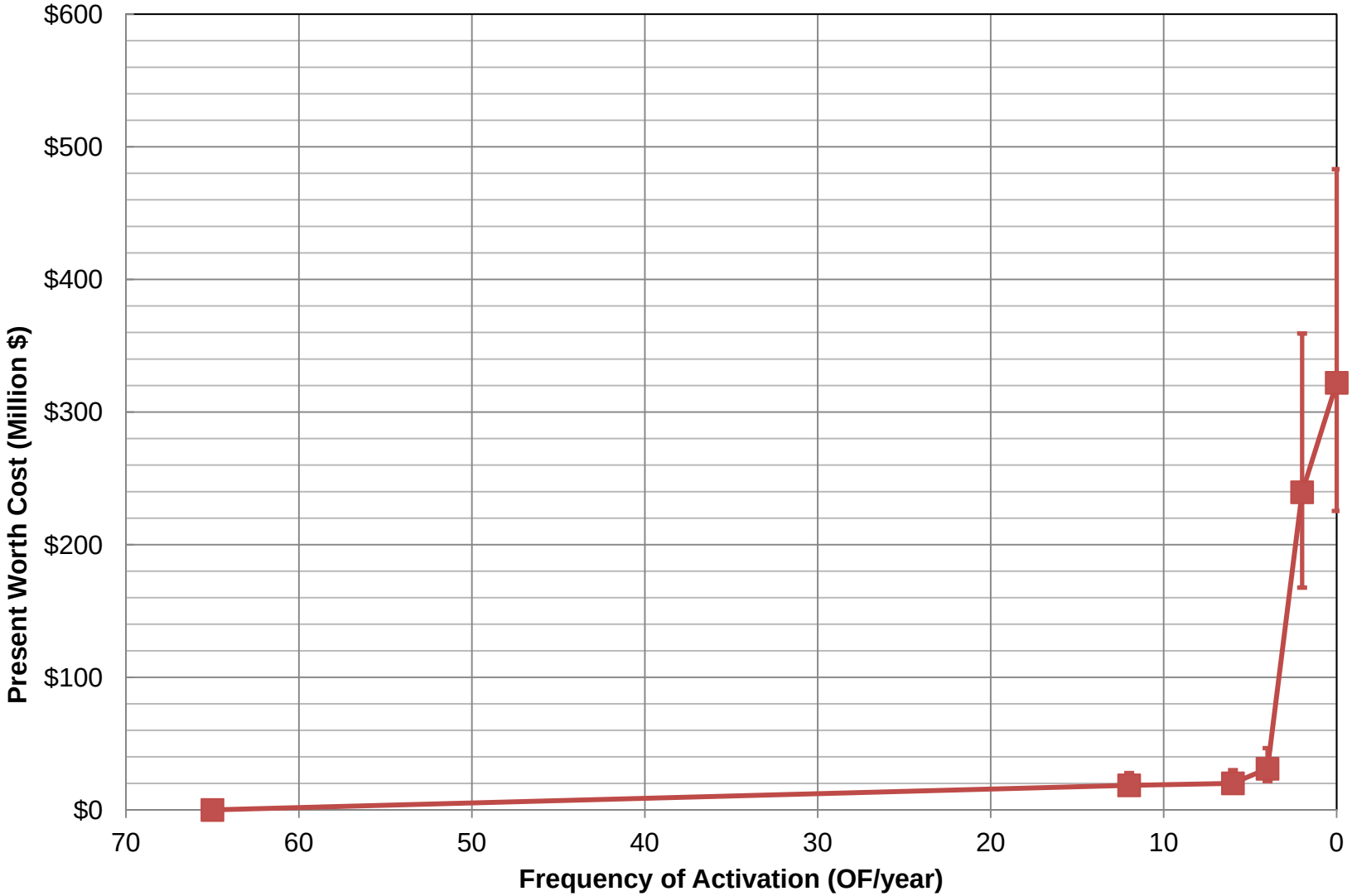


Figure B: Present Worth Costs vs. Frequency of Activation for Buffalo River
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

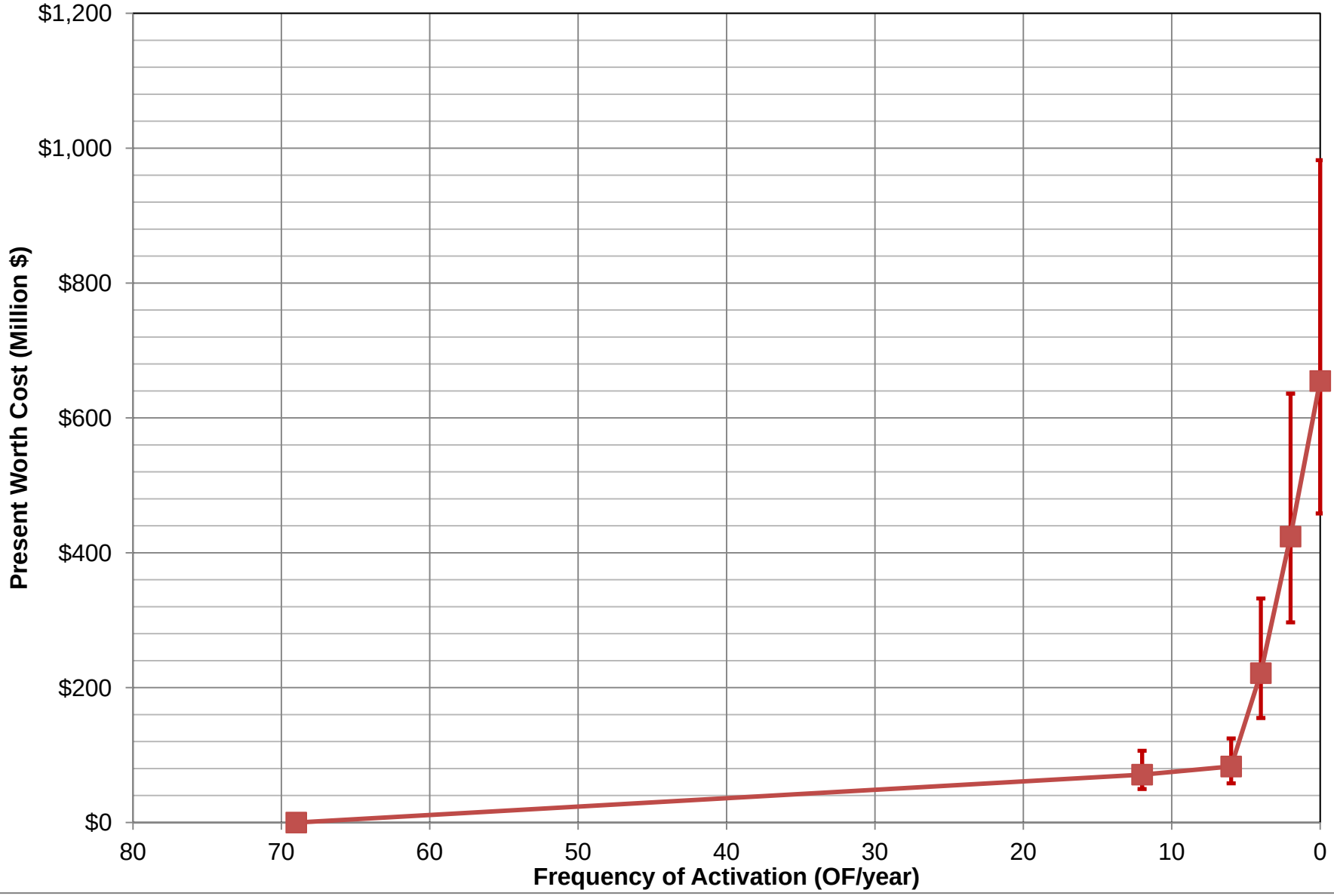


Figure C: Present Worth Costs vs. Frequency of Activation for Cazenovia Creek (C)
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

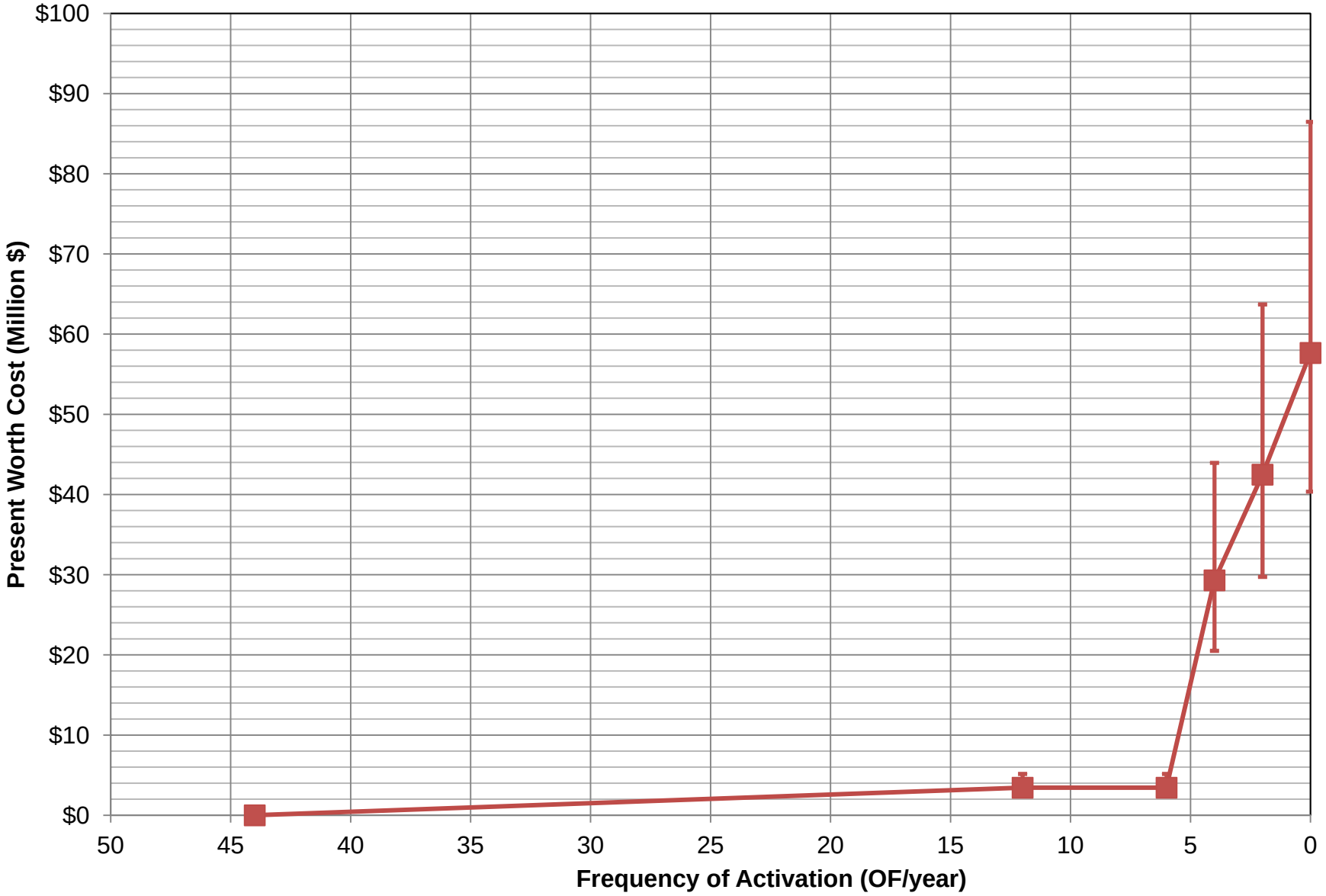


Figure D: Present Worth Costs vs. Frequency of Activation for Cazenovia Creek (B)
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

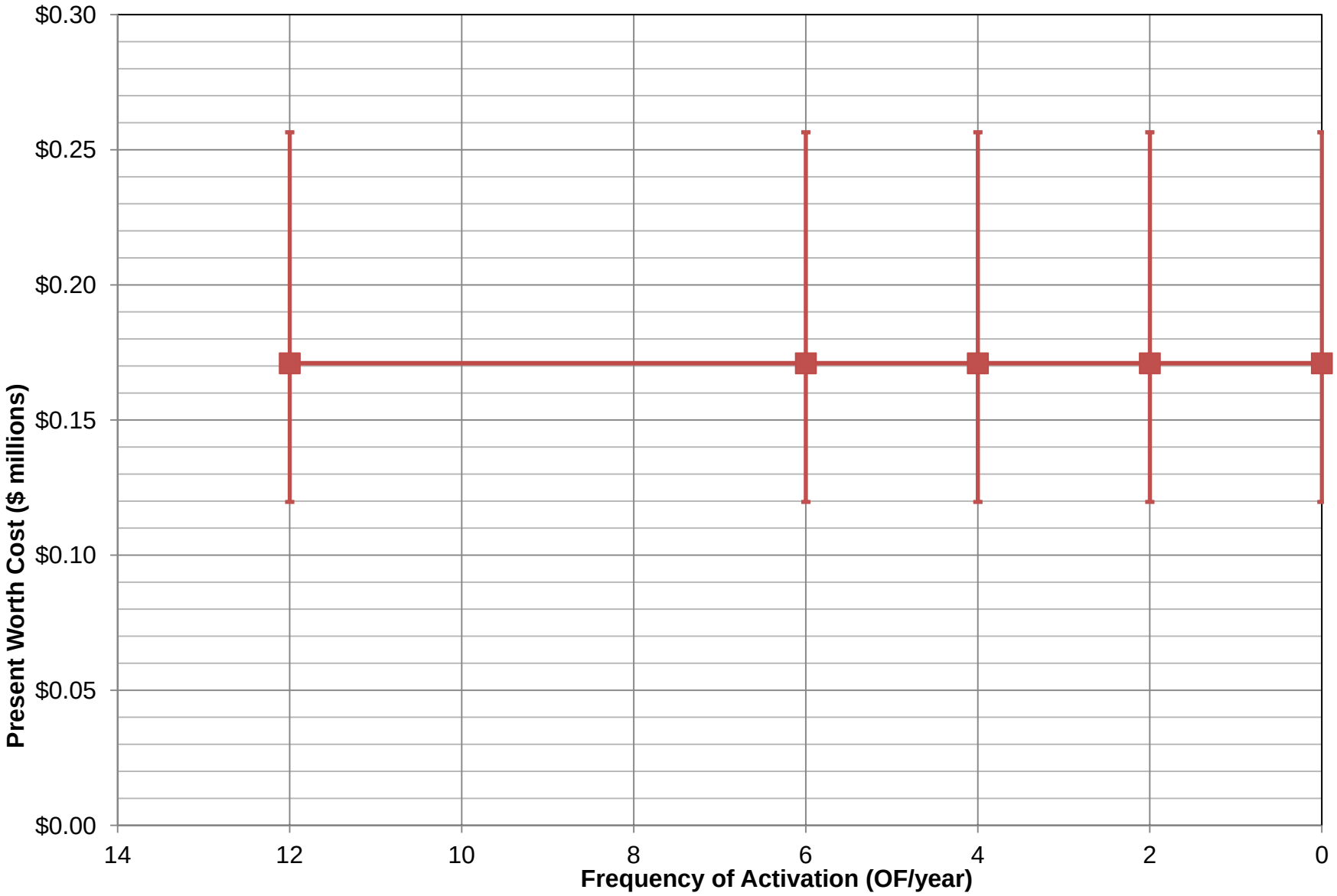


Figure E: Present Worth Costs vs. Frequency of Activation for Niagara River and CSO-055
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

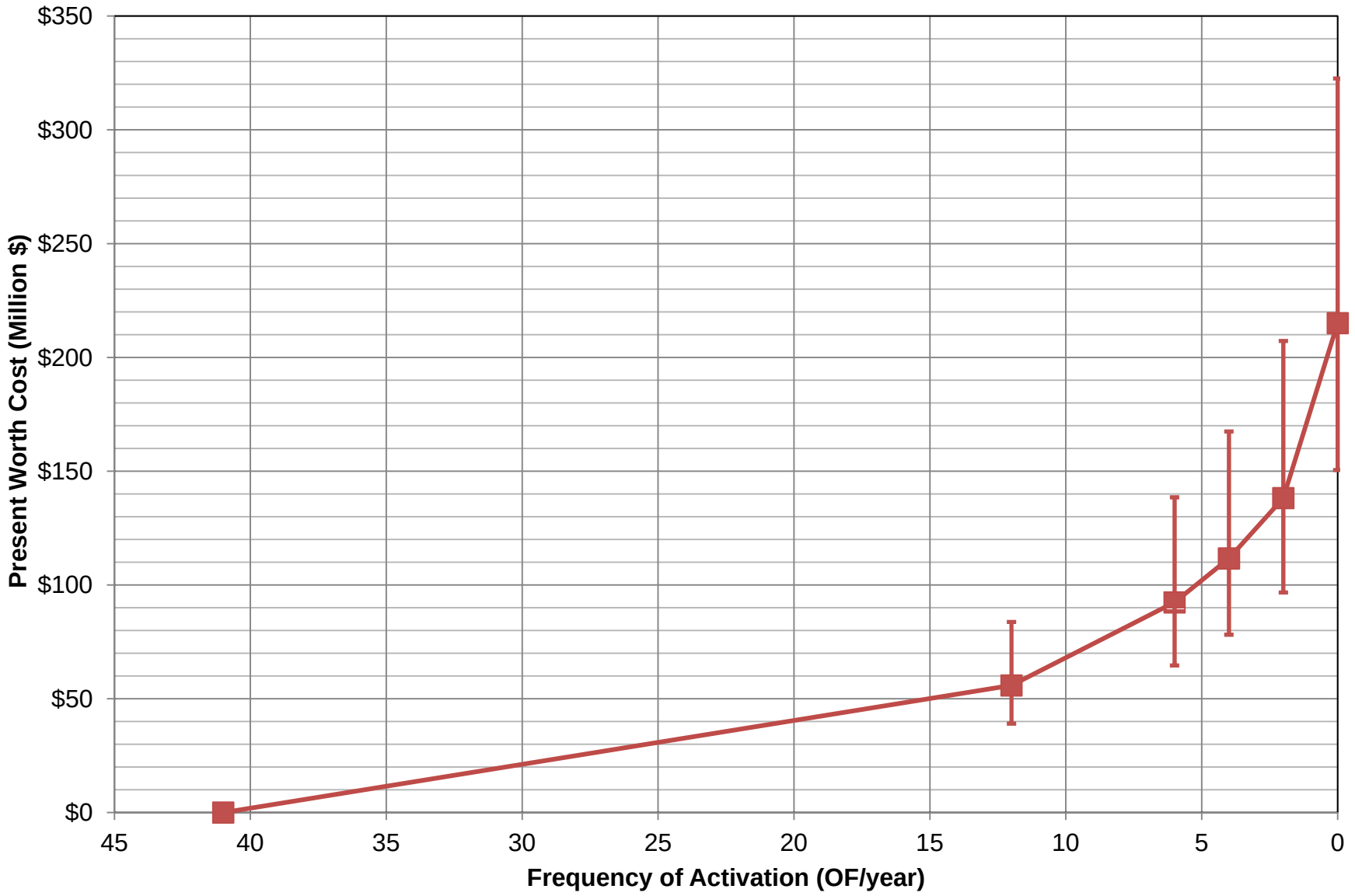


Figure F: Present Worth Costs vs. Frequency of Activation for Erie Basin
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

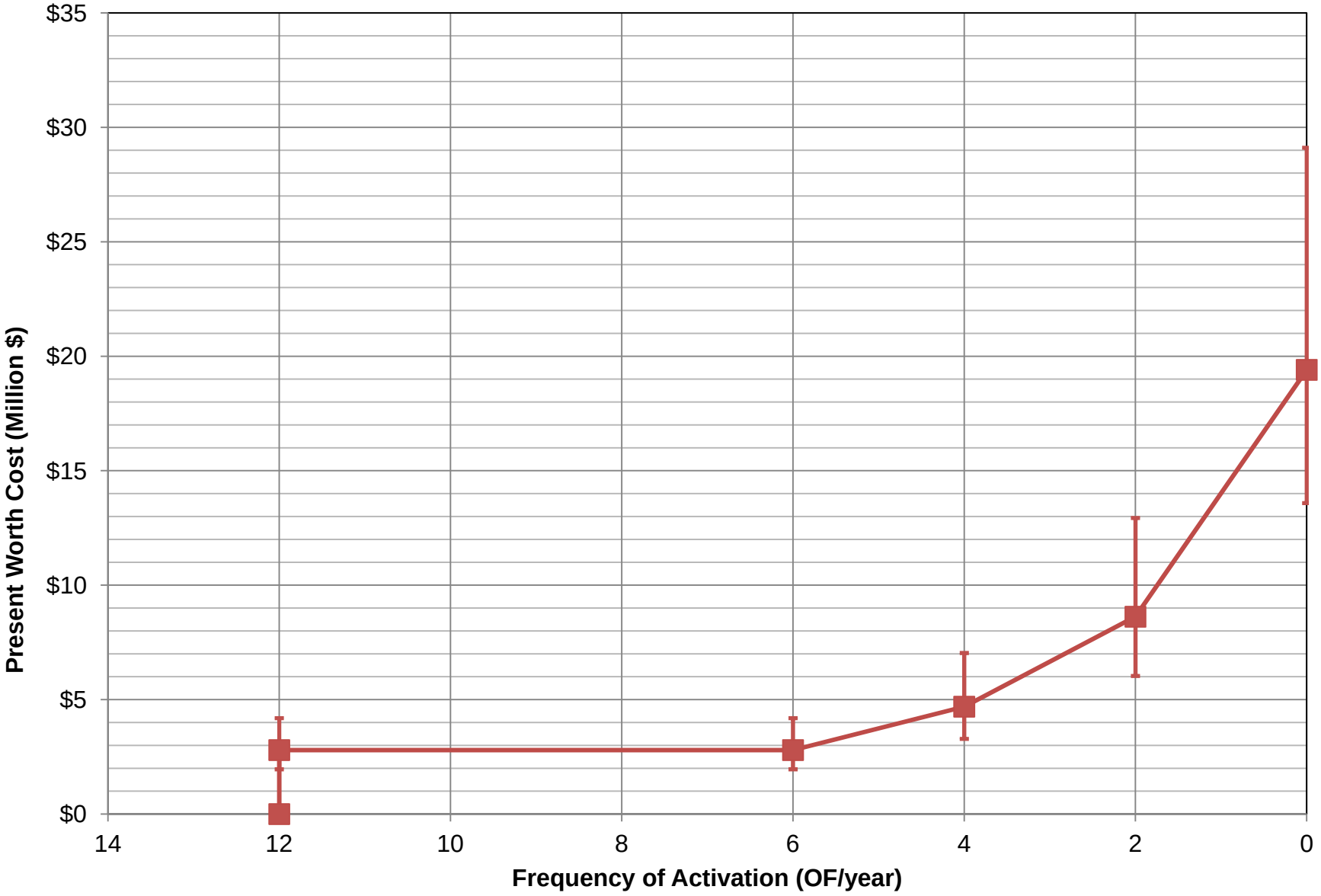


Figure G: Present Worth Costs vs. Frequency of Activation for Scajaquada Creek (System-wide Alternative UA2)
1993 TY - 2011 Dollars

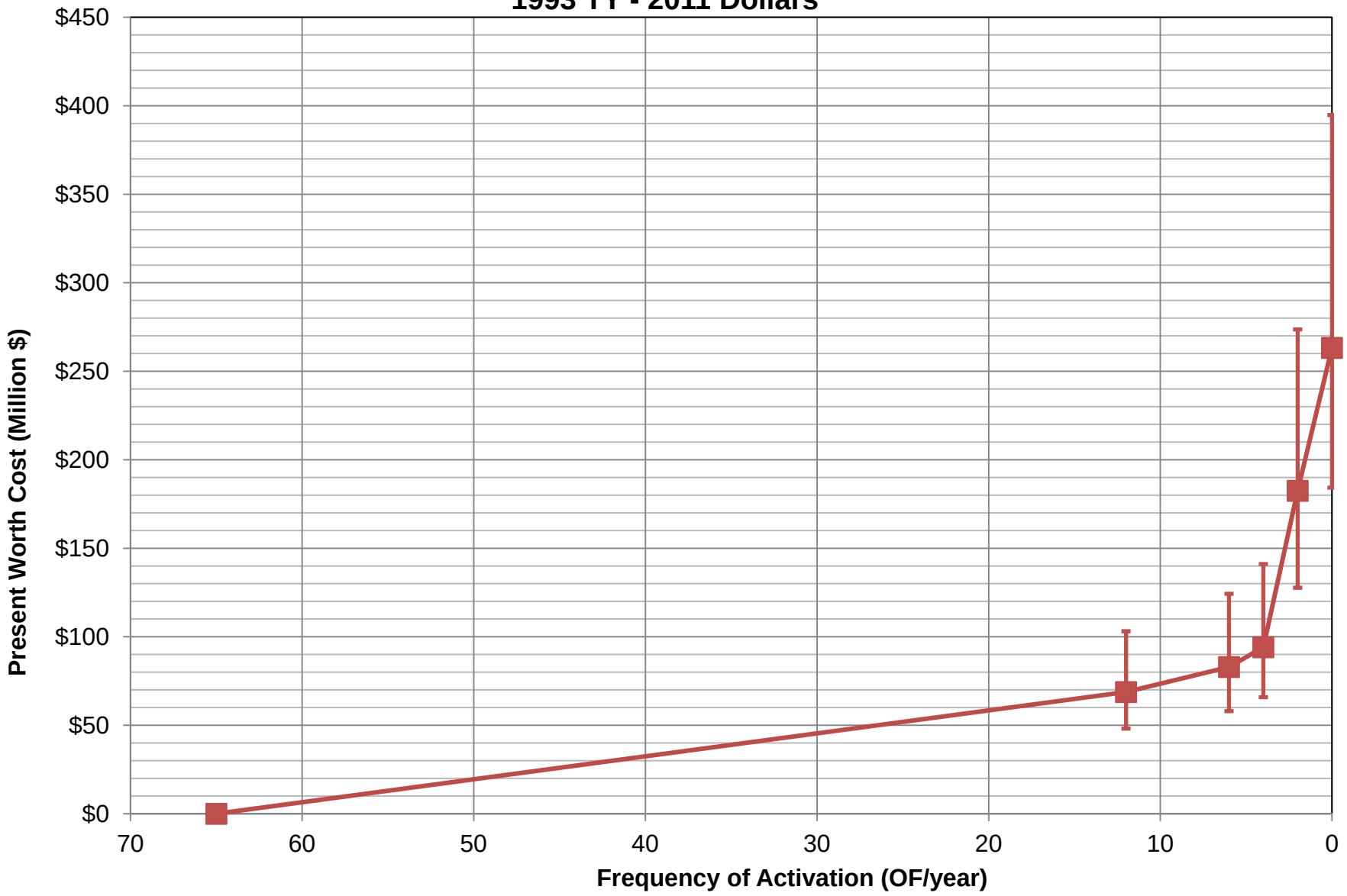


Figure H: Present Worth Costs vs. Remaining CSO Volumes for Black Rock Canal (System-wide Alternative UA2)
1993 TY - 2011 Dollars

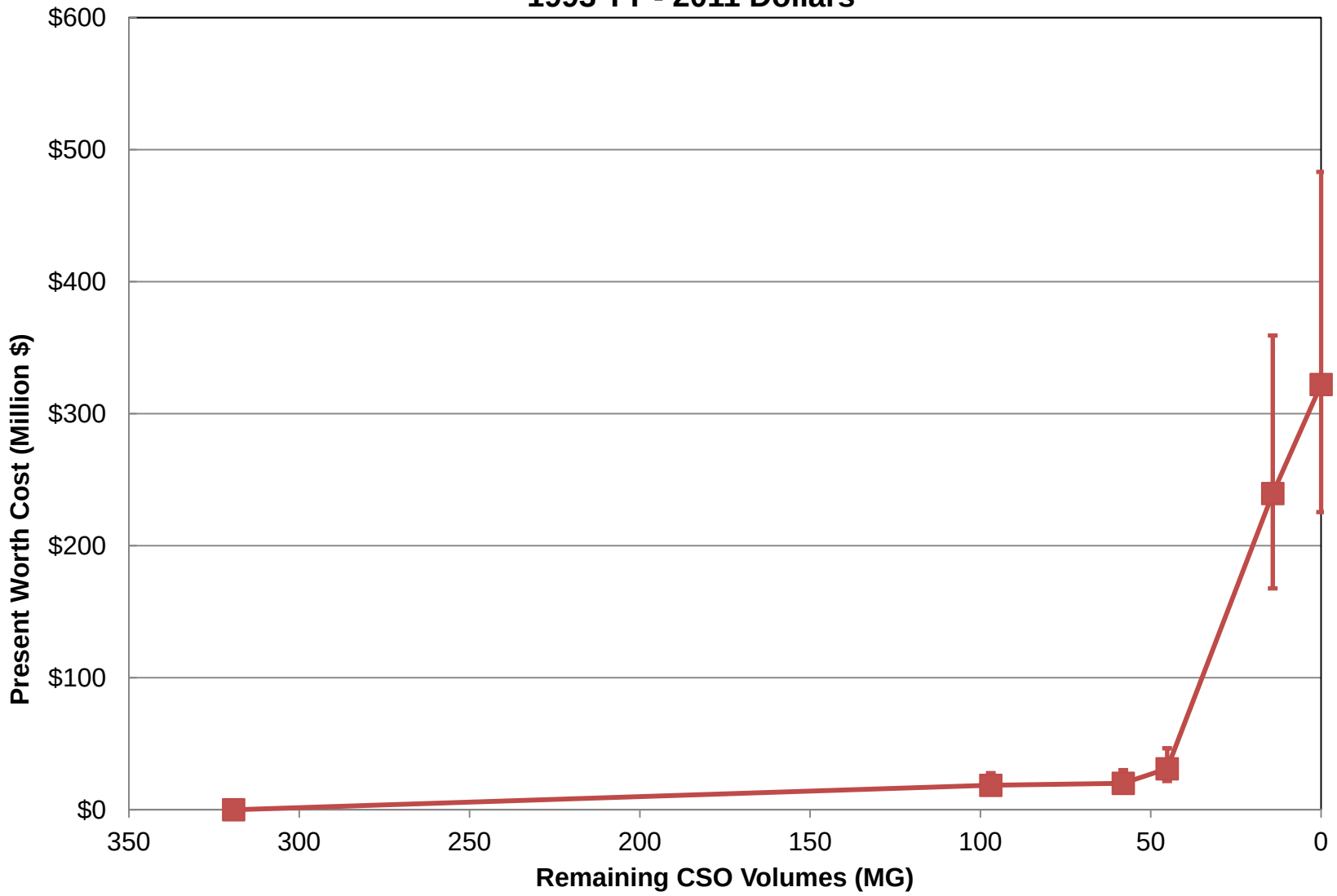


Figure I: Present Worth Costs vs. Remaining CSO Volumes for Buffalo River
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

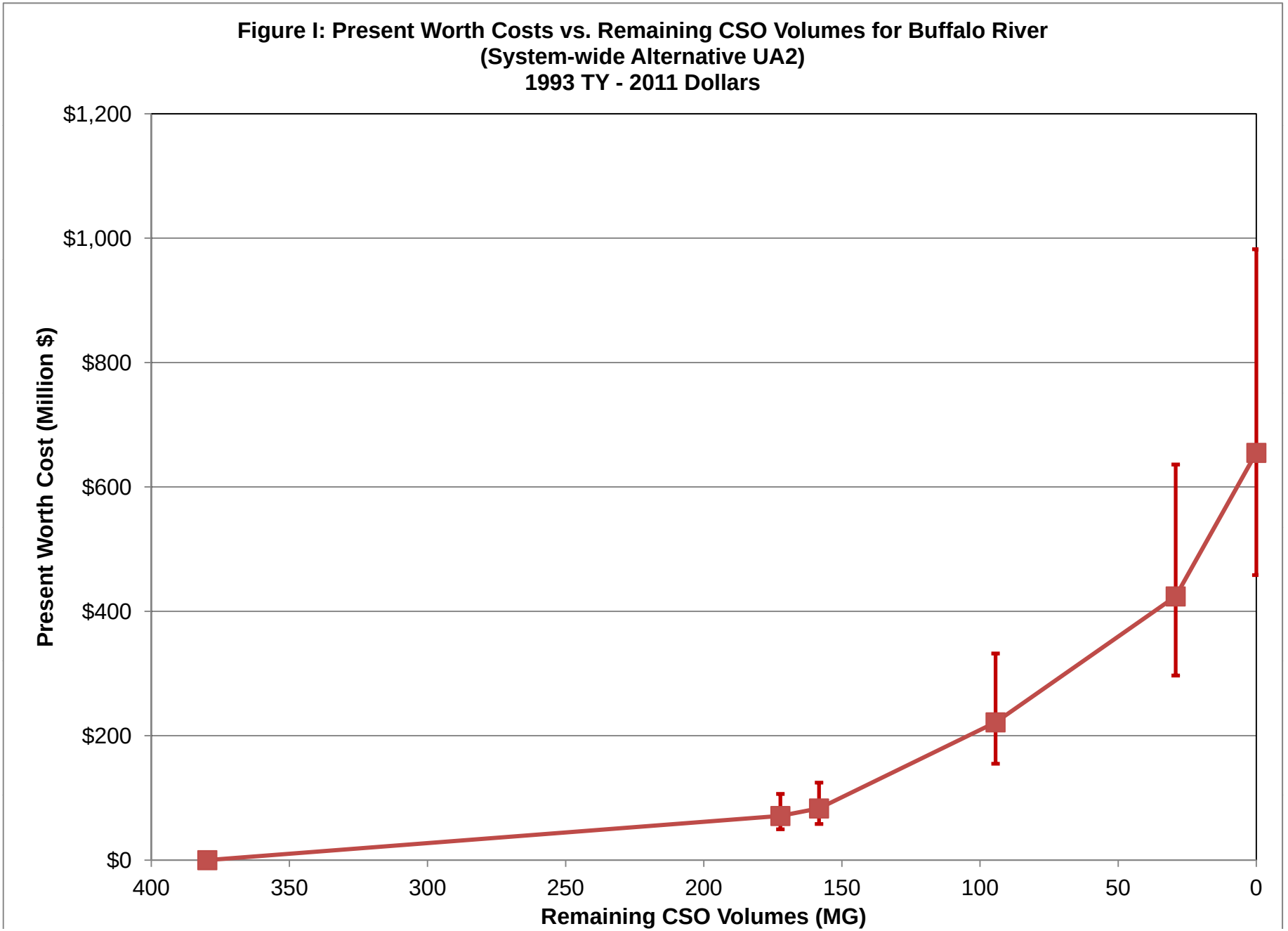


Figure J: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (C)
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

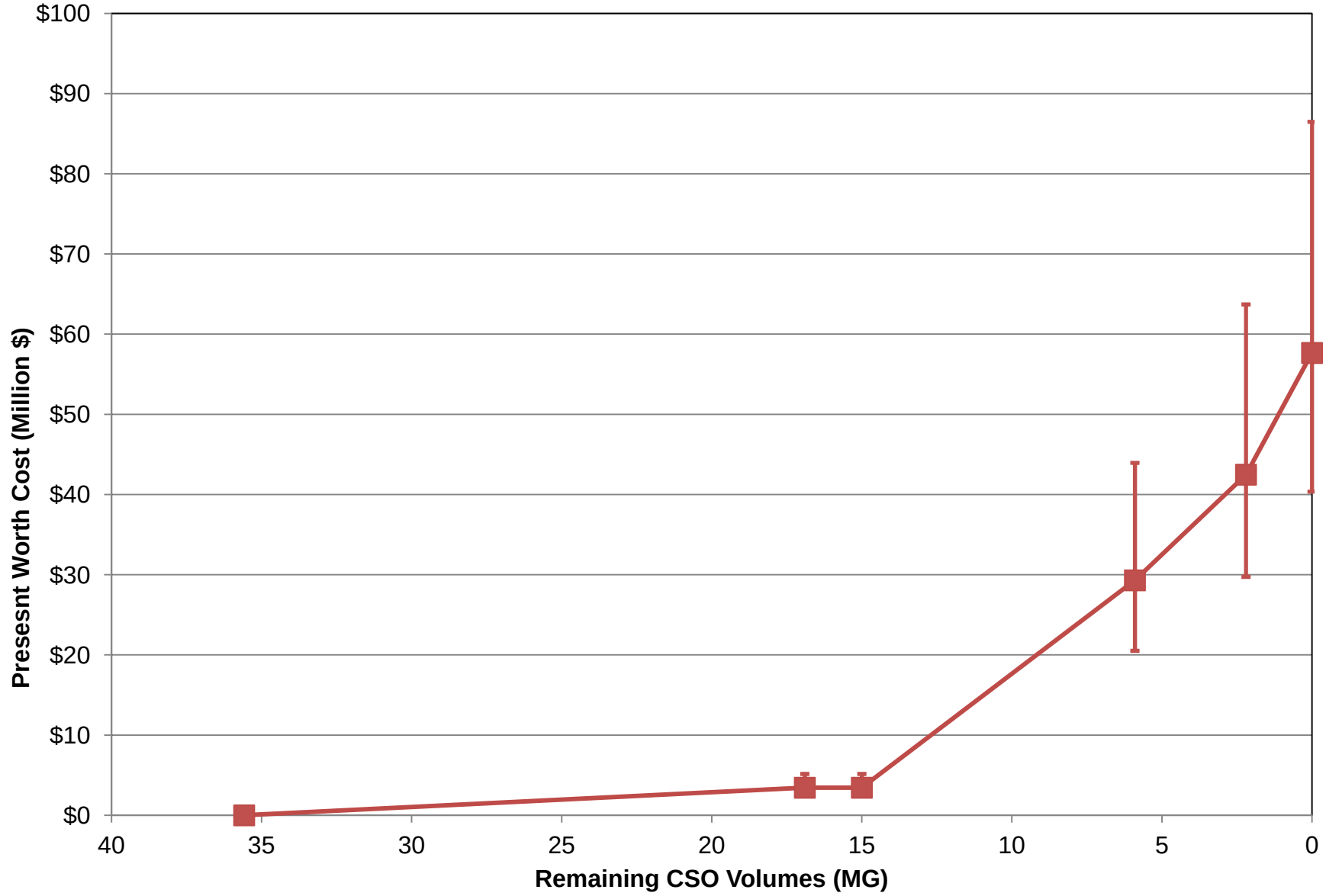


Figure K: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (B)
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

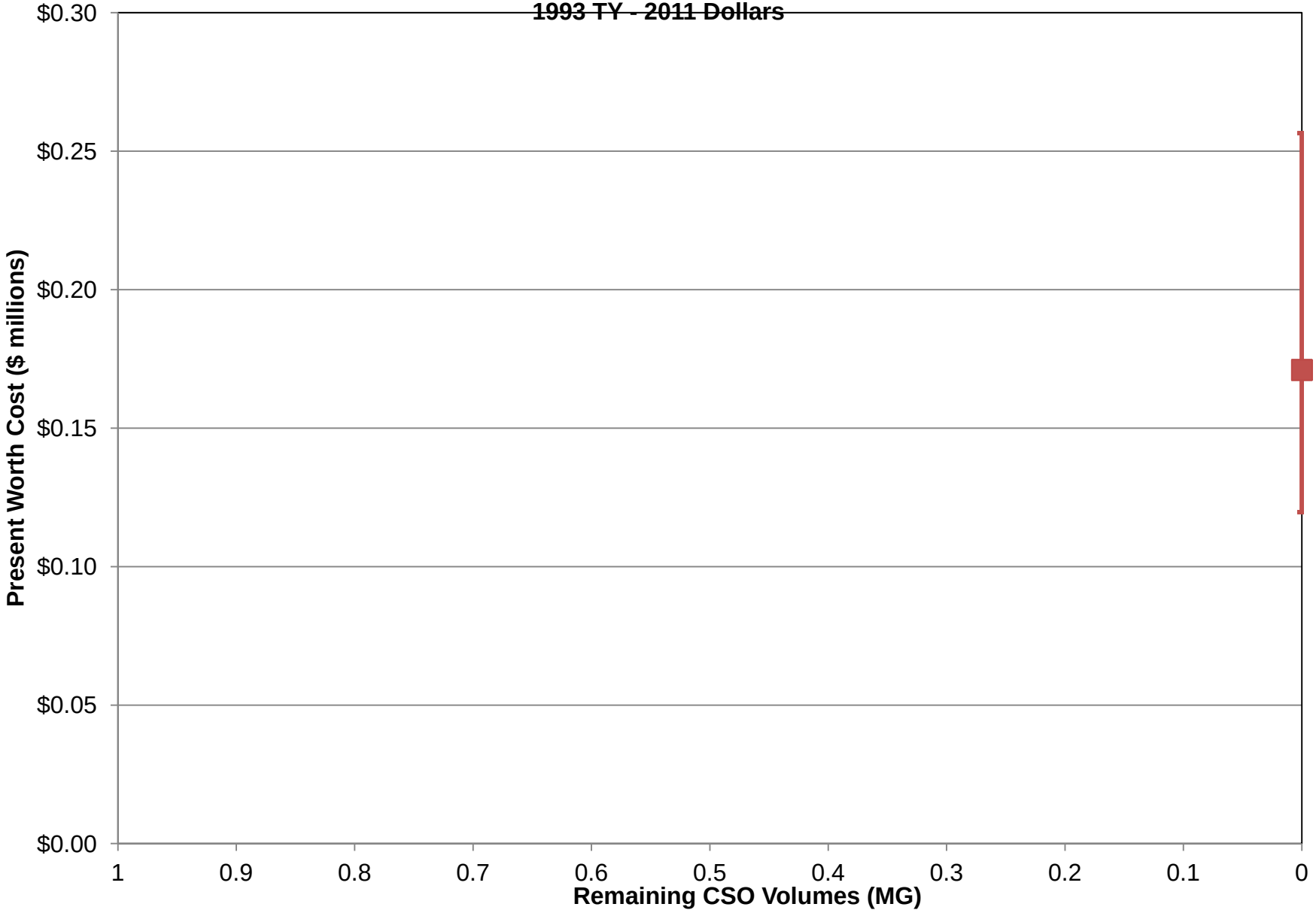


Figure L: Present Worth Costs vs. Remaining CSO Volumes for Niagara River and CSO-055
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

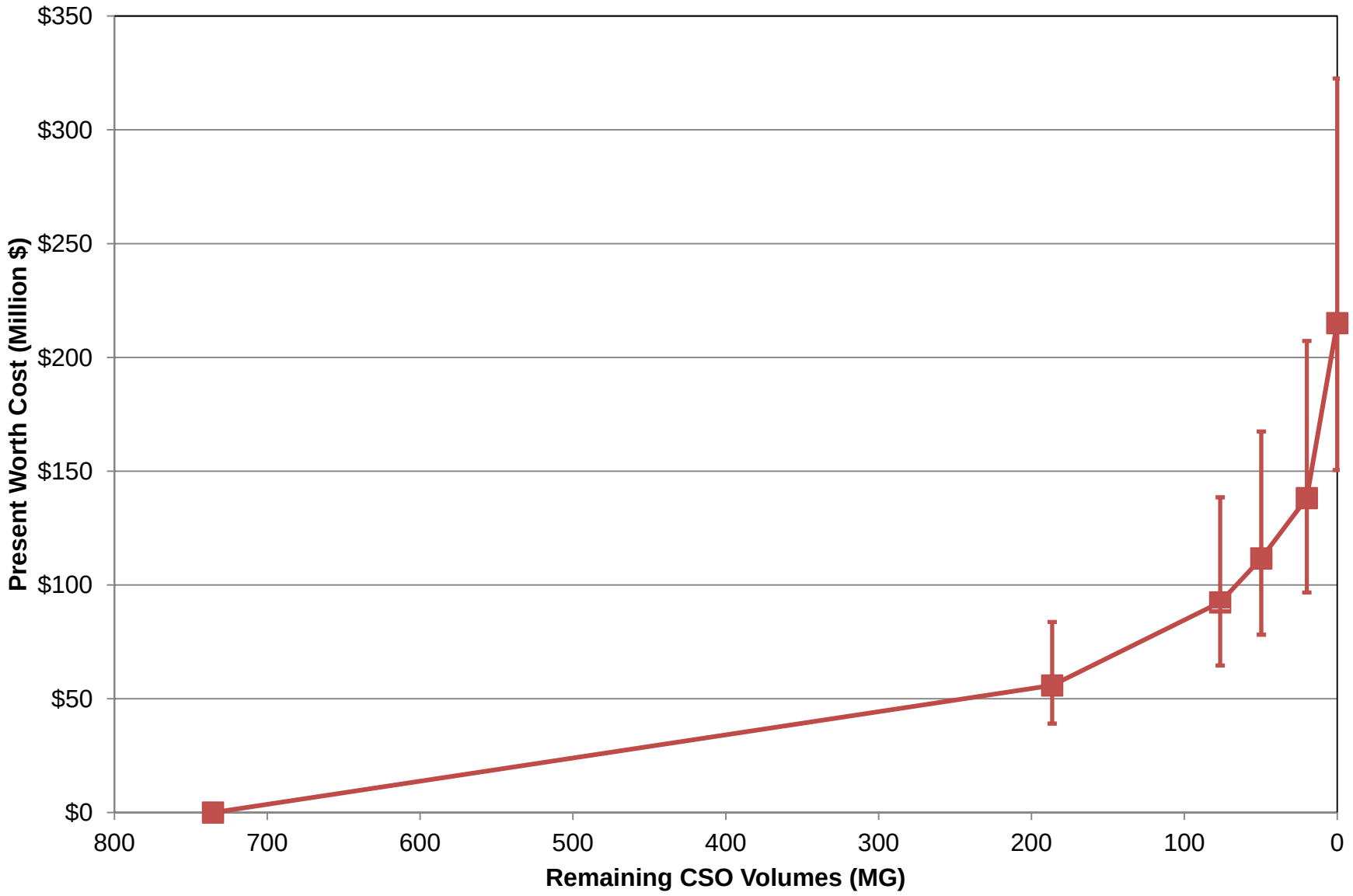


Figure M: Present Worth Costs vs. Remaining CSO Volumes for Erie Basin
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

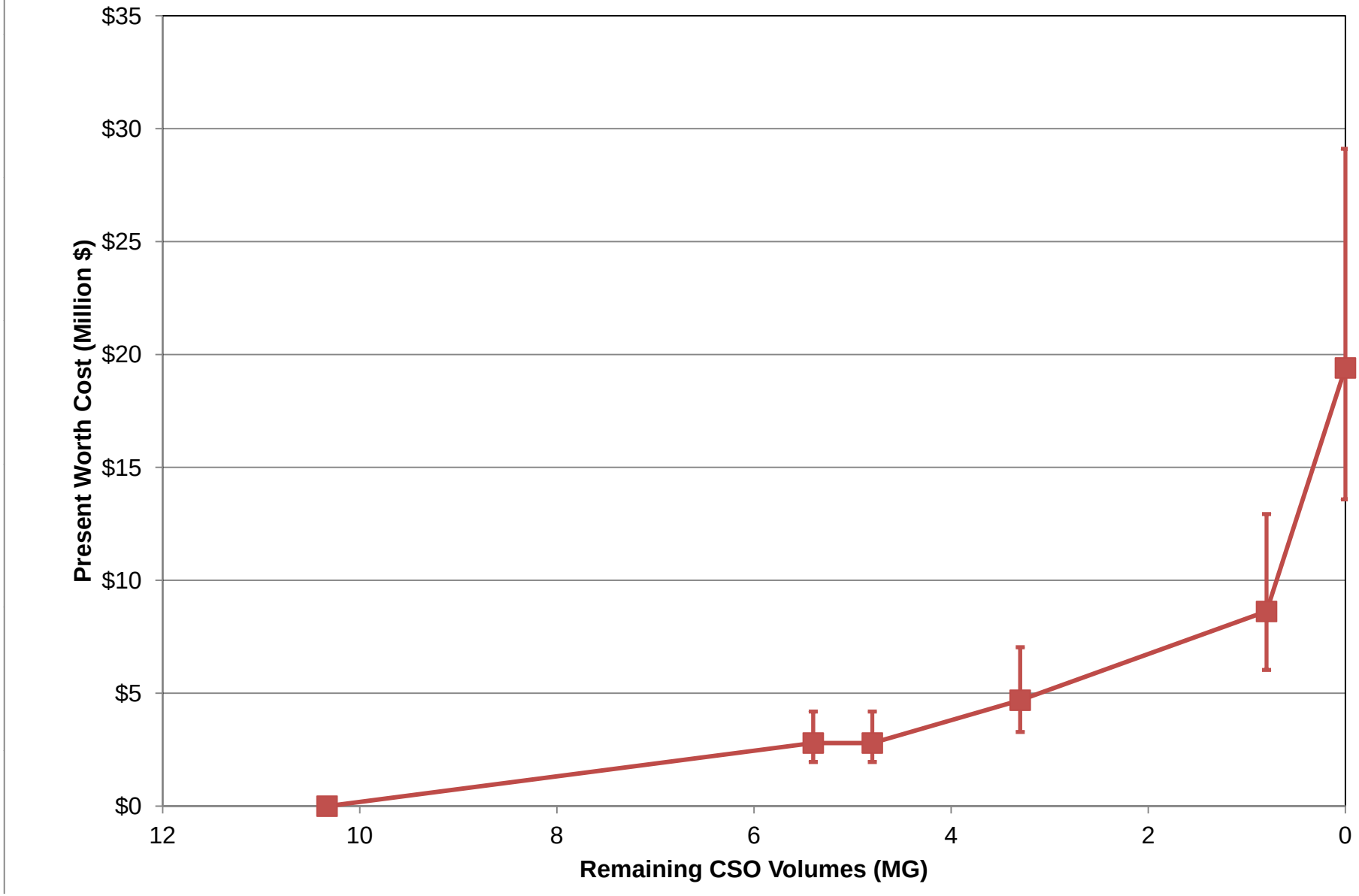


Figure N: Present Worth Costs vs. Remaining CSO Volumes for Scajaquada Creek (System-wide Alternative UA2)
1993 TY - 2011 Dollars

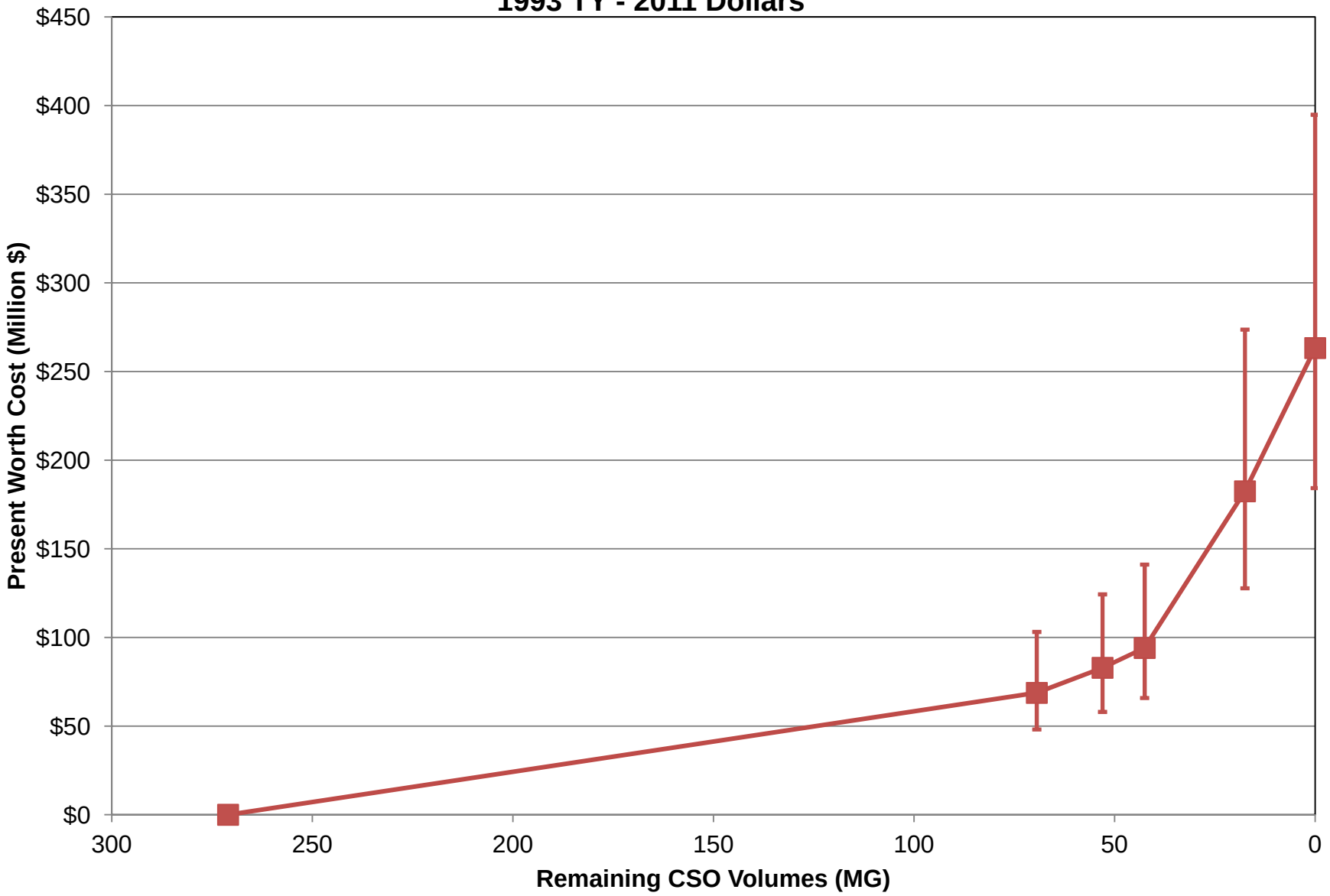


Figure O: Present Worth Costsvs Remaining Fecal Coliform Annual Loadings for System-wide Alternative UA2 1993 TY - 2011 Dollars

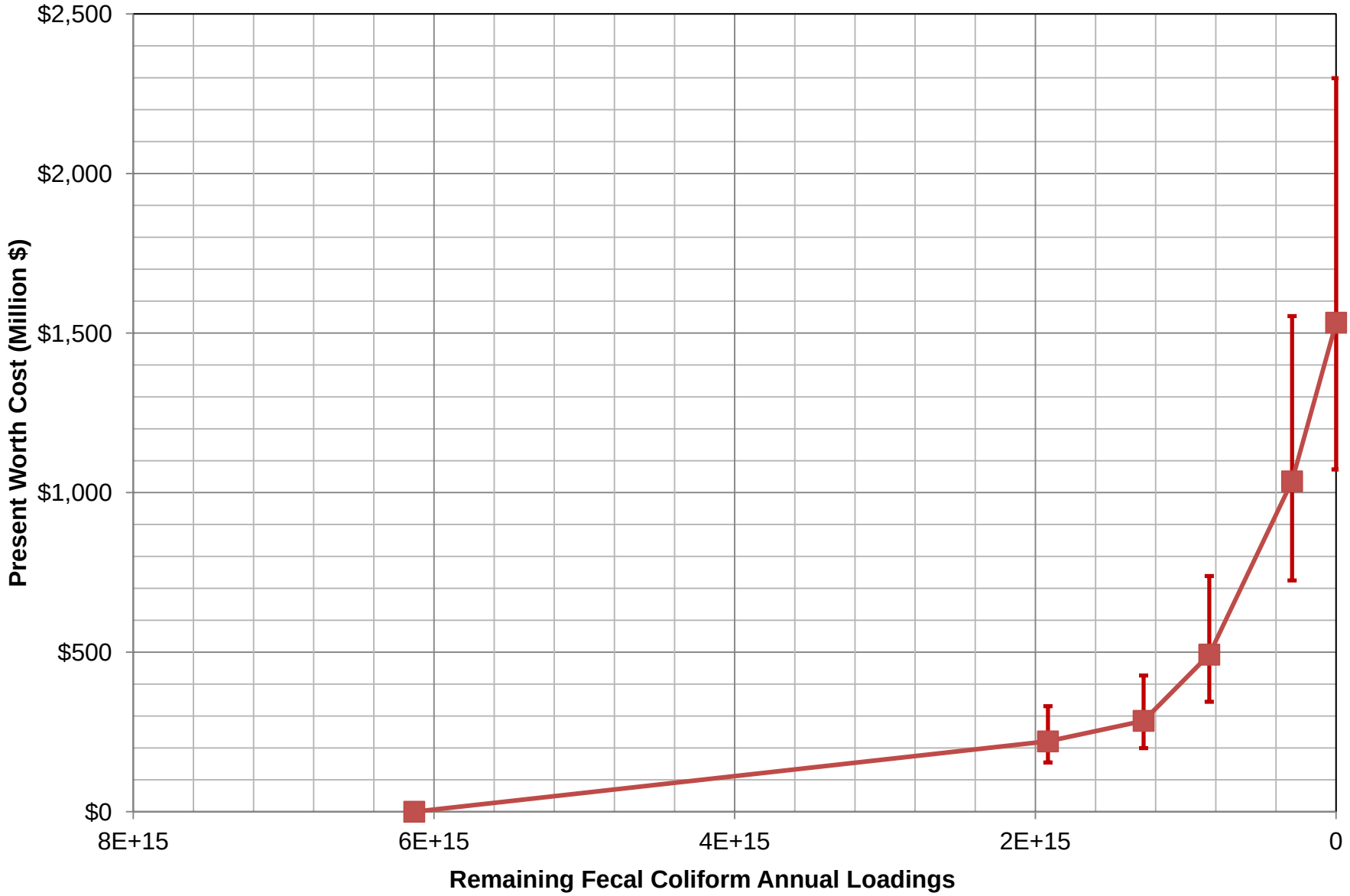


Figure P: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Black Rock Canal (System-wide Alternative UA2)
1993 TY - 2011 Dollars

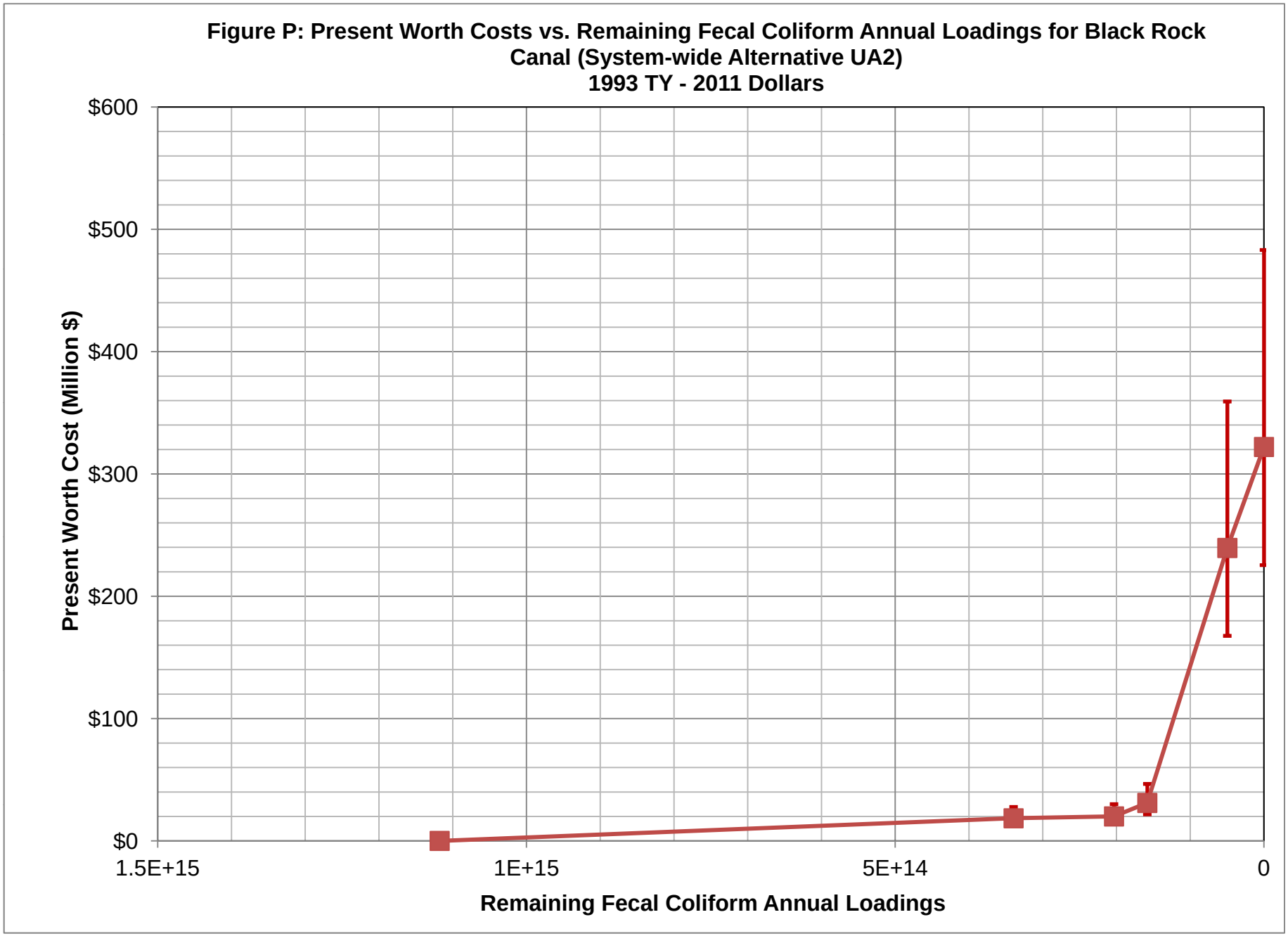


Figure Q: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Buffalo River
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

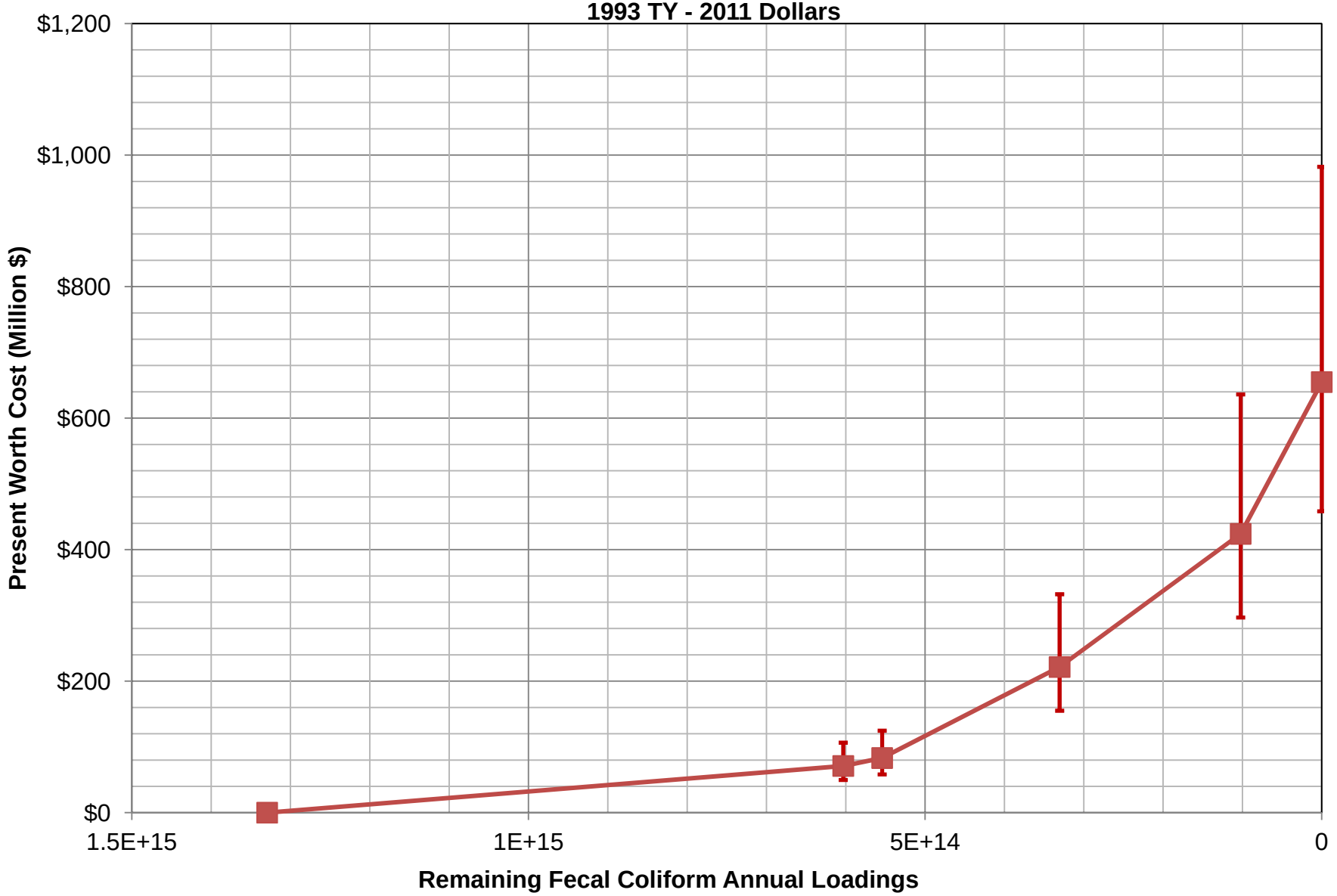


Figure R: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Cazenovia Creek (B) (System-wide Alternative UA2)
1993 TY - 2011 Dollars

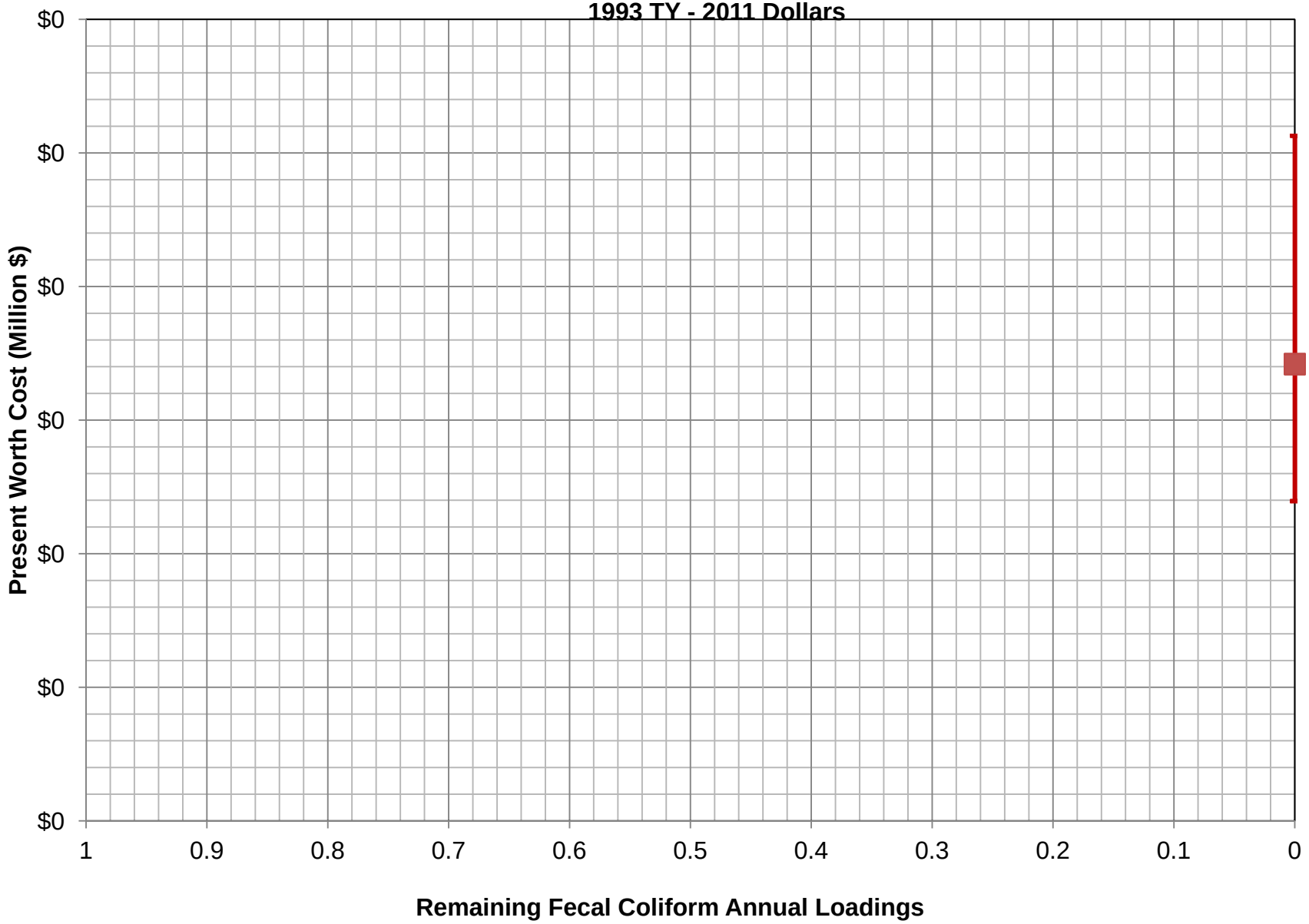


Figure S: Present Worth Costs vs. Remaining Fecal Coliform Loadings for Cazenovia Creek (C)
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

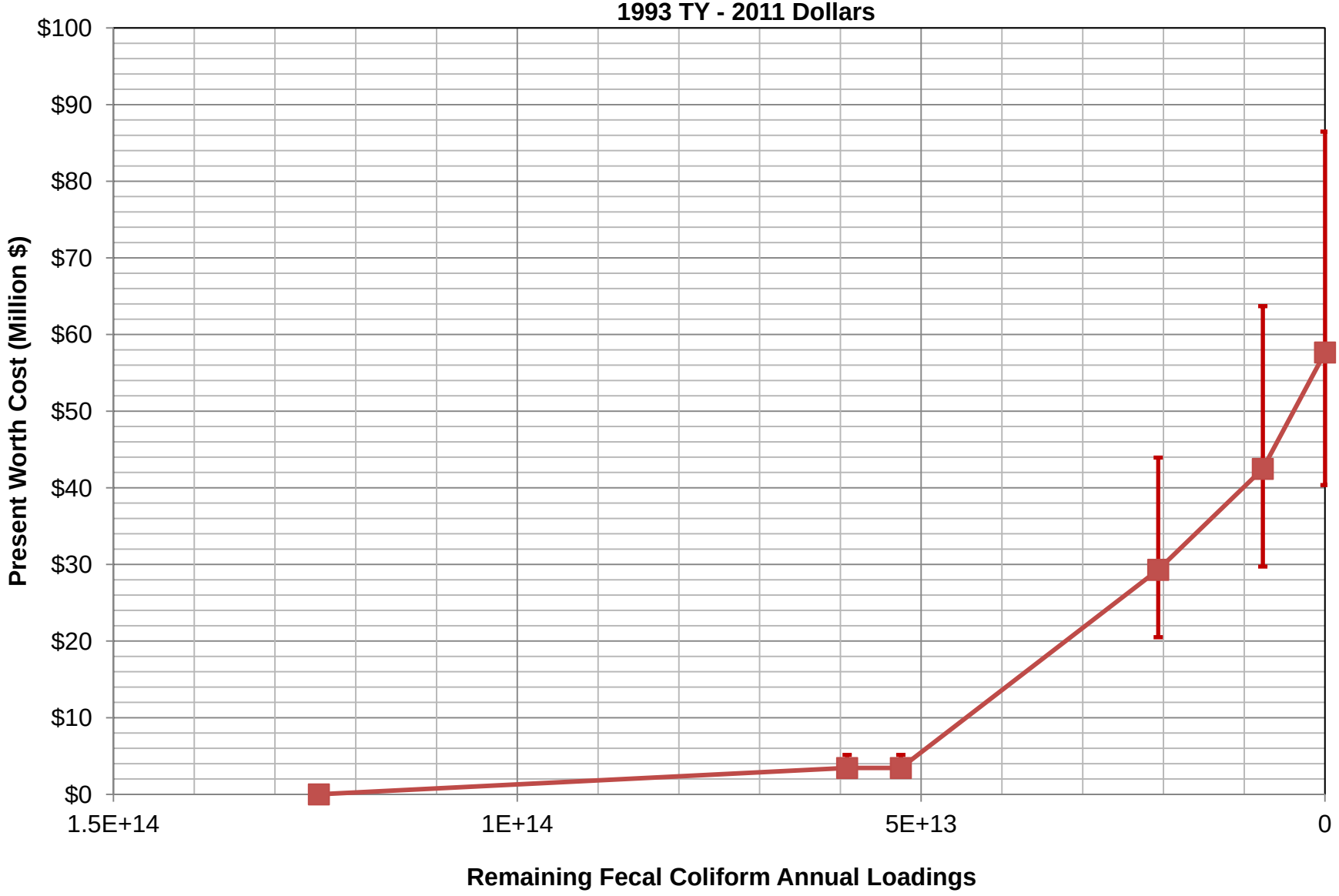


Figure T: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Niagara River CSO-055
(System-wide Alternative UA2)
1993 TY - 2011 Dollars

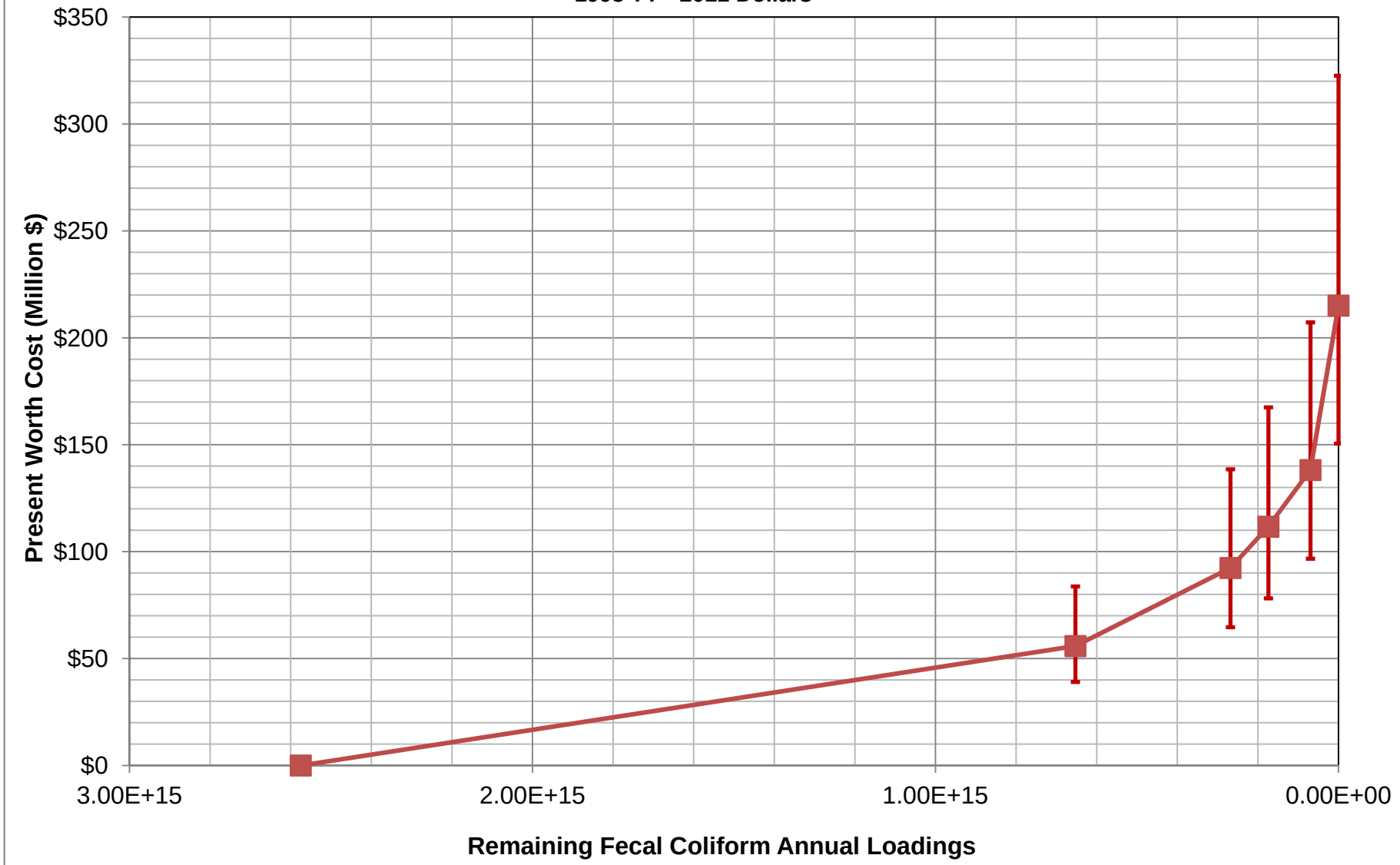


Figure U: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Erie Basin (System-wide Alternative UA2) 1993 TY - 2011 Dollars

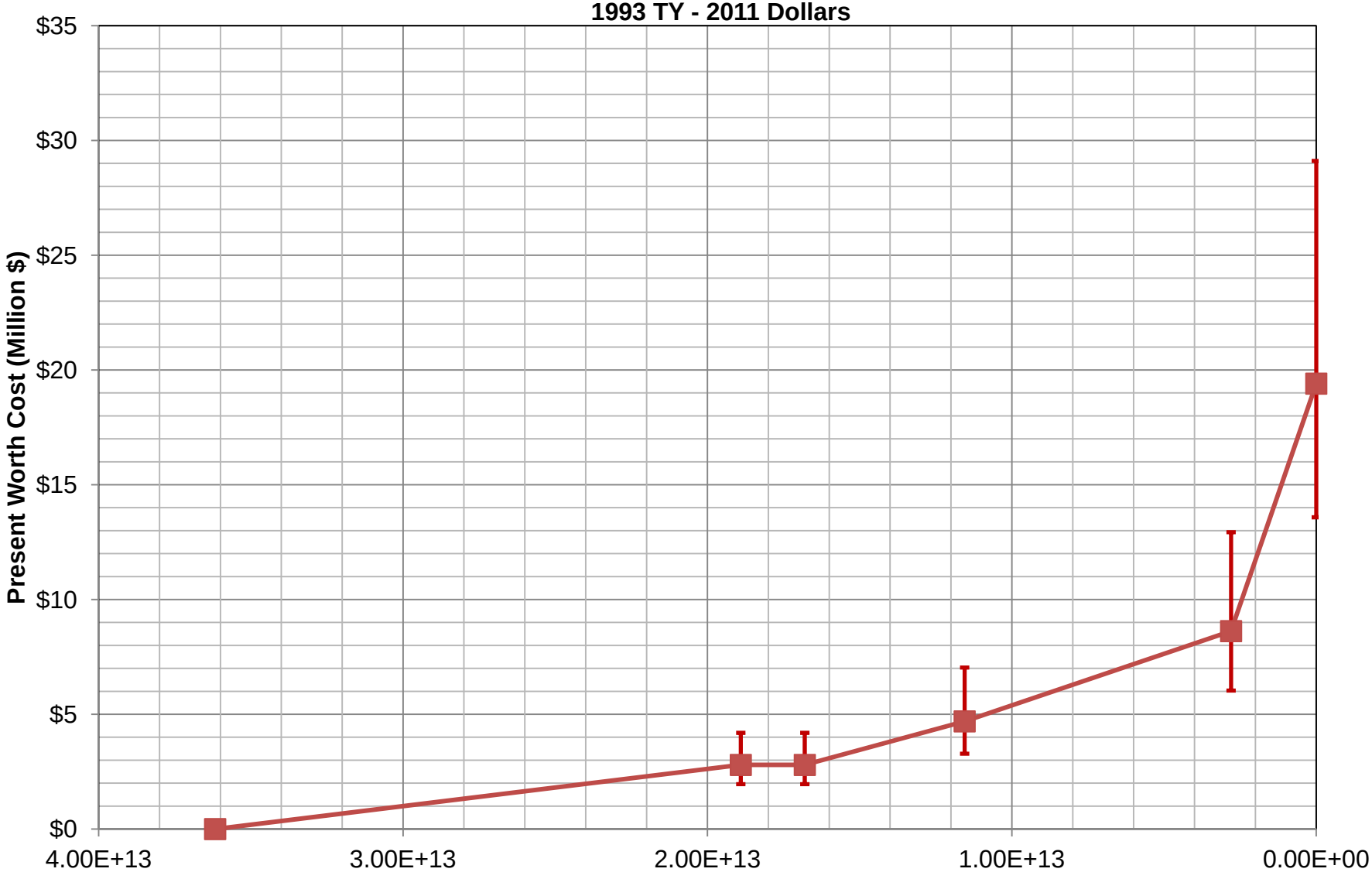
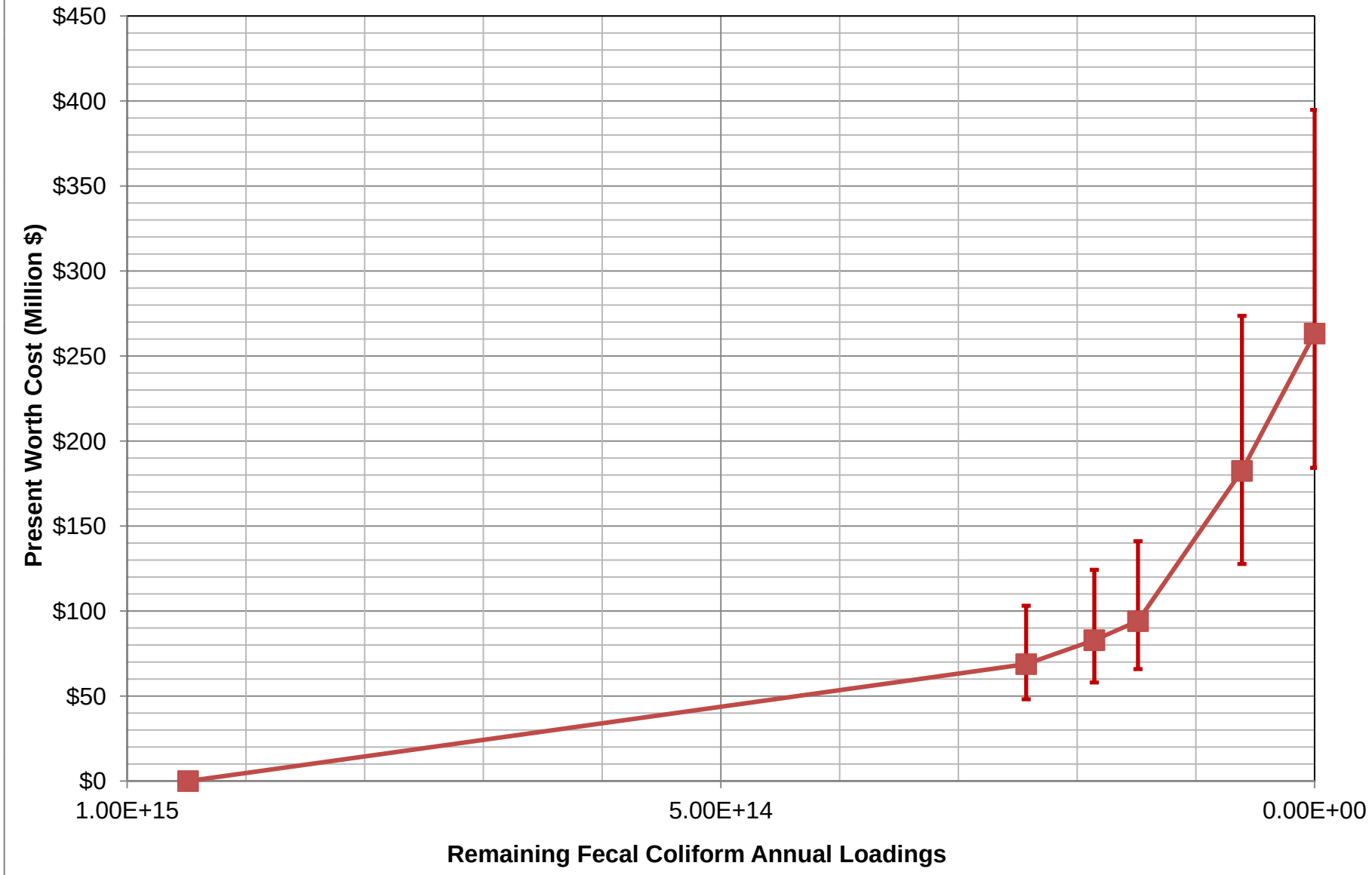


Figure V: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Scajaquada Creek (System-wide Alternative UA2)
1993 TY - 2011 Dollars



Alternative UA3 Overflow Volume Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	Revised Baseline 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)
004	Scajaquada	Black Rock Canal	16.2	11.2	16.0	6.9	5.5	1.5
005	Scajaquada	Black Rock Canal	0.1	0.1	0.1	0.1	0.1	0.1
006	Scajaquada	Black Rock Canal	201.4	198.9	44.4	29.4	14.5	4.1
008	Scajaquada	Black Rock Canal	8.2	6.1	2.5	1.6	1.9	0.9
010	Scajaquada	Black Rock Canal	11.8	11.9	2.2	1.1	0.9	0.4
012	Albany	Black Rock Canal	52.0	52.5	20.6	8.1	6.7	2.9
013	South Central	Black Rock Canal	13.6	6.8	0.8	0.0	0.0	0.0
061	Scajaquada	Black Rock Canal	33.8	31.2	41.2	21.1	19.6	12.1
063	South Central	Black Rock Canal	1.5	0.6	0.0	0.0	0.0	0.0
017	South Central	Buffalo River	101.6	71.3	31.0	29.7	29.2	21.8
022	South Central	Buffalo River	42.7	29.8	0.7	0.2	0.2	0.0
025	South Central	Buffalo River	1.4	1.4	0.4	0.1	0.1	0.0
026	South Central	Buffalo River	146.5	124.2	26.4	26.1	26.1	18.1
027	South Central	Buffalo River	19.4	31.7	30.6	23.4	22.1	13.1
028	South Central	Buffalo River	44.4	45.5	39.4	18.8	16.6	10.7
029	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
032	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
033	South Central	Buffalo River	35.7	37.8	23.0	13.5	12.1	5.3
034	South Central	Buffalo River	0.1	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
050	South Central	Buffalo River	4.1	3.2	1.3	0.7	0.6	0.1
051	South Central	Buffalo River	3.7	1.2	1.2	To Storage	To Storage	To Storage
052	South Central	Buffalo River	13.6	10.9	10.9	15.9	14.7	12.3
064	South Central	Buffalo River	27.2	21.1	5.1	4.5	4.5	0.0
066	South Central	Buffalo River	2.5	1.7	0.9	To Storage	To Storage	To Storage
035	South Central	Cazenovia Creek - B	4.8	0.0	0.0	0.0	0.0	0.0
037	South Central	Cazenovia Creek - C	21.2	23.3	14.4	8.3	7.6	4.4
039	South Central	Cazenovia Creek - C	0.0	0.0	0.0	0.0	0.0	0.0
044	South Central	Cazenovia Creek - C	6.5	2.3	0.9	0.4	0.2	0.0
046	South Central	Cazenovia Creek - C	1.1	1.3	0.0	0.0	0.0	0.0
047	South Central	Cazenovia Creek - C	10.4	8.7	3.4	1.7	1.5	0.8
048	South Central	Cazenovia Creek - C	1.5	0.0	0.0	0.0	0.0	0.0
055	Hertel	Cornelius Creek	613.6	601.1	222.0	103.5	65.3	30.9
014	South Central	Erie Basin	25.9	4.2	3.1	1.7	1.4	0.0
015	South Central	Erie Basin	5.7	6.1	2.4	0.6	0.4	0.0
016	South Central	Erie Basin	0.0	0.0	0.0	0.0	0.0	0.0
003	Parish	Niagara River	4.5	0.1	0.1	0.1	0.1	0.1
011	Albany	Niagara River	125.7	134.3	67.5	34.6	29.6	21.1
054	Ontario	Niagara River	0.1	0.0	0.0	0.0	0.0	0.0
053	Scajaquada	Scajaquada Creek	275.0	268.0	74.3	67.9	45.3	29.0
056	Hertel	Scajaquada Creek	0.0	0.0	0.0	0.0	To Storage	To Storage
057	Parish	Scajaquada Creek	0.3	0.0	0.0	0.0	0.0	0.0
058	Parish	Scajaquada Creek	0.0	0.0	0.0	0.0	0.0	0.0
059	Scajaquada	Scajaquada Creek	5.1	0.0	0.0	0.0	0.0	0.0
060	Scajaquada	Scajaquada Creek	2.9	0.7	0.7	0.7	0.6	0.3
Totals			1886	1749.1	688	421	327	190

Total CSO Combined Only Volume by District (MG)	Albany		177.7	186.8	88.0	42.8	36.4	24.0
	Hertel		613.7	601.1	222.0	103.6	65.3	30.9
	Ontario		0.1	0.0	0.0	0.0	0.0	0.0
	Parish		4.7	0.1	0.1	0.1	0.1	0.1
	Scajaquada		554.7	528.1	181.4	128.7	88.5	48.2
	South Central		535.2	433.0	195.9	145.5	137.2	86.7
Total CSO Combined Only Volume by Receiving Water (MG)		Black Rock Canal	338.7	319.3	127.8	68.3	49.3	21.9
		Buffalo River	442.9	379.7	170.8	132.9	126.1	81.5
		Cazenovia Creek - B	4.8	0.0	0.0	0.0	0.0	0.0
		Cazenovia Creek - C	40.7	35.6	18.8	10.3	9.3	5.2
		Cornelius Creek	613.6	601.1	222.0	103.5	65.3	30.9
		Erie Basin	31.6	10.3	5.5	2.3	1.7	0.0
		Niagara River	130.2	134.4	67.6	34.8	29.8	21.2
		Scajaquada Creek	283.4	268.7	75.0	68.6	46.0	29.2

Alternative UA3 Overflow Frequency Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency
004	Scajaquada	Black Rock Canal	7	5	4	2	2	1
005	Scajaquada	Black Rock Canal	0	4	4	4	4	2
006	Scajaquada	Black Rock Canal	65	65	8	6	4	0
008	Scajaquada	Black Rock Canal	42	39	8	2	2	2
010	Scajaquada	Black Rock Canal	44	44	5	2	2	2
012	Albany	Black Rock Canal	42	42	7	2	3	2
013	South Central	Black Rock Canal	14	7	2	0	0	0
061	Scajaquada	Black Rock Canal	10	10	9	4	3	2
063	South Central	Black Rock Canal	50	13	1	0	0	0
017	South Central	Buffalo River	55	49	3	3	3	2
022	South Central	Buffalo River	55	49	5	2	2	0
025	South Central	Buffalo River	11	11	2	2	1	0
026	South Central	Buffalo River	61	63	3	3	3	2
027	South Central	Buffalo River	36	36	6	3	2	2
028	South Central	Buffalo River	69	69	10	6	3	2
029	South Central	Buffalo River	0	0	0	0	0	0
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	8	9	6	3	2	2
034	South Central	Buffalo River	5	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0	0	1	0	0	0
050	South Central	Buffalo River	22	14	4	3	2	2
051	South Central	Buffalo River	16	4	4	To Storage	To Storage	To Storage
052	South Central	Buffalo River	11	10	10	5	4	2
064	South Central	Buffalo River	55	56	2	2	2	0
066	South Central	Buffalo River	16	10	5	To Storage	To Storage	To Storage
035	South Central	Cazenovia Creek - B	29	0	0	0	0	0
037	South Central	Cazenovia Creek - C	14	13	7	3	3	2
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	15	7	2	2	1	0
046	South Central	Cazenovia Creek - C	9	1	1	0	0	0
047	South Central	Cazenovia Creek - C	47	44	9	3	3	2
048	South Central	Cazenovia Creek - C	12	0	0	0	0	0
055	Hertel	Cornelius Creek	40	41	10	6	4	2
014	South Central	Erie Basin	17	4	4	2	2	0
015	South Central	Erie Basin	12	12	4	2	2	0
016	South Central	Erie Basin	3	0	0	0	0	0
003	Parish	Niagara River	27	6	6	5	4	2
011	Albany	Niagara River	41	41	10	5	2	2
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	65	65	8	6	4	0
056	Hertel	Scajaquada Creek	5	5	5	5	To Storage	To Storage
057	Parish	Scajaquada Creek	11	0	0	0	0	0
058	Parish	Scajaquada Creek	2	0	0	0	0	0
059	Scajaquada	Scajaquada Creek	17	0	0	0	0	0
060	Scajaquada	Scajaquada Creek	11	5	5	5	4	2

Max Events	Albany		42	42	10	5	3	2
	Hertel		40	41	10	6	4	2
	Ontario		4	0	0	0	0	0
	Parish		27	6	6	5	4	2
	Scajaquada		65	65	8	6	4	2
	South Central		69	69	10	6	4	2
Max Events		Black Rock Canal	65	65	9	6	4	2
		Buffalo River	69	69	10	6	4	2
		Cazenovia Creek - B	29	0	0	0	0	0
		Cazenovia Creek - C	47	44	9	3	3	2
		Cornelius Creek	40	41	10	6	4	2
		Erie Basin	17	12	4	2	2	0
		Niagara River	41	41	10	5	4	2
		Scajaquada Creek	65	65	8	6	4	2

Alternative UA3 Overflow Duration Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)
004	Scajaquada	Black Rock Canal	12	8	8	5	5	2
005	Scajaquada	Black Rock Canal	5	5	5	0	5	5
006	Scajaquada	Black Rock Canal	322	344	71	66	42	0
008	Scajaquada	Black Rock Canal	105	90	49	20	19	16
010	Scajaquada	Black Rock Canal	103	103	18	11	11	5
012	Albany	Black Rock Canal	111	111	22	13	10	9
013	South Central	Black Rock Canal	58	25	17	0	0	0
061	Scajaquada	Black Rock Canal	31	29	32	16	14	11
063	South Central	Black Rock Canal	110	19	3	0	0	0
017	South Central	Buffalo River	166	124	51	44	43	39
022	South Central	Buffalo River	166	124	16	7	6	0
025	South Central	Buffalo River	17	17	19	14	8	0
026	South Central	Buffalo River	232	247	18	17	17	14
027	South Central	Buffalo River	127	131	78	34	28	26
028	South Central	Buffalo River	328	328	124	63	42	37
029	South Central	Buffalo River	0	0	0	0	0	0
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	20	21	60	35	29	24
034	South Central	Buffalo River	8	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0	0	4	0	0	0
050	South Central	Buffalo River	47	22	15	12	8	6
051	South Central	Buffalo River	56	14	14	To Storage	To Storage	To Storage
052	South Central	Buffalo River	112	70	70	103	85	62
064	South Central	Buffalo River	166	181	38	11	11	0
066	South Central	Buffalo River	26	17	11	To Storage	To Storage	To Storage
035	South Central	Cazenovia Creek - B	55	0	0	0	0	0
037	South Central	Cazenovia Creek - C	42	40	20	12	11	8
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	37	12	5	2	1	0
046	South Central	Cazenovia Creek - C	37	1	7	0	0	0
047	South Central	Cazenovia Creek - C	108	94	17	9	7	6
048	South Central	Cazenovia Creek - C	42	0	0	0	0	0
055	Hertel	Cornelius Creek	184	174	78	37	24	16
014	South Central	Erie Basin	61	15	28	16	15	0
015	South Central	Erie Basin	43	43	17	9	5	0
016	South Central	Erie Basin	4	0	0	0	0	0
003	Parish	Niagara River	224	32	34	33	33	18
011	Albany	Niagara River	240	243	97	47	34	28
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	322	344	71	66	42	0
056	Hertel	Scajaquada Creek	8	8	8	8	To Storage	To Storage
057	Parish	Scajaquada Creek	15	0	0	0	0	0
058	Parish	Scajaquada Creek	2	10	60	24	23	19
059	Scajaquada	Scajaquada Creek	45	26	12	4	4	0
060	Scajaquada	Scajaquada Creek	25	11	11	11	11	5

APPENDIX 11-6

ALTERNATIVE UA3A - System-wide Tunnel and Revised Foundation

FINANCIAL ASSUMPTIONS

Current ENR CCI:	9,011	i (interest rate):	5.00%
2004 BSA LTCP ENR CCI:	6,695	j (discount rate):	2.50%
Project Contingency Percentage:	25%	t (time horizon for plan):	20
Engineering Percentage:	15%	Present Worth Factor:	15.30
O/M Contingency Percentage:	10%	Assumed Escalation (for O&M) per year:	3.50%

REVISED 4/13/2012 VIA EMAIL FROM BILL BARRACK

Sewer Separation (Based on similar projects, partial separation is $25,000/ac and full separation is $50,000/ac)

Receiving Basin	Area (ac)					Cost ($ millions)		
	Partial Sewer Separation	Full Sewer Separation (ac)	Proposed Foundation Partial Separation	Full Separation	Total	Partial Sewer Separation	Full Sewer Separation	Total
Buffalo River	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cazenovia Creek - B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cazenovia Creek - C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Storage (data provided by collection system modeling); (updated all LOCs except 0 on 4/24/2012 by JAH)

BSA 2004 COST CURVE (unit cost per gal stored): $Cost = 220 * V^{-0.27}$

ALCOSAN COST CURVE (Dec 2008): $Cost = 3.4 \times V^{0.826}$

EPA CSO Cost Manual (using costs for sed basins) - 1995: [illegible]

	Receiving Basin	Volume (MG)					Construction Cost ($ millions) - Updated BSA Curve					Construction Cost ($ millions) - ALCOSAN Curve					Present Worth O/M Cost ($ millions)					Total Present Worth Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO 003	Niagara River	0.12	0	0	0	0	$1.51	$0.00	$0.00	$0.00	$0.00	$0.62	$0.00	$0.00	$0.00	$0.00	$0.12	$0.00	$0.00	$0.00	$0.00	$0.75	$0.00	$0.00	$0.00	$0.00
CSO 051/052/066	Buffalo River	15	3.8	2.75	2.5	0	$51.29	$18.82	$14.87	$13.87	$0.00	$33.55	$10.79	$8.26	$7.64	$0.00	$1.83	$0.85	$0.71	$0.67	$0.00	$35.38	$11.64	$8.97	$8.31	$0.00
CSO 056/060	Scajaquada Creek	0.5	0.25	0.14	0	0	$4.28	$2.58	$1.69	$0.00	$0.00	$2.02	$1.14	$0.71	$0.00	$0.00	$0.27	$0.19	$0.13	$0.00	$0.00	$2.29	$1.33	$0.84	$0.00	$0.00
CSO 055	Cornelius Creek	78.6	54.1	37	28	13.3	$171.83	$130.82	$99.14	$80.89	$46.97	$131.78	$96.80	$70.72	$56.18	$30.38	$4.63	$3.75	$3.04	$2.60	$1.71	$136.41	$100.55	$73.76	$58.78	$32.09
Total		**94.22**	**58.15**	**39.89**	**30.50**	**13.30**	**$228.91**	**$152.23**	**$115.69**	**$94.75**	**$46.97**	**$167.97**	**$108.73**	**$79.69**	**$63.82**	**$30.38**	**$6.85**	**$4.79**	**$3.88**	**$3.27**	**$1.71**	**$174.83**	**$113.52**	**$83.57**	**$67.09**	**$32.09**

Storage Consolidation Piping (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length	Diameter (ft)	Unit Cost ($/ft)	Construction Cost ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CSO 055	Cornelius Creek	1,262	10	$1,963	$2.48	$2.48	$2.48	$2.48	$2.48
CSO 003	Niagara River	159	1.5	$183	$0.03	$0.00	$0.00	$0.00	$0.00
CSO 060	Scajaquada Creek	234	2.5	$289	$0.07	$0.07	$0.07	$0.00	$0.00
CSO 056	Scajaquada Creek	355	1	$188	$0.07	$0.07	$0.07	$0.00	$0.00
CSO 051	Buffalo River	2,226	3	$362	$0.81	$0.81	$0.81	$0.81	$0.00
CSO 066	Buffalo River	591	3.5	$420	$0.25	$0.25	$0.25	$0.25	$0.00
CSO 052	Buffalo River	406	2.5	$289	$0.12	$0.12	$0.12	$0.12	$0.00
Total		**5,232**			**$3.81**	**$3.78**	**$3.78**	**$3.65**	**$2.48**

Storage Dewatering Force Main (data provided by collection system modeling) (priced in terms of unit cost per foot for particular diameter) (O&M costs assumed to be zero)

	Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Cost ($ millions)				
			0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO 051/052/066	Buffalo River	1,336	24	16	14	14	0	$161	$102	$84	$84	$0	$0.22	$0.14	$0.11	$0.11	$0.00
CSO 055	Cornelius Creek	707	78	66	54	48	24	$1,030	$680	$449	$365	$161	$0.73	$0.48	$0.32	$0.26	$0.11
CSO 003	Niagara River	291	4	0	0	0	0	$32	$0	$0	$0	$0	$0.01	$0.00	$0.00	$0.00	$0.00
CSO 056/060	Scajaquada Creek	2,496	8	4	4	0	0	$46	$32	$32	$0	$0	$0.12	$0.08	$0.08	$0.00	$0.00
Total		**4,830**											**$1.07**	**$0.70**	**$0.51**	**$0.37**	**$0.11**

High Rate Treatment (data provided by collection system modeling); updated based on Jon's email on 4/25/2012

ALCOSAN COST CURVE (DEC 2008): [illegible]

ALCOSAN COST CURVE (DEC 2008): [illegible]

BSA O&M (2004): $O/M Cost = 4347.2 \times Flow + 18228$

ALCOSAN COST CURVE (DEC 2008) - Intermed. Cost: $Cost = 385002 \times Flow(in MGD)^{0.8941}$

ALCOSAN COST CURVE (DEC 2008) - Source 1: $Cost = (770.4 + 925.8) \times Flow + (536.98 + 18536)$ (Addition of O/M Cost for HRT and for PS)

(Using AlCOSAN cost curves)

	Receiving Basin	Peak Flow (mgd)					Construction Cost ($ millions) - Alcosan Curve					Present Worth O/M Cost ($ millions) - Alcosan Curve					Present Worth O/M Cost ($ millions) - BSA Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North Relief	Black Rock Canal	466.0	316.7	0.0	0.0	0.0	$52.26	$39.76	$0.00	$0.00	$0.00	$61.17	$48.67	$0.00	$0.00	$0.00	$39.78	$27.15	$0.00	$0.00	$0.00
Total		**466**	**317**	**0**	**0**	**0**	**$52.26**	**$39.76**	**$0.00**	**$0.00**	**$0.00**	**$61.17**	**$48.67**	**$0.00**	**$0.00**	**$0.00**	**$39.78**	**$27.15**	**$0.00**	**$0.00**	**$0.00**

	HRT PS Construction Cost ($ millions) - ALCOSAN Curve					PW HRT PS O/M Cost ($ millions) - ALCOSAN Curve					Total Present Worth O/M Cost ($ millions)					Total Construction Cost ($ millions)					Total Present Worth Cost ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North Relief	$98.63	$69.84	$0.00	$0.00	$0.00	$13.73	$9.43	$0.00	$0.00	$0.00	$74.89	$58.10	$0.00	$0.00	$0.00	$150.89	$109.60	$0.00	$0.00	$0.00	$225.78	$167.70	$0.00	$0.00	$0.00
Total	**$98.63**	**$69.84**	**$0.00**	**$0.00**	**$0.00**	**$13.73**	**$9.43**	**$0.00**	**$0.00**	**$0.00**	**$74.89**	**$58.10**	**$0.00**	**$0.00**	**$0.00**	**$150.89**	**$109.60**	**$0.00**	**$0.00**	**$0.00**	**$225.78**	**$167.70**	**$0.00**	**$0.00**	**$0.00**

High Rate Treatment Disinfection (data provided by collection system modeling)

EPA Cost Curve (1993): $Cost = 0.121Q^{0.464}$

EPA Cost Curve (1993): $Cost = 0.1144Q^{0.479}$

	Receiving Basin	Peak Flow (mgd)					Construction Cost ($ millions) - EPA Curve					Present Worth O&M Cost ($ millions) - EPA Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North Relief	Black Rock Canal	466.0	257.0	0.0	0.0	0.0	$3.93	$2.98	$0.00	$0.00	$0.00	$0.06	$0.05	$0.00	$0.00	$0.00
Total		**466**	**257**	**0**	**0**	**0**	**$3.93**	**$2.98**	**$0.00**	**$0.00**	**$0.00**	**$0.06**	**$0.05**	**$0.00**	**$0.00**	**$0.00**

High Rate CCT (data provided by collection system modeling)

ALCOSAN COST CURVE (DEC 2008): $Cost = 3.4 \times V^{0.826}$

	Receiving Basin	CCT Volume (MG)					Construction Cost ($ millions) - ALCOSAN Curve				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North Relief	Black Rock Canal	1.62	0.89	0.00	0.00	0.00	$3.96	$2.42	$0.00	$0.00	$0.00
Total		**1.62**	**0.89**	**0.00**	**0.00**	**0.00**	**$3.96**	**$2.42**	**$0.00**	**$0.00**	**$0.00**

Tunnel Storage (data provided by collection system model)

BSA 2004 Curve: $BRC\ cost = 5631858 \times dia$; $SC\ cost = 2846725.52 x dia$

ALCOSAN cost curve (deep tunnel dewatering, Fig D-3): $Cost = 910439 \times Flow^{0.9421}$

Calculation Based on per Gal Pumped

ALCOSAN COST CURVE (DEC 2008) - Source 2: $Cost = 749.43 \times VOL + 17816$

ALCOSAN COST CURVE (DEC 2008) - Source 2: $Cost = 959.78 * VOL + 22246$

BSA 2004 LTCP Equation: [illegible]

	Receiving Basin	Volume (MG) or Dewatering (MGD) or Diameter (ft)					Length (ft)	Tunnel Cost ($ millions) - linear curve					Dewatering PS Cost ($ millions) - Alcosan Curve					Total Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South Volume	Black Rock Canal	105.74	32.64	14.51	7.11	7.11	24,700	$204.66	$113.70	$75.80	$53.06	$53.06	$83.43	$27.57	$12.84	$6.56	$6.56	$288.09	$141.27	$88.65	$59.62	$59.62
North-South Diameter		27	15	10	7	7																
East-West Volume	Scajaquada Creek	53.6	30	16	7.4	3.2	14,200	$95.79	$72.80	$53.64	$34.48	$26.82	$43.99	$25.46	$14.08	$6.81	$3.09	$139.78	$98.26	$67.72	$41.29	$29.91
East-West Diameter		25	19	14	9	7																
Total		**159.3**	**62.6**	**30.5**	**14.5**	**10.3**	**38,900**	**$300.45**	**$186.50**	**$129.44**	**$87.54**	**$79.88**	**$127.42**	**$53.03**	**$26.93**	**$13.37**	**$9.65**	**$427.87**	**$239.53**	**$156.37**	**$100.91**	**$89.53**
		105.8	32.6	14.5	7.1	7.1																

	Annual Volume Pumped (MG)					Annual Present Worth O/M Costs - Energy ($ millions)					Annual Present Worth O/M Costs - Materials ($ millions)					Annual Present Worth O/M Costs - Labor ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South	434.7	251.4	182.7	108.1	24.21	$0.39	$0.23	$0.16	$0.10	$0.02	$1.65	$0.72	$0.49	$0.39	$0.39	$2.10	$0.91	$0.62	$0.50	$0.50
East-West	253	219.9	189.1	150.7	139.8	$0.23	$0.20	$0.17	$0.14	$0.13	$0.98	$0.68	$0.51	$0.40	$0.34	$1.25	$0.87	$0.64	$0.50	$0.43
Total	**687.7**	**471.3**	**371.8**	**258.8**	**164.0**	**$0.62**	**$0.42**	**$0.33**	**$0.23**	**$0.15**	**$2.63**	**$1.40**	**$0.99**	**$0.79**	**$0.74**	**$3.36**	**$1.78**	**$1.26**	**$1.00**	**$0.93**

	Present Worth O/M Costs - Tunnel ($ millions)					Present Worth O/M Costs - Total ($ millions)					Costs - Total ($ millions)				
	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
North-South	$7.07	$5.92	$5.64	$5.52	$5.52	$11.21	$7.78	$6.91	$6.51	$6.43	$299.30	$149.04	$95.55	$66.13	$66.05
East-West	$6.25	$5.88	$5.66	$5.53	$5.46	$8.71	$7.63	$6.98	$6.56	$6.36	$148.49	$105.89	$74.70	$47.85	$36.27
Total	**$13.32**	**$11.80**	**$11.30**	**$11.05**	**$10.98**	**$19.92**	**$15.41**	**$13.88**	**$13.07**	**$12.79**	**$447.79**	**$254.93**	**$170.25**	**$113.98**	**$102.33**

Dynamic Head (ft):	125
Efficiency (%):	67%
Electricity Cost ($/kWhr):	0.1

Tunnel Collectors (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length (ft)	Diameter (ft)	Unit Cost ($/ft)	Construction Costs - Total ($ millions)				
					0 OF	2 OF	4 OF	6 OF	12 OF
CazCrk1	Cazenovia Creek - C	1,201	7.0	$1,072	*$1.29*	*$1.29*	*$1.29*	*$1.29*	*$1.29*
CazCrk2	Cazenovia Creek - C	412	7.0	$1,072	*$0.44*	*$0.44*	*$0.44*	*$0.44*	*$0.44*
CazCrk3	Cazenovia Creek - C	401	5.5	$739	*$0.30*	*$0.30*	*$0.30*	*$0.30*	*$0.30*
CazCrk4	Cazenovia Creek - C	606	5.5	$739	*$0.45*	*$0.45*	*$0.45*	*$0.45*	*$0.45*
CSO 004	Black Rock Canal	977	0.0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 008	Black Rock Canal	387	0.0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 010	Black Rock Canal	1,496	0.0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 011	Niagara River	1,512	0.0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 012	Black Rock Canal	22	0.0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 013	Black Rock Canal	3,643	5.0	$645	*$2.35*	*$2.35*	*$2.35*	*$2.35*	*$0.00*
CSO 014	Erie Basin	970	4.5	$559	*$0.54*	*$0.54*	*$0.54*	*$0.00*	*$0.00*
CSO 015	Erie Basin	176	4.0	$478	*$0.08*	*$0.08*	*$0.08*	*$0.08*	*$0.00*
CSO 017	Buffalo River	1,486	7.0	$1,072	*$1.59*	*$1.59*	*$0.00*	*$0.00*	*$0.00*
CSO 022	Buffalo River	870	3.0	$362	*$0.32*	*$0.32*	*$0.32*	*$0.32*	*$0.00*
CSO 025	Buffalo River	3,306	2.5	$289	*$0.96*	*$0.96*	*$0.96*	*$0*	*$0.00*
CSO 026	Buffalo River	1,869	6.5	$953	*$1.78*	*$1.78*	*$0*	*$0*	*$0.00*
CSO 027	Buffalo River	1,597	5.5	$739	*$1.18*	*$1.18*	*$1.18*	*$1.18*	*$0.00*
CSO 028	Buffalo River	25	7.0	$1,072	*$0.03*	*$0.03*	*$0.03*	*$0.03*	*$0.03*
CSO 029	Buffalo River	2,504	7.0	$1,072	*$2.69*	*$2.69*	*$2.69*	*$2.69*	*$2.69*
CSO 033	Buffalo River	573	6.0	$842	*$0.48*	*$0.48*	*$0.48*	*$0.48*	*$0.48*
CSO 035	Cazenovia Creek - B	4,431	2.5	$289	*$1.28*	*$1.28*	*$1.28*	*$0.00*	*$0.00*
CSO 037	Cazenovia Creek - C	597	4.5	$559	*$0.33*	*$0.33*	*$0.33*	*$0.00*	*$0.00*
CSO 039	Cazenovia Creek - C	2,133	4.5	$559	*$1.19*	*$1.19*	*$1.19*	*$1.19*	*$1.19*
CSO 044	Cazenovia Creek - C	1,366	5.0	$645	*$0.88*	*$0.88*	*$0.88*	*$0.88*	*$0.88*
CSO 046	Cazenovia Creek - C	1,485	3.0	$362	*$0.54*	*$0.54*	*$0.54*	*$0.00*	*$0.00*
CSO 047	Cazenovia Creek - C	36	3.0	$362	*$0.01*	*$0.01*	*$0.01*	*$0.01*	*$0.01*
CSO 047 (2)	Cazenovia Creek - C	21	3.0	$362	*$0.01*	*$0.01*	*$0.01*	*$0.01*	*$0.01*
CSO 048	Cazenovia Creek - C	70	0.8	$181	*$0.01*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO 049	Buffalo River	390	3.5	$420	*$0.16*	*$0.16*	*$0.16*	*$0.16*	*$0.00*
CSO 050	Buffalo River	1,531	3.0	$362	*$0.55*	*$0.55*	*$0.55*	*$0.55*	*$0.00*
CSO 057	Scajaquada Creek	862	2.5	$289	*$0.25*	*$0.25*	*$0.25*	*$0.25*	*$0.00*
CSO 058	Scajaquada Creek	324	2.5	$289	*$0.09*	*$0.09*	*$0.09*	*$0.09*	*$0.00*
CSO 059	Scajaquada Creek	1,639	3.0	$362	*$0.59*	*$0.59*	*$0.59*	*$0.59*	*$0.00*
CSO 061	Black Rock Canal	239	5.0	$645	*$0.15*	*$0.15*	*$0.15*	*$0.15*	*$0.15*
CSO 063	Black Rock Canal	1,783	2.0	$247	*$0.44*	*$0.44*	*$0.00*	*$0.00*	*$0.00*
CSO 064	Buffalo River	1,121	6.5	$953	*$1.07*	*$1.07*	*$1.07*	*$1.07*	*$1.07*
SPP156	Scajaquada Creek	105	1.0	$188	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP157	Scajaquada Creek	772	2.5	$289	*$0.22*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP163	Scajaquada Creek	837	3.0	$362	*$0.30*	*$0.30*	*$0.30*	*$0.00*	*$0.00*
SPP165a&b	Scajaquada Creek	123	2.5	$289	*$0.04*	*$0.04*	*$0.04*	*$0.04*	*$0.04*
SPP166	Scajaquada Creek	247	2.0	$247	*$0.06*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP170b	Scajaquada Creek	1,036	5.5	$739	*$0.77*	*$0.77*	*$0.77*	*$0.77*	*$0.77*
SPP178	Scajaquada Creek	1,385	4.0	$478	*$0.66*	*$0.66*	*$0.66*	*$0.00*	*$0.00*
SPP179	Black Rock Canal	2,721	5.0	$645	*$1.75*	*$1.75*	*$1.75*	*$0.00*	*$0.00*
SPP180	Black Rock Canal	1,395	4.0	$478	*$0.67*	*$0.67*	*$0.67*	*$0.00*	*$0.00*
SPP200a&b	Scajaquada Creek	130	2.5	$289	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.00*
SPP201	Scajaquada Creek	1,123	3.5	$420	*$0.47*	*$0.47*	*$0.00*	*$0.00*	*$0.00*
SPP202	Scajaquada Creek	774	3.0	$362	*$0.28*	*$0.28*	*$0.00*	*$0.00*	*$0.00*
SPP203	Scajaquada Creek	39	3.0	$362	*$0.01*	*$0.01*	*$0.00*	*$0.00*	*$0.00*
SPP204	Scajaquada Creek	1,752	4.0	$478	*$0.84*	*$0.84*	*$0.84*	*$0.00*	*$0.00*
SPP229a	Scajaquada Creek	92	3.5	$420	*$0.04*	*$0.04*	*$0.00*	*$0.00*	*$0.00*
SPP331	Black Rock Canal	2,587	3.5	$420	*$1.09*	*$1.09*	*$1.09*	*$0.00*	*$0.00*
SPP335	Scajaquada Creek	1,706	3.0	$362	*$0.62*	*$0.62*	*$0.00*	*$0.00*	*$0.00*
SPP335a	Scajaquada Creek	24	1.5	$183	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
SPP336a	Scajaquada Creek	144	2.5	$289	*$0.04*	*$0.04*	*$0.04*	*$0.04*	*$0.04*
SPP336b	Scajaquada Creek	2,324	5.0	$645	*$1.50*	*$1.50*	*$1.50*	*$1.50*	*$1.50*
SPP337	Scajaquada Creek	1,418	5.5	$739	*$1.05*	*$1.05*	*$1.05*	*$1.05*	*$1.05*
SPP338	Scajaquada Creek	1,905	5.0	$645	*$1.23*	*$1.23*	*$0.00*	*$0.00*	*$0.00*
SPP339	Scajaquada Creek	1,285	4.0	$478	*$0.61*	*$0.61*	*$0.61*	*$0.00*	*$0.00*
SPP340	Scajaquada Creek	1,164	5.5	$739	*$0.86*	*$0.86*	*$0.86*	*$0.00*	*$0.00*
SPP341a	Scajaquada Creek	957	3.0	$362	*$0.35*	*$0.35*	*$0.35*	*$0.00*	*$0.00*
SPP342a&b	Scajaquada Creek	1,628	2.0	$247	*$0.40*	*$0.40*	*$0.00*	*$0.00*	*$0.00*
SPP345	Scajaquada Creek	1,735	2.0	$247	*$0.43*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Total		**71,466**			***$36.37***	***$35.65***	***$28.74***	***$17.95***	***$12.37***

Tunnel Dewatering Force Main (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

Receiving Basin	Length	Nominal Diameter (in)					Unit Cost ($/ft)					Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
Scajaquada Creek	231	90	72	54	18	10	$1,560	$837	$449	$121	$54	*$0.36*	*$0.19*	*$0.10*	*$0.03*	*$0.01*
Black Rock Canal	1,267	102	78	60	30	10	$2,363	$1,030	$553	$193	$54	*$2.99*	*$1.31*	*$0.70*	*$0.24*	*$0.07*
Total	1,497											*$3.35*	*$1.50*	*$0.80*	*$0.27*	*$0.08*

Relief Piping (data provided by collection system model); (updated the 4 and 12 LOC sizes 4/24/2012 by JAH) (priced in terms of unit cost per foot for particular diameter)

Receiving Basin	Length	Nominal Diameter (ft)					Unit Cost ($/ft)					Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	3,256	8	6	8.5	5	0	$1,336	$842	$1,480	$362	$0	*$4.35*	*$2.74*	*$4.62*	*$1.18*	*$0.00*
Black Rock Canal	2,066	8	9.5	8.5	7	4	$1,336	$1,794	$1,480	$1,072	$478	*$2.76*	*$3.71*	*$3.06*	*$2.22*	*$0.99*
Black Rock Canal	500	10	10	11	8	4	$1,963	$1,963	$2,327	$1,336	$478	*$0.98*	*$0.98*	*$1.16*	*$0.67*	*$0.24*
Total	5,822											***$8.09***	***$7.43***	***$9.04***	***$4.06***	***$1.23***

Underflow Piping (data provided by collection system model) (priced in terms of unit cost per foot for particular diameter)

	Receiving Basin	Length (LF)					Nominal Diameter (ft)					Unit Cost ($/ft)					Construction Cost ($ millions)				
		0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF	0 OF	2 OF	4 OF	6 OF	12 OF
CSO-04	Black Rock Canal	123	123	123	13	13	6	5	4.5	2.5	2.5	$842	$645	$559	$289	$289	*$0.10*	*$0.08*	*$0.07*	*$0.00*	*$0.00*
CSO-04	Black Rock Canal	0	0	0	110	110	0	0	O	0	0	$0	$0	$0	$0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-08	Black Rock Canal	243	243	1,042	243	243	2.5	2	2	1.5	1	$289	$247	$247	$183	$188	*$0.07*	*$0.06*	*$0.26*	*$0.04*	*$0.05*
CSO-08	Black Rock Canal	799	799	577	799	799	3	2.5	2.5	2	0	$362	$289	$289	$247	$0	*$0.29*	*$0.23*	*$0.17*	*$0.20*	*$0.00*
CSO-08	Black Rock Canal	577	577	67	577	577	3.5	3	3	2.5	0	$420	$362	$362	$289	$0	*$0.24*	*$0.21*	*$0.02*	*$0.17*	*$0.00*
CSO-08	Black Rock Canal	67	67	0	67	67	4	3.5	0	3	0	$478	$420	$0	$362	$0	*$0.03*	*$0.03*	*$0.00*	*$0.02*	*$0.00*
CSO-10	Black Rock Canal	40	40	40	40	40	3.5	2.5	2	2	0	$420	$289	$247	$247	$0	*$0.02*	*$0.01*	*$0.01*	*$0.01*	*$0.00*
CSO-11	Black Rock Canal	0	0	0	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-12	Black Rock Canal	0	0	0	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
CSO-61	Black Rock Canal	50	50	50	50	50	6	5	6	6	0	$842	$645	$842	$842	$0	*$0.04*	*$0.03*	*$0.04*	*$0.04*	*$0.00*
	Total	**1,899**	**1,899**	**1,899**	**1,899**	**1,899**											***$0.80***	***$0.65***	***$0.57***	***$0.49***	***$0.05***

Total - Capital Cost

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$465.21*	*$272.11*	*$104.97*	*$66.92*	*$61.12*
Buffalo River	*$45.74*	*$22.91*	*$16.98*	*$15.40*	*$4.26*
Cazenovia Creek - B	*$1.28*	*$1.28*	*$1.28*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$5.45*	*$5.44*	*$5.44*	*$4.57*	*$4.57*
Cornelius Creek	*$134.99*	*$99.75*	*$73.52*	*$58.92*	*$32.97*
Erie Basin	*$0.63*	*$0.63*	*$0.63*	*$0.08*	*$0.00*
Niagara River	*$0.66*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$154.16*	*$110.72*	*$76.56*	*$45.65*	*$33.31*
Sub-Total	***$808.12***	***$512.83***	***$279.37***	***$191.53***	***$136.23***

Sub-Total - Present Worth O/M

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$86.16*	*$65.92*	*$6.91*	*$6.51*	*$6.43*
Buffalo River	*$1.83*	*$0.85*	*$0.71*	*$0.67*	*$0.00*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cornelius Creek	*$4.63*	*$3.75*	*$3.04*	*$2.60*	*$1.71*
Erie Basin	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Niagara River	*$0.12*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$8.99*	*$7.81*	*$7.11*	*$6.56*	*$6.36*
Sub-Total	***$101.72***	***$78.34***	***$17.76***	***$16.34***	***$14.51***

Sub-Total - Engineering

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$69.78*	*$40.82*	*$15.74*	*$10.04*	*$9.17*
Buffalo River	*$6.86*	*$3.44*	*$2.55*	*$2.31*	*$0.64*
Cazenovia Creek - B	*$0.19*	*$0.19*	*$0.19*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$0.82*	*$0.82*	*$0.82*	*$0.69*	*$0.69*
Cornelius Creek	*$20.25*	*$14.96*	*$11.03*	*$8.84*	*$4.95*
Erie Basin	*$0.09*	*$0.09*	*$0.09*	*$0.01*	*$0.00*
Niagara River	*$0.10*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$23.12*	*$16.61*	*$11.48*	*$6.85*	*$5.00*
Sub-Total	***$121.22***	***$76.92***	***$41.91***	***$28.73***	***$20.43***

Sub-Total - Present Worth O/M Contigency

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$8.62*	*$6.59*	*$0.69*	*$0.65*	*$0.64*
Buffalo River	*$0.18*	*$0.08*	*$0.07*	*$0.07*	*$0.00*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cornelius Creek	*$0.46*	*$0.38*	*$0.30*	*$0.26*	*$0.17*
Erie Basin	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Niagara River	*$0.01*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$0.90*	*$0.78*	*$0.71*	*$0.66*	*$0.64*
Sub-Total	***$10.17***	***$7.83***	***$1.78***	***$1.63***	***$1.45***

Sub-Total - Project Contingency

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$133.75*	*$78.23*	*$30.18*	*$19.24*	*$17.57*
Buffalo River	*$13.15*	*$6.59*	*$4.88*	*$4.43*	*$1.23*
Cazenovia Creek - B	*$0.37*	*$0.37*	*$0.37*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$1.57*	*$1.56*	*$1.56*	*$1.31*	*$1.31*
Cornelius Creek	*$38.81*	*$28.68*	*$21.14*	*$16.94*	*$9.48*
Erie Basin	*$0.18*	*$0.18*	*$0.18*	*$0.02*	*$0.00*
Niagara River	*$0.19*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$44.32*	*$31.83*	*$22.01*	*$13.12*	*$9.58*
Sub-Total	***$232.33***	***$147.44***	***$80.32***	***$55.06***	***$39.17***

Sub-Total - Present Worth O/M with Contingency

Receiving Basin	Alternative UA3				
	0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$94.77*	*$72.52*	*$7.60*	*$7.16*	*$7.08*
Buffalo River	*$2.01*	*$0.93*	*$0.78*	*$0.74*	*$0.00*
Cazenovia Creek - B	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Cornelius Creek	*$5.09*	*$4.13*	*$3.34*	*$2.86*	*$1.88*
Erie Basin	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Niagara River	*$0.14*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$9.88*	*$8.60*	*$7.82*	*$7.21*	*$7.00*
Sub-Total	***$111.90***	***$86.18***	***$19.54***	***$17.97***	***$15.96***

Total - Project Cost with Contingencies

Receiving Basin	Foundation Alternative	Alternative UA3				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$6.89*	*$668.73*	*$391.15*	*$150.89*	*$96.19*	*$87.86*
Buffalo River	*$41.13*	*$65.75*	*$32.93*	*$24.40*	*$22.13*	*$6.13*
Cazenovia Creek - B	*$0.00*	*$1.84*	*$1.84*	*$1.84*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$0.02*	*$7.84*	*$7.82*	*$7.82*	*$6.57*	*$6.57*
Cornelius Creek	*$8.70*	*$194.04*	*$143.40*	*$105.68*	*$84.69*	*$47.39*
Erie Basin	*$0.01*	*$0.90*	*$0.90*	*$0.90*	*$0.12*	*$0.00*
Niagara River	*$0.00*	*$0.95*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$27.75*	*$221.61*	*$159.15*	*$110.06*	*$65.62*	*$47.89*
Sub-Total		***$1,161.67***	***$737.19***	***$401.59***	***$275.32***	***$195.83***
Total (with Foundation Alternative)	***$84.49***	***$1,246.15***	***$821.68***	***$486.08***	***$359.80***	***$280.31***

Total - Project Cost and Present Worth O/M with Contingencies Formatted for Report by EMH: 4/18/12

Receiving Basin	Foundation Alternative	Alternative UA3				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	*$6.89*	*$763.51*	*$463.67*	*$158.49*	*$103.35*	*$94.93*
Buffalo River	*$41.13*	*$67.77*	*$33.86*	*$25.18*	*$22.87*	*$6.13*
Cazenovia Creek - B	*$0.00*	*$1.84*	*$1.84*	*$1.84*	*$0.00*	*$0.00*
Cazenovia Creek - C	*$0.02*	*$7.84*	*$7.82*	*$7.82*	*$6.57*	*$6.57*
Cornelius Creek	*$8.70*	*$199.13*	*$147.53*	*$109.02*	*$87.55*	*$49.27*
Erie Basin	*$0.01*	*$0.90*	*$0.90*	*$0.90*	*$0.12*	*$0.00*
Niagara River	*$0.00*	*$1.08*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Scajaquada Creek	*$27.75*	*$231.49*	*$167.75*	*$117.88*	*$72.83*	*$54.88*
Sub-Total		***$1,273.56***	***$823.37***	***$421.13***	***$293.29***	***$211.78***
Total (with Foundation Alternative)	***$84.49***	***$1,358.05***	***$907.85***	***$505.62***	***$377.77***	***$296.27***

Receiving Basin	Foundation Alternative	Alternative UA3A				
		0 OF	2 OF	4 OF	6 OF	12 OF
Black Rock Canal	$6.89	$763.51	$463.67	$158.49	$103.35	$94.93
Buffalo River	$41.13	$67.77	$33.86	$25.18	$22.87	$6.13
Cazenovia Creek - B	$0.00	$1.84	$1.84	$1.84	$0.00	$0.00
Cazenovia Creek - C	$0.02	$7.84	$7.82	$7.82	$6.57	$6.57
Erie Basin	$0.01	$0.90	$0.90	$0.90	$0.12	$0.00
Niagara River (includes CSO OSS)	$8.70	$200.22	$147.53	$109.02	$87.55	$49.27
Scajaquada Creek	$27.75	$231.49	$167.75	$117.88	$72.83	$54.88
Sub-Total		$1,273.56	$823.37	$421.13	$293.29	$211.78
Total (with Revised Foundation Plan)	$84.49	$1,358.05	$907.85	$505.62	$377.77	$296.27

Fecal 92500

Figure A: Present Worth Costs vs. Frequency of Activation for Black Rock Canal
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

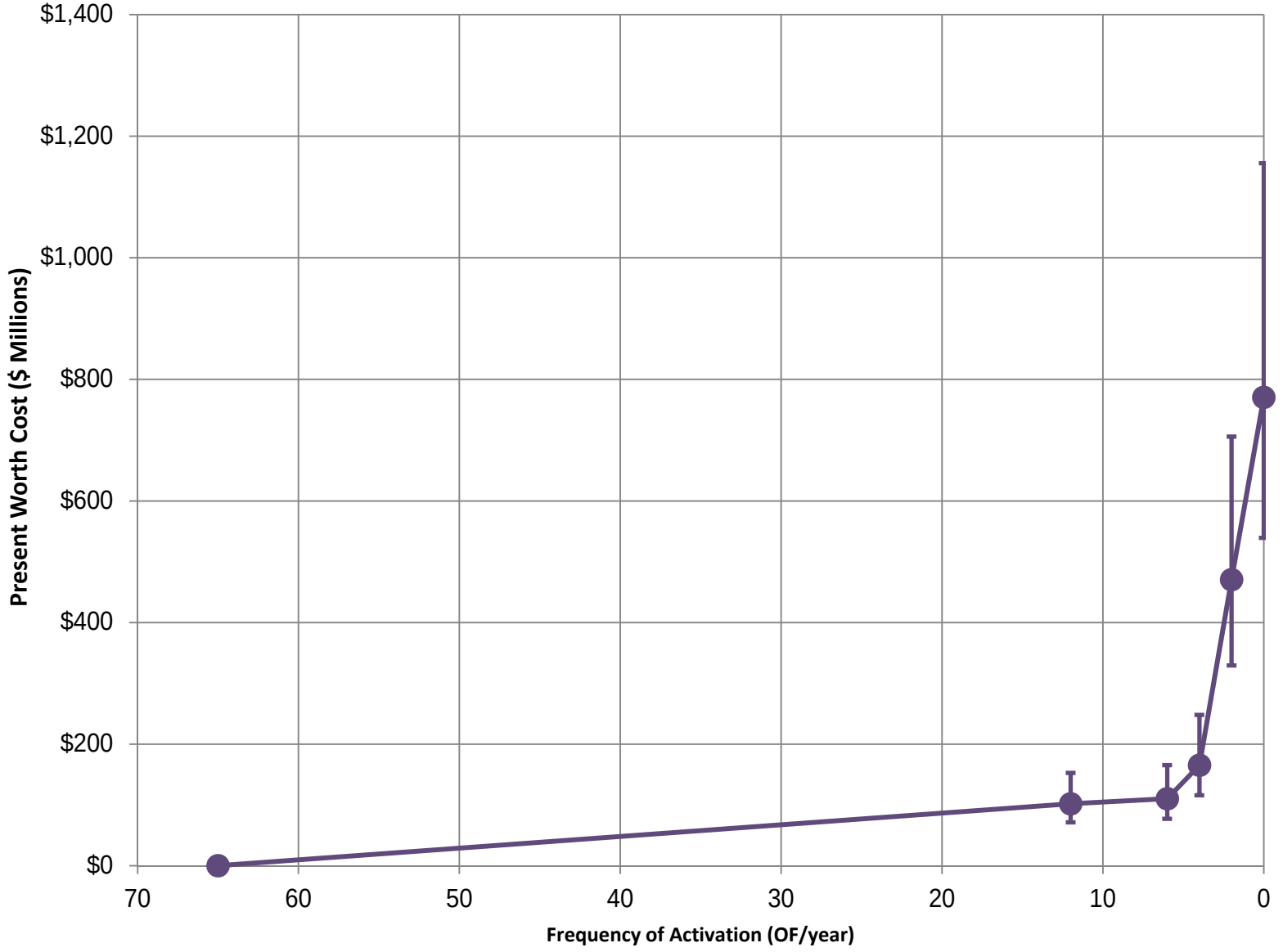


Figure B: Present Worth Costs vs. Frequency of Activations for Buffalo River (System-wide Alternative UA3A) 1993 TY- 2012 Dollars

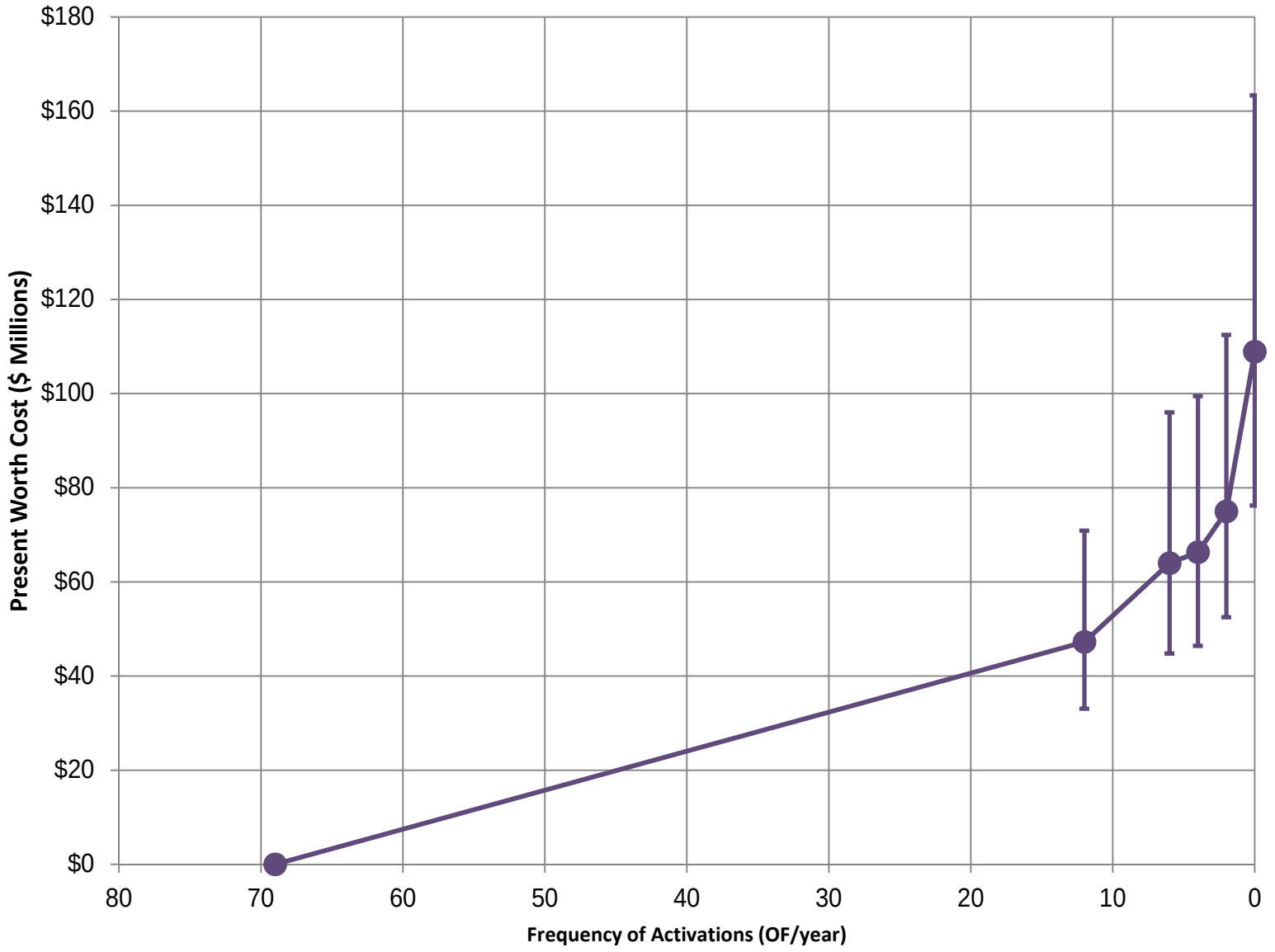


Figure C: Present Worth Costs vs. Frequency of Activation for Cazenovia Creek (B)
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

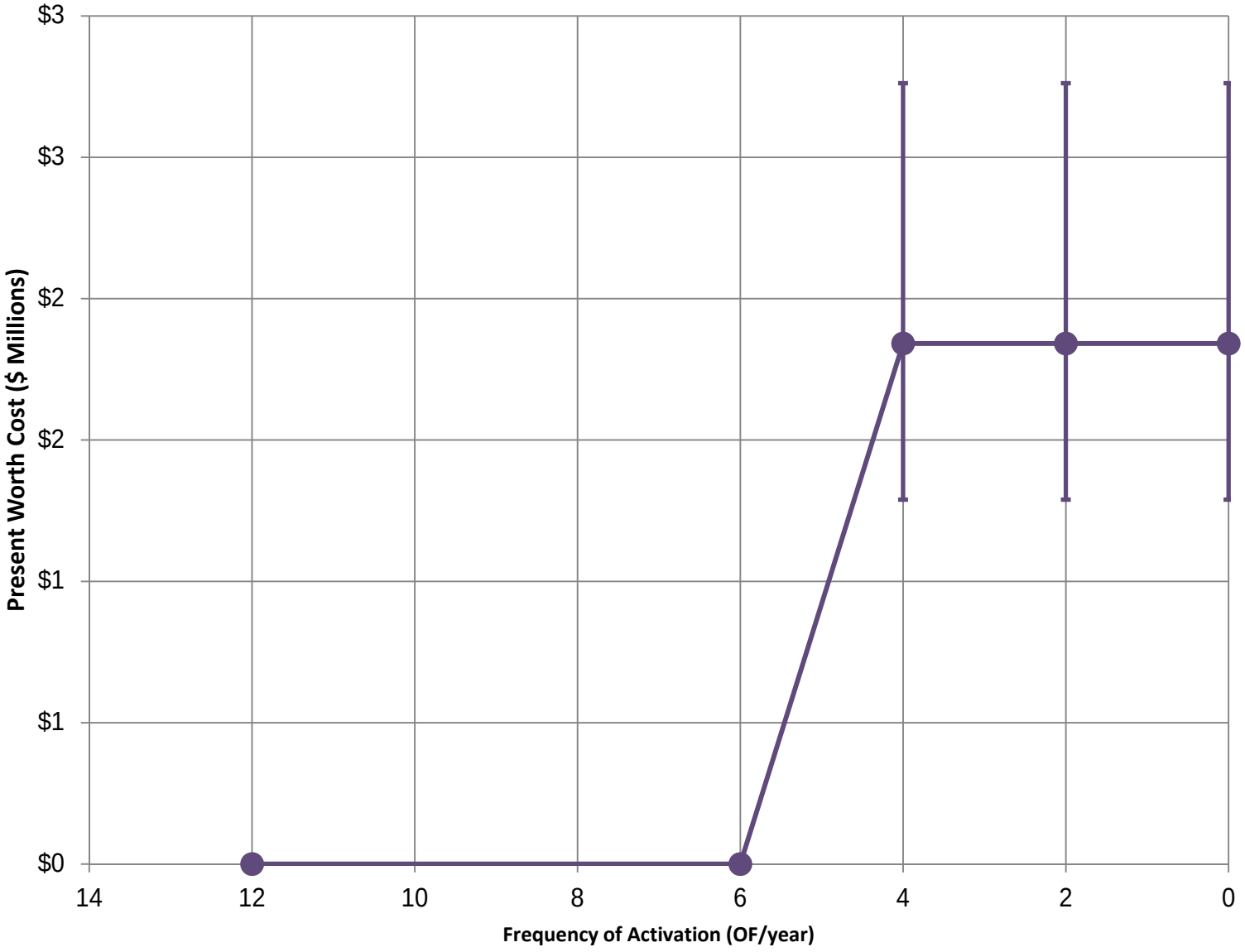


Figure D: Present Worth Costs vs. Frequency of Activation for Cazenovia Creek (C)
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

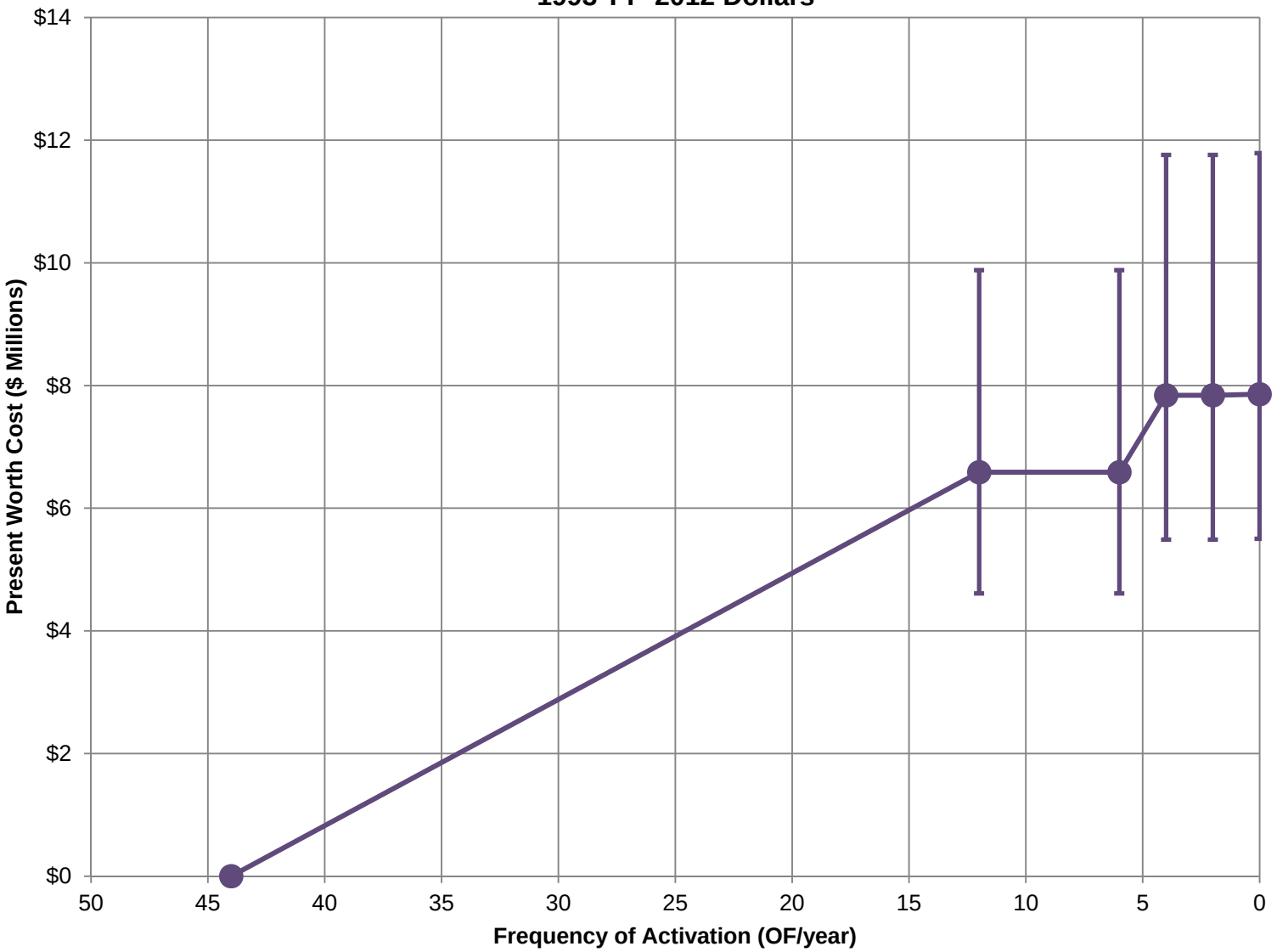


Figure E: Present Worth Costs vs. Frequency of Activation for Niagara River and CSO-055 (System-wide Alternative UA3A) 1993 TY- 2012 Dollars

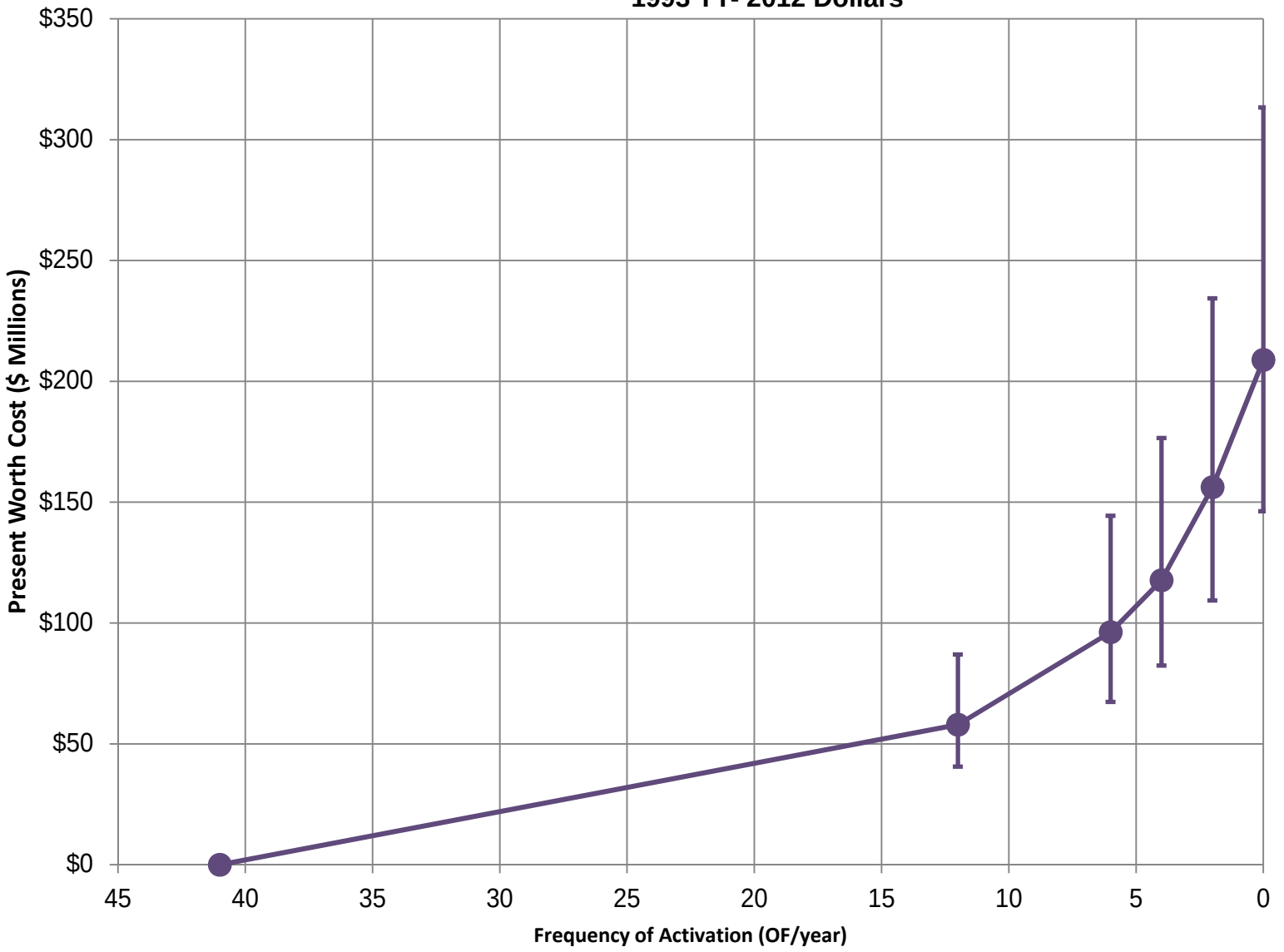


Figure F: Present Worth Costs vs. Frequency of Activation for Erie Basin
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

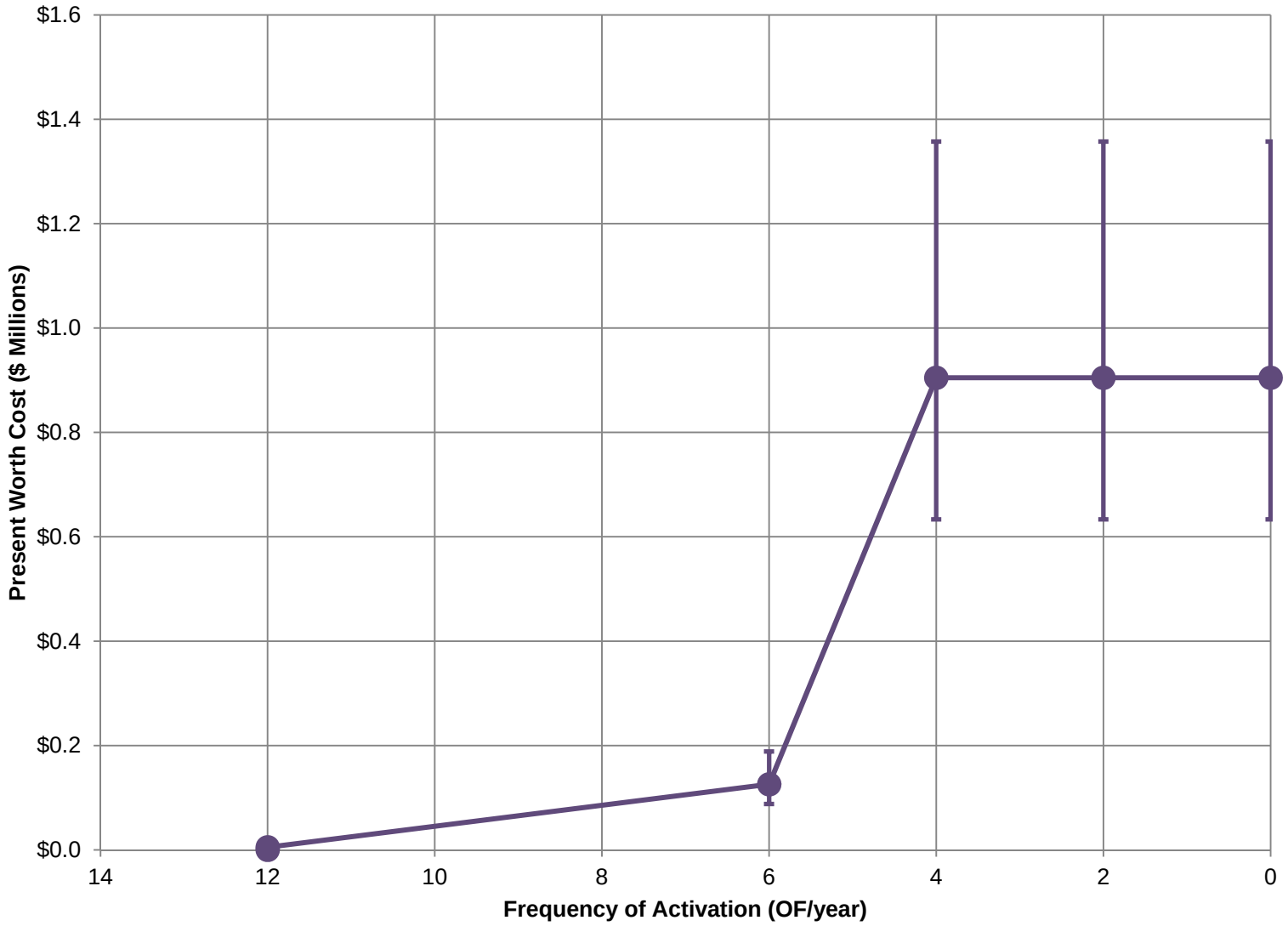


Figure G: Present Worth Costs vs. Frequency of Activation for Scajaquada Creek
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

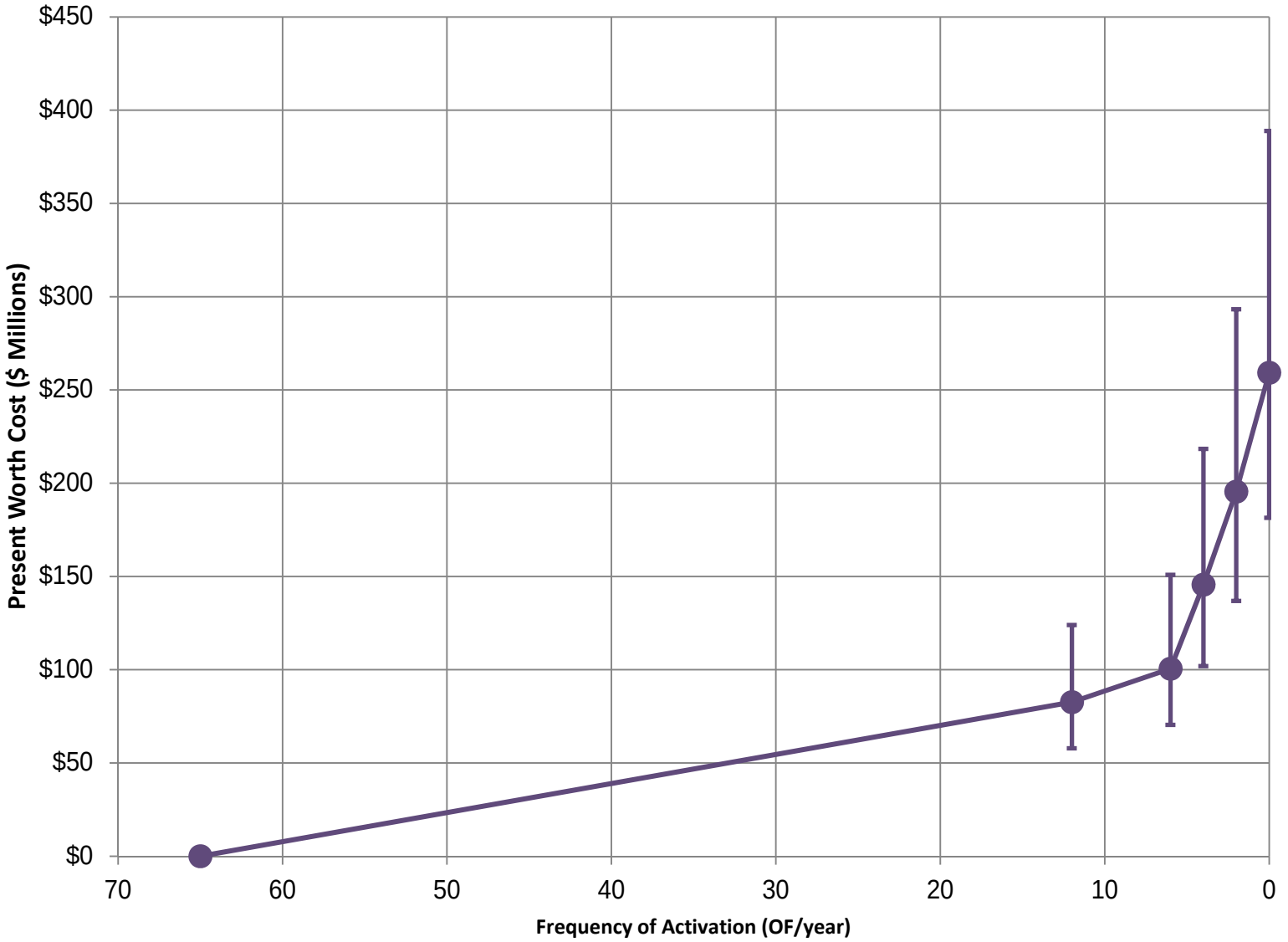


Figure H: Present Worth Costs vs. Remaining CSO Volumes for Black Rock Canal (System-wide Alternative UA3A) 1993 TY- 2012 Dollars

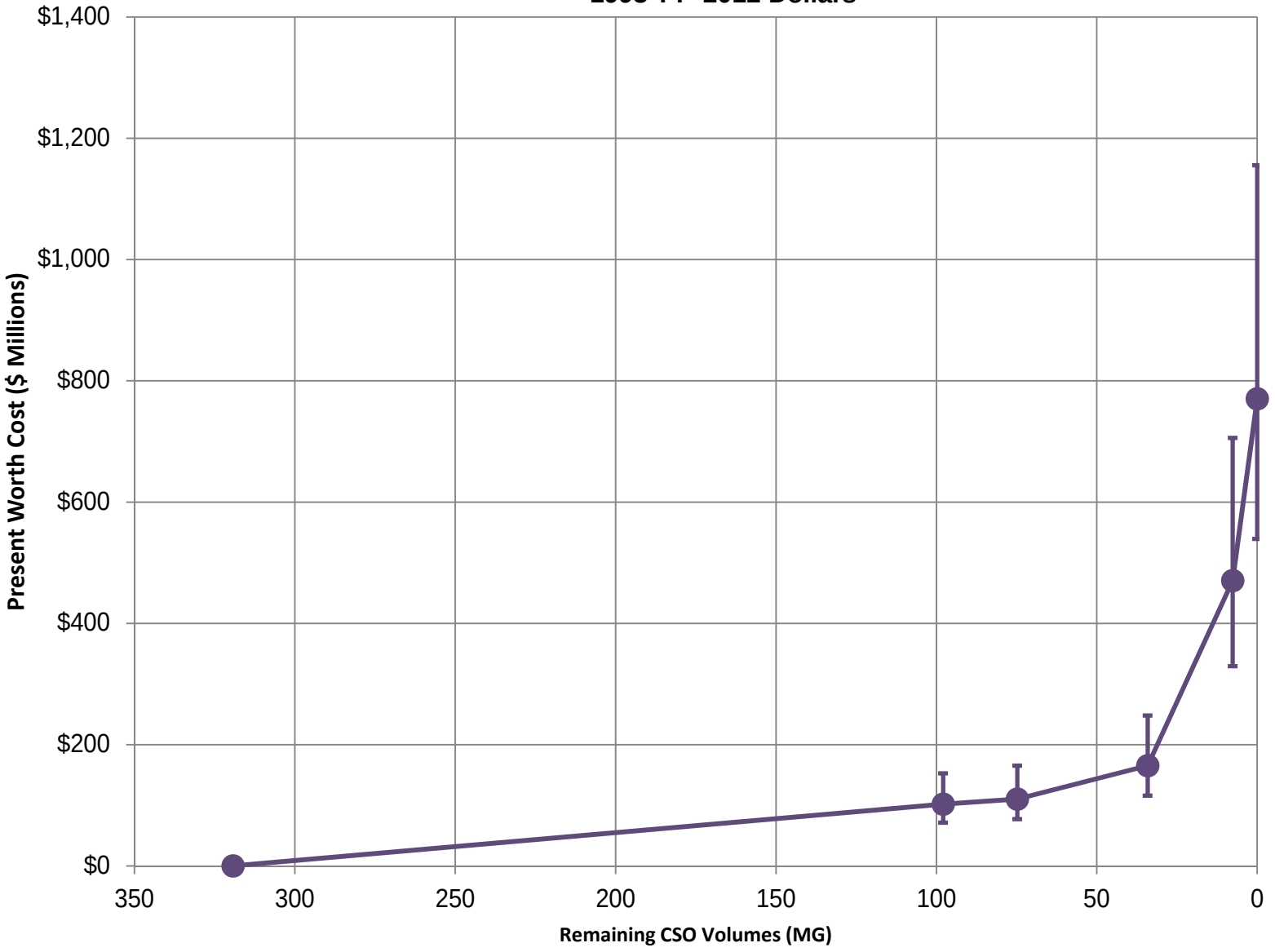


Figure I: Present Worth Costs vs. Remaining CSO Volumes for Buffalo River
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

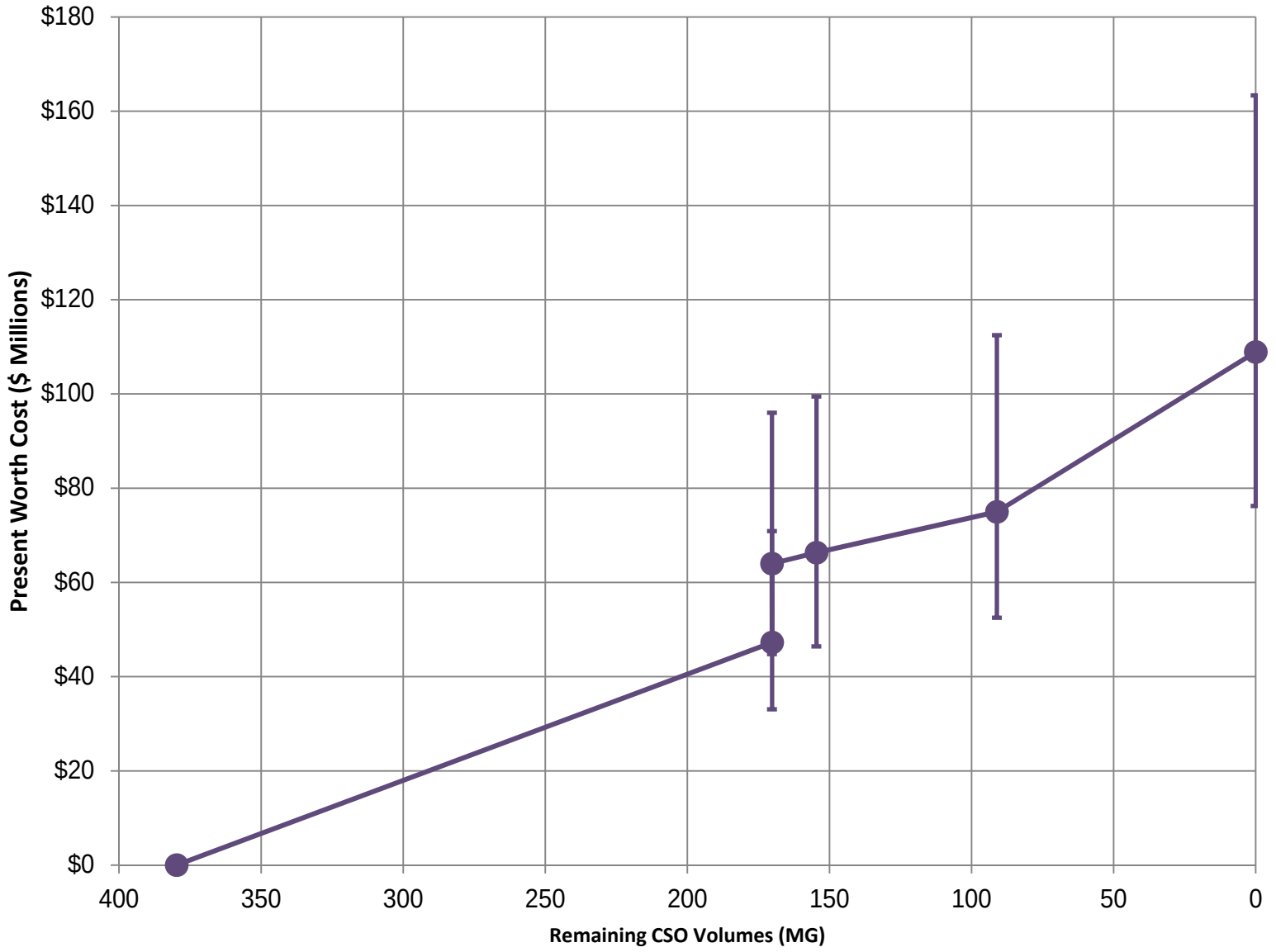


Figure J: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (B)
1993 TY- 2012 Dollars

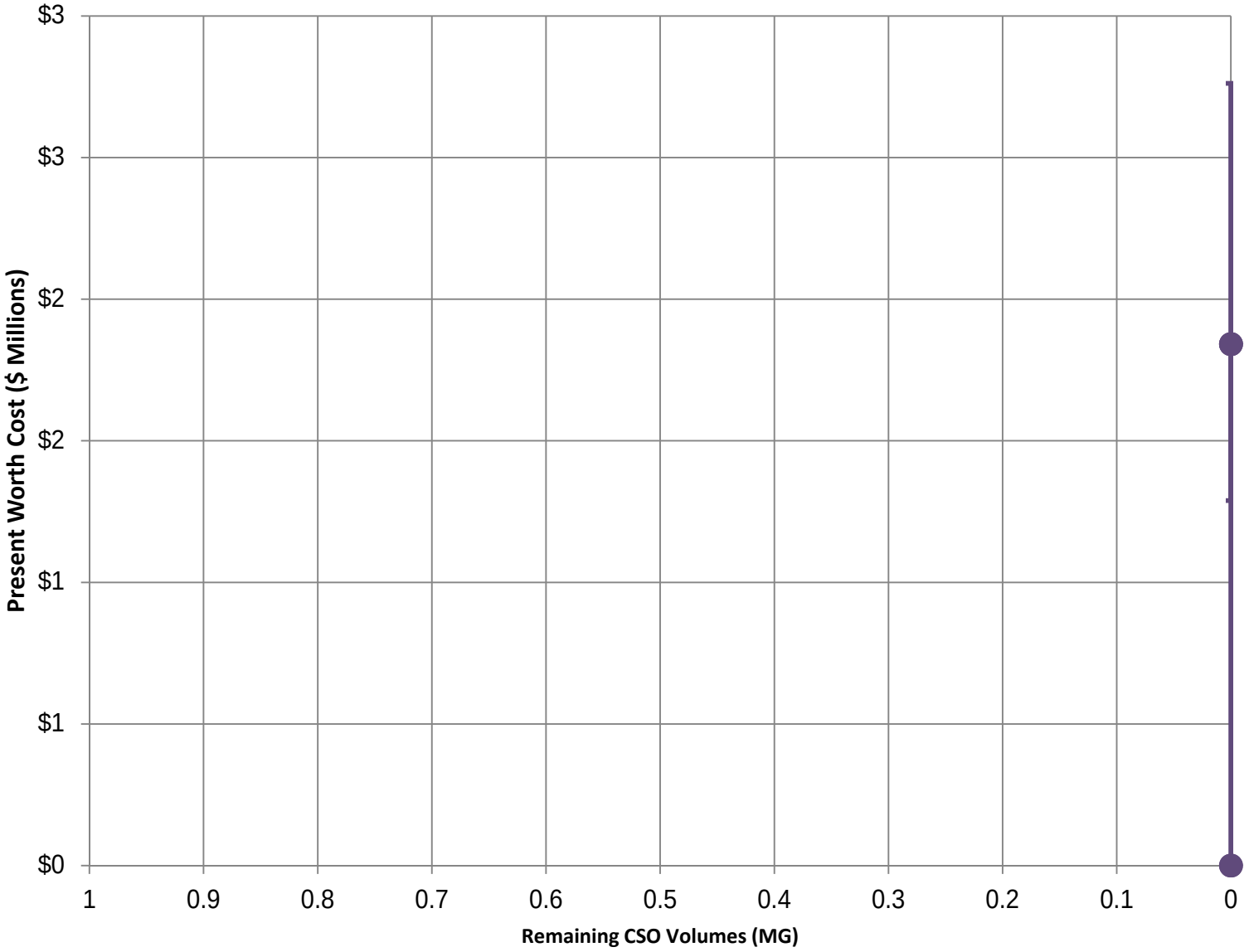


Figure K: Present Worth Costs vs. Remaining CSO Volumes for Cazenovia Creek (C)
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

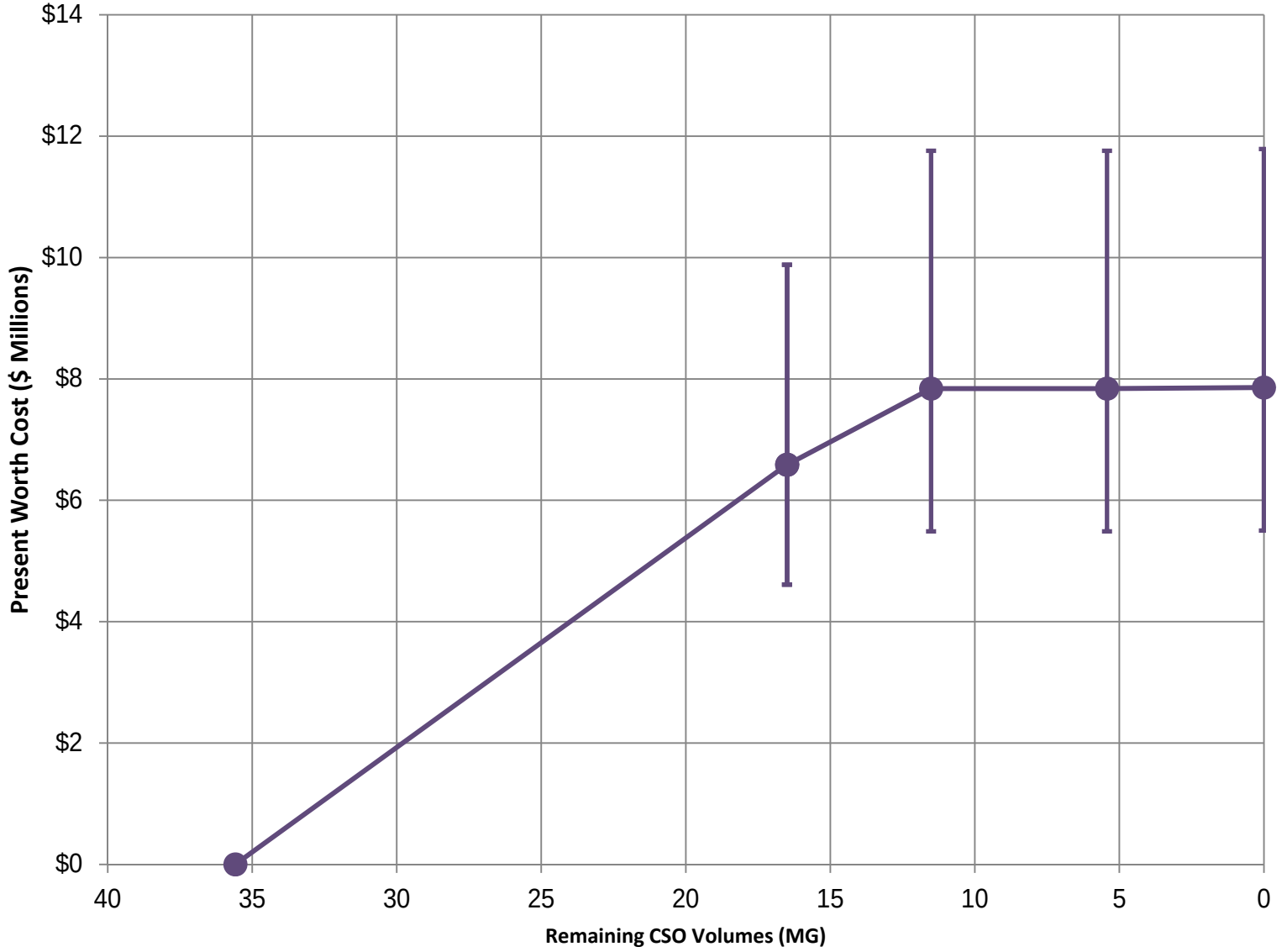


Figure L: Present Worth Costs vs. Remaining CSO Volumes for Niagara River and CSO-055
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

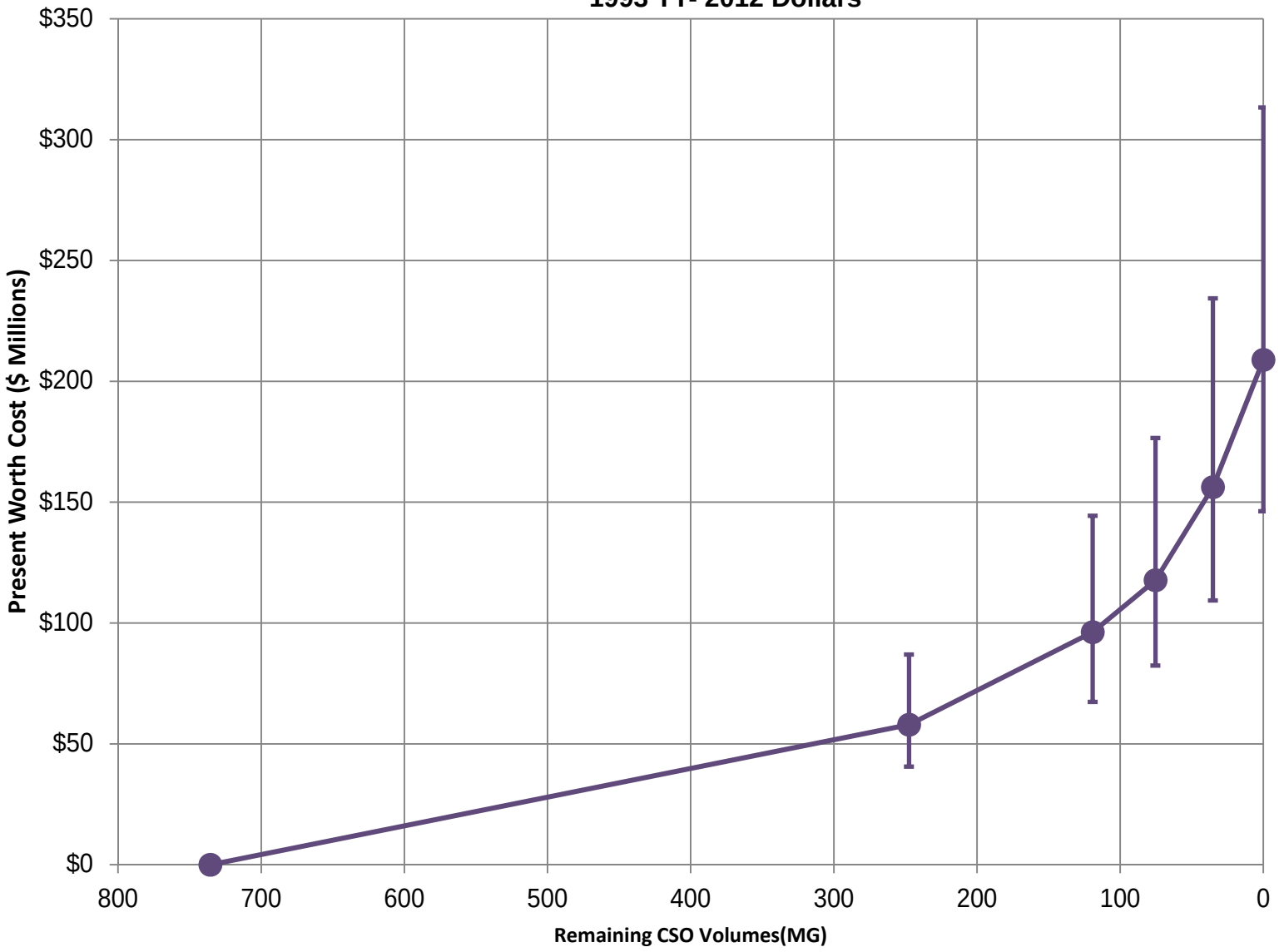


Figure M: Present Worth Costs vs. Remaining CSO Volumes for Erie Basin
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

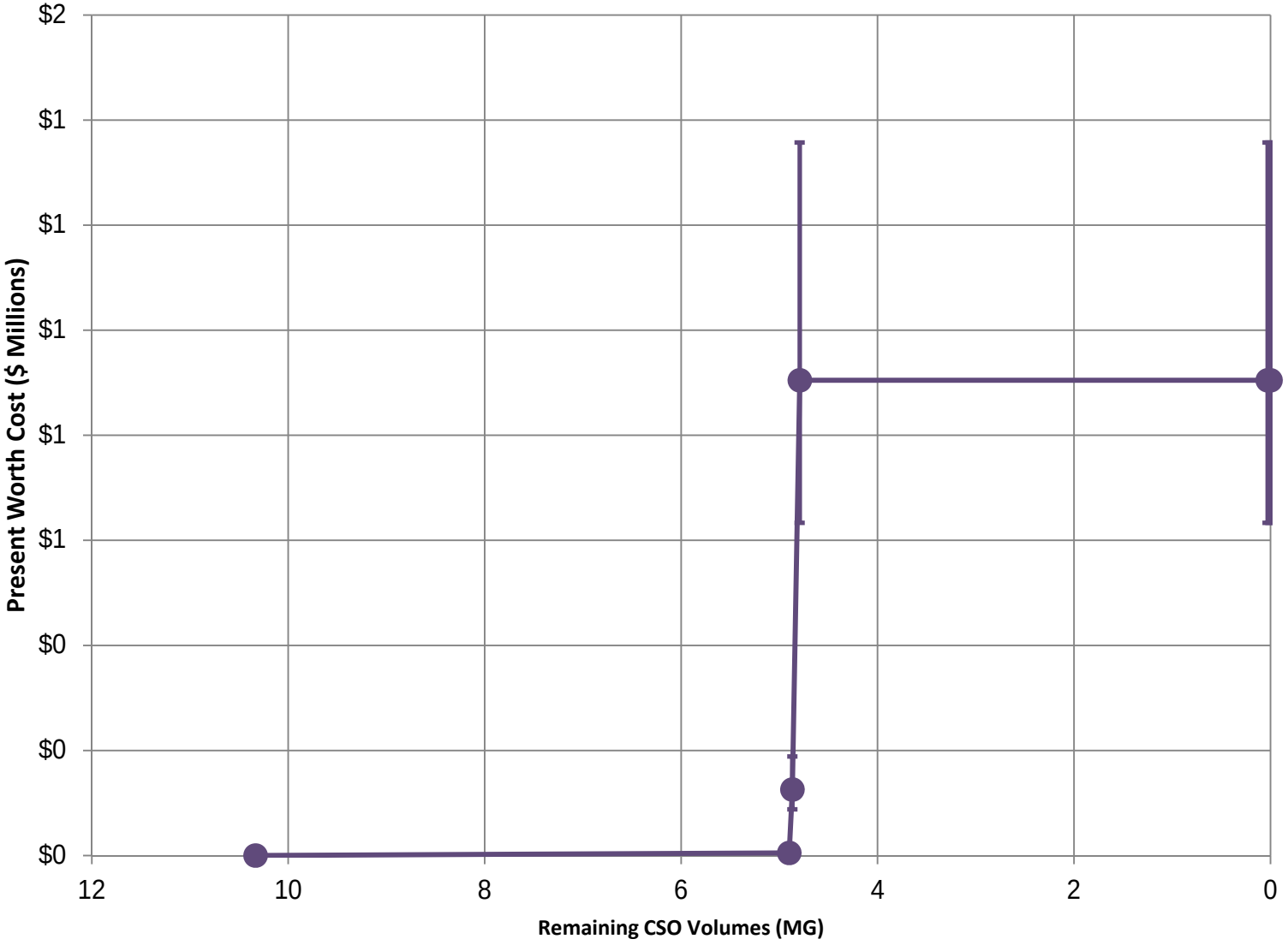


Figure N: Present Worth Costs vs. Remaining CSO Volumes for Scajaquada Creek
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

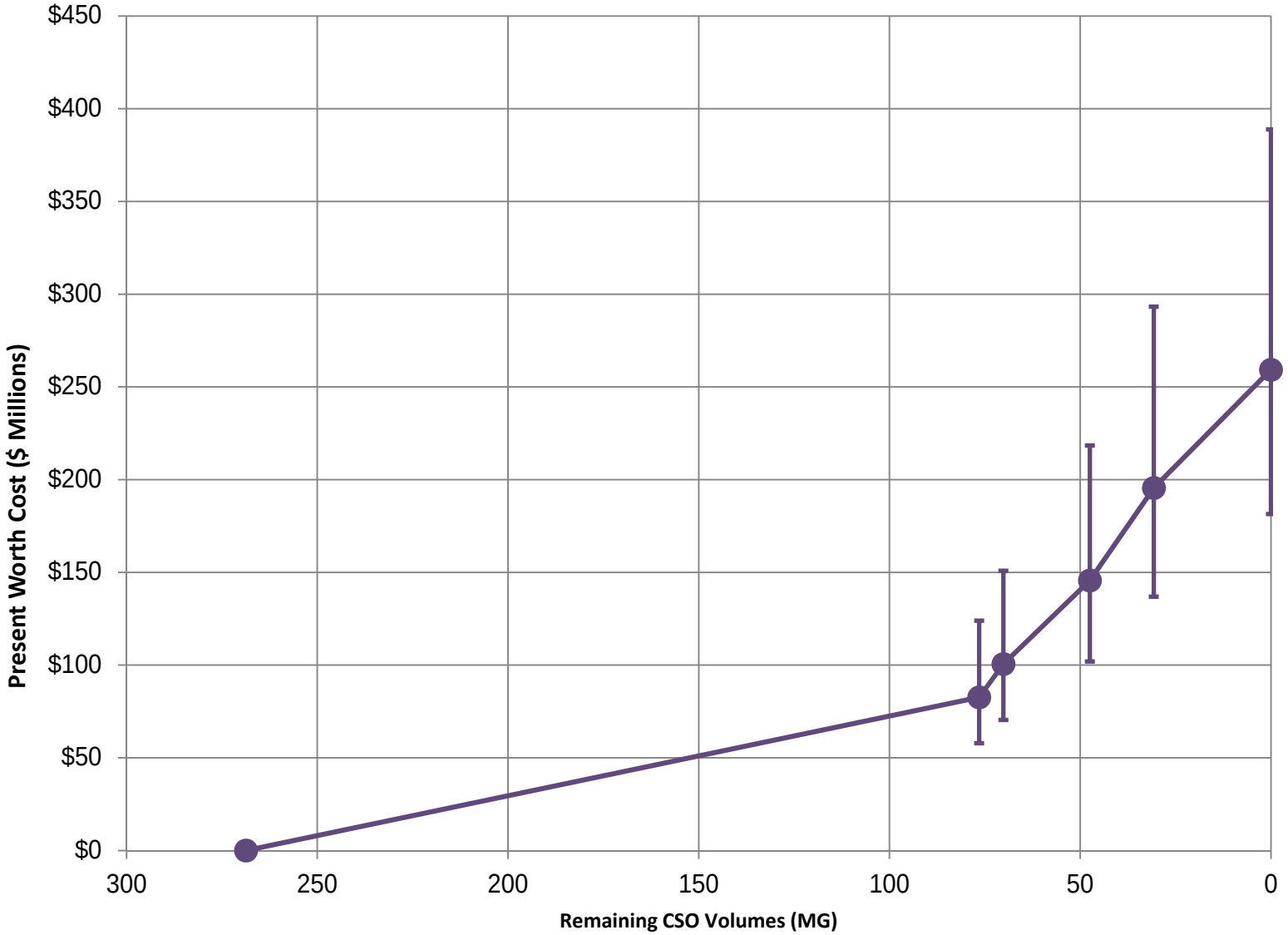


Figure O: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for System-wide Alternative UA3A 1993 TY- 2012 Dollars

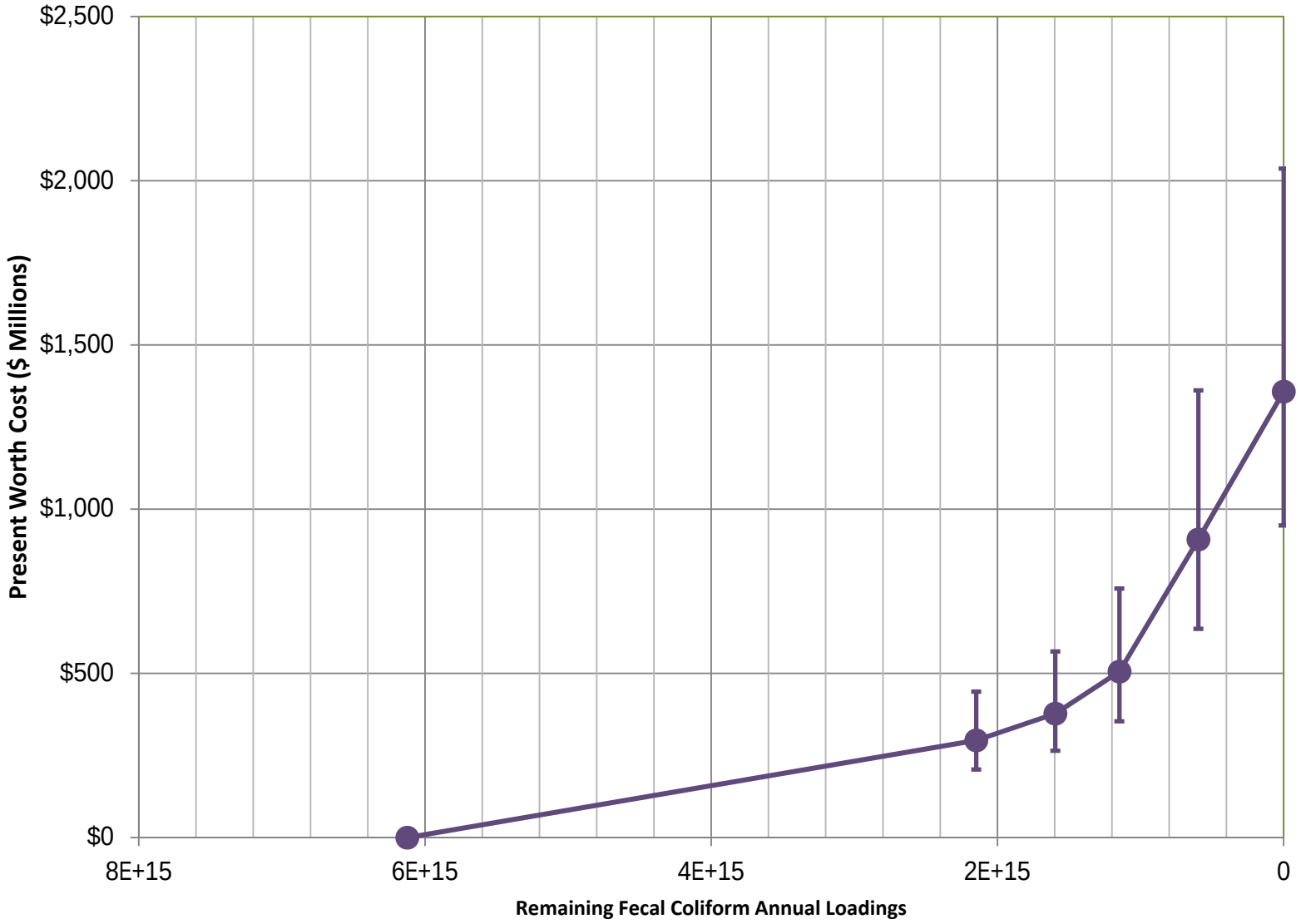


Figure P: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Black Rock Canal(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

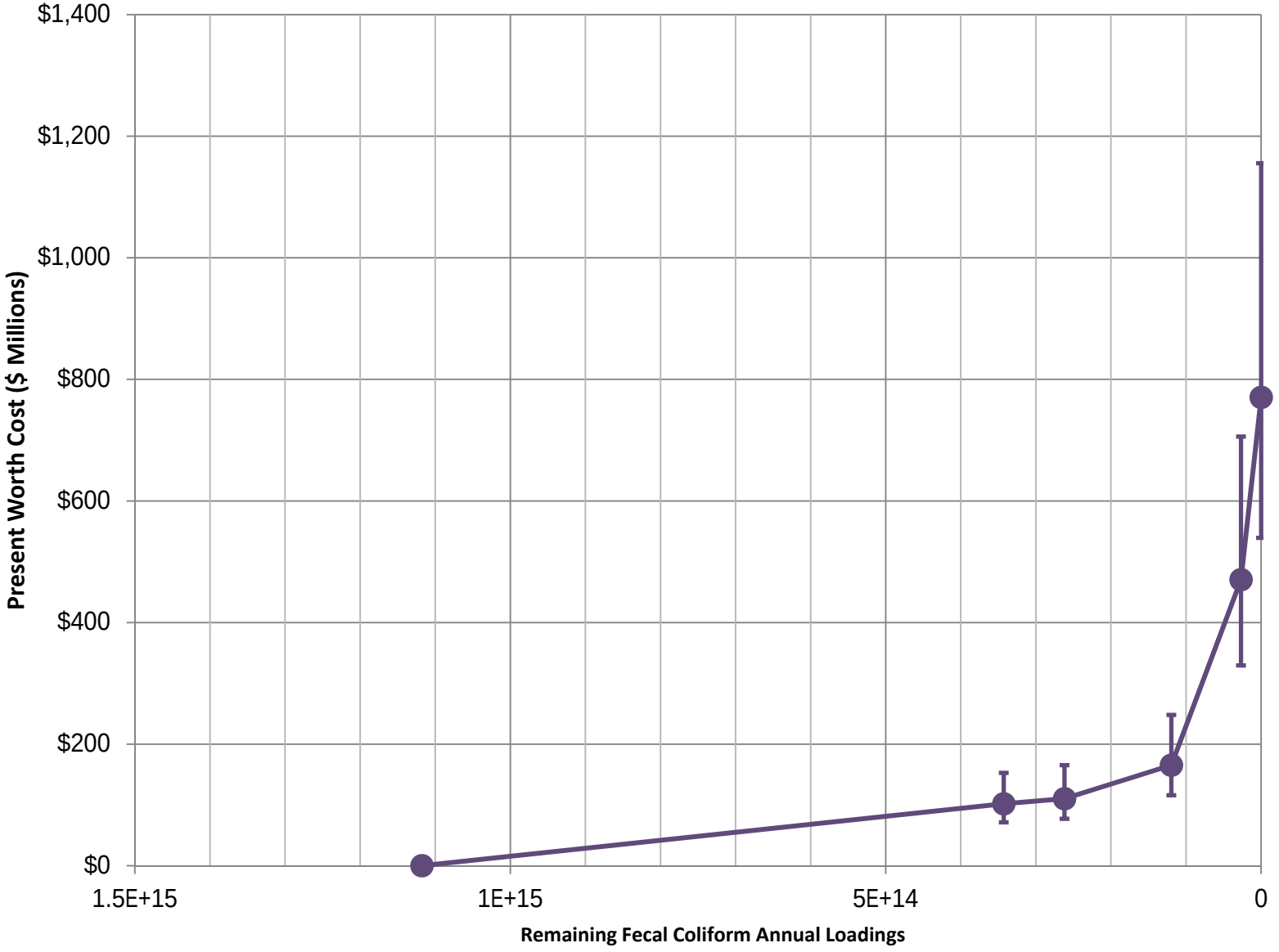


Figure Q: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Buffalo River(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

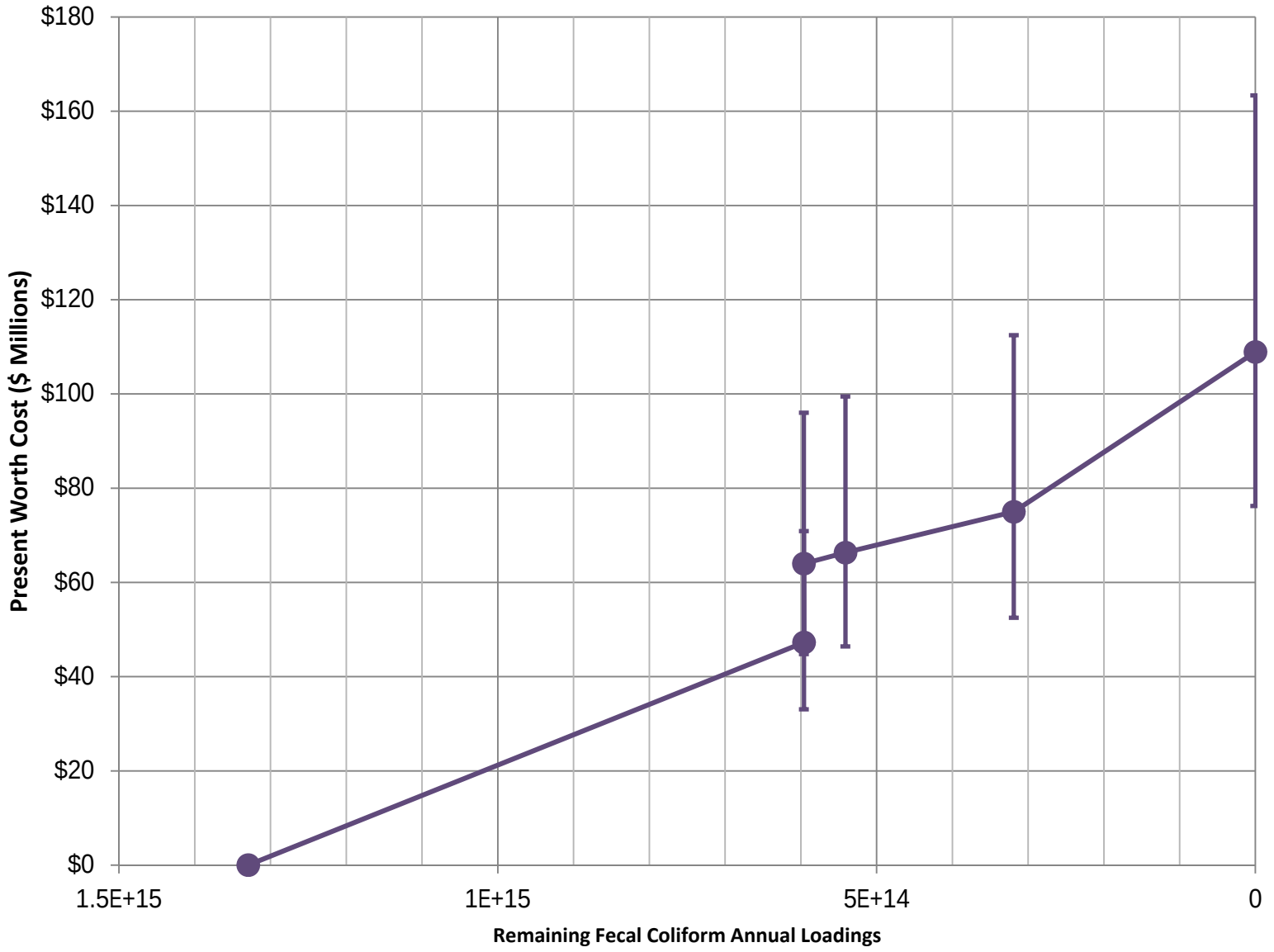


Figure R: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Cazenovia Creek (B)(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

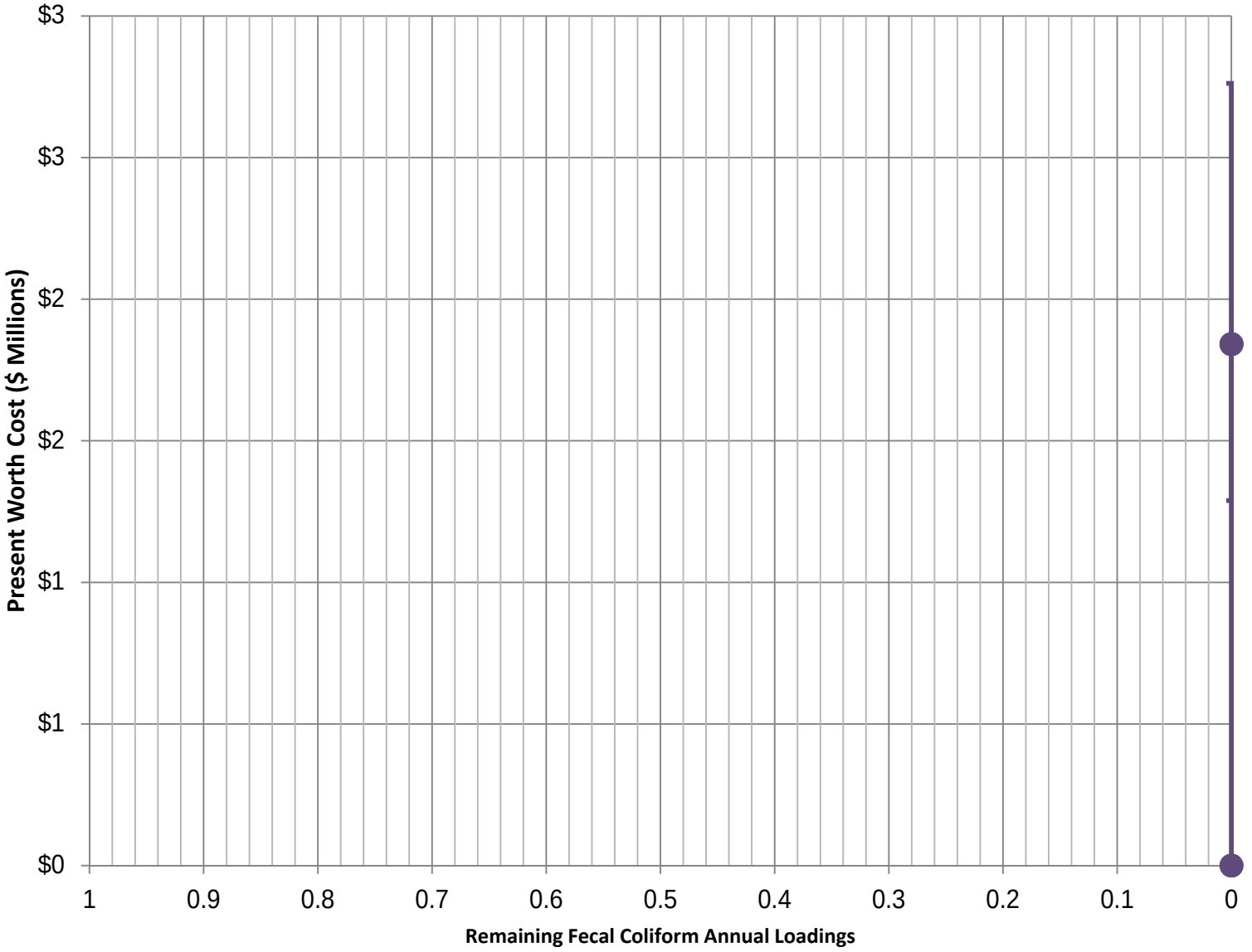


Figure S: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Cazenovia Creek (C)(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

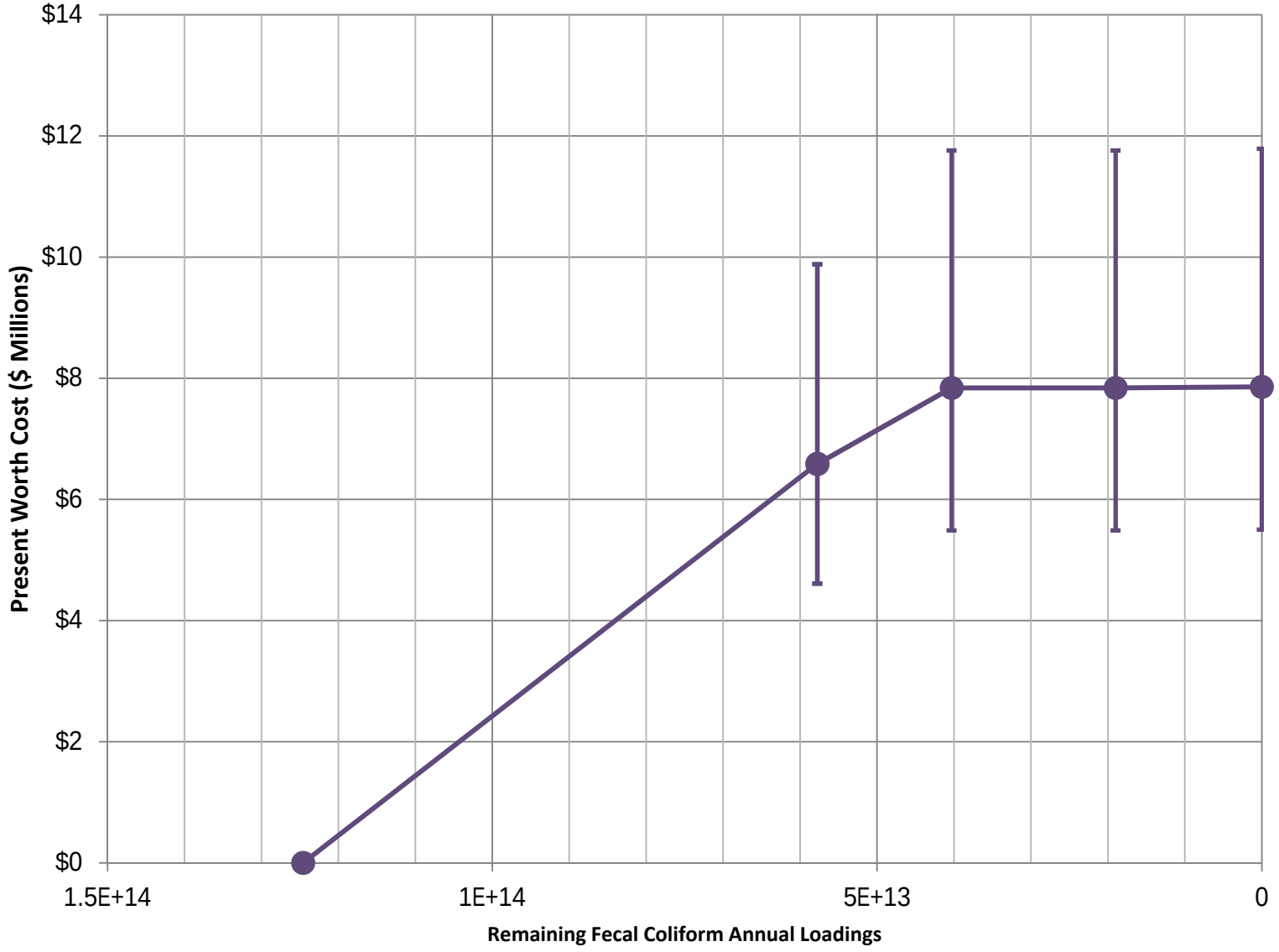


Figure T: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Niagara River and CSO-055 (System-wide Alternative UA3A)
1993 TY- 2012 Dollars (Includes O&M)

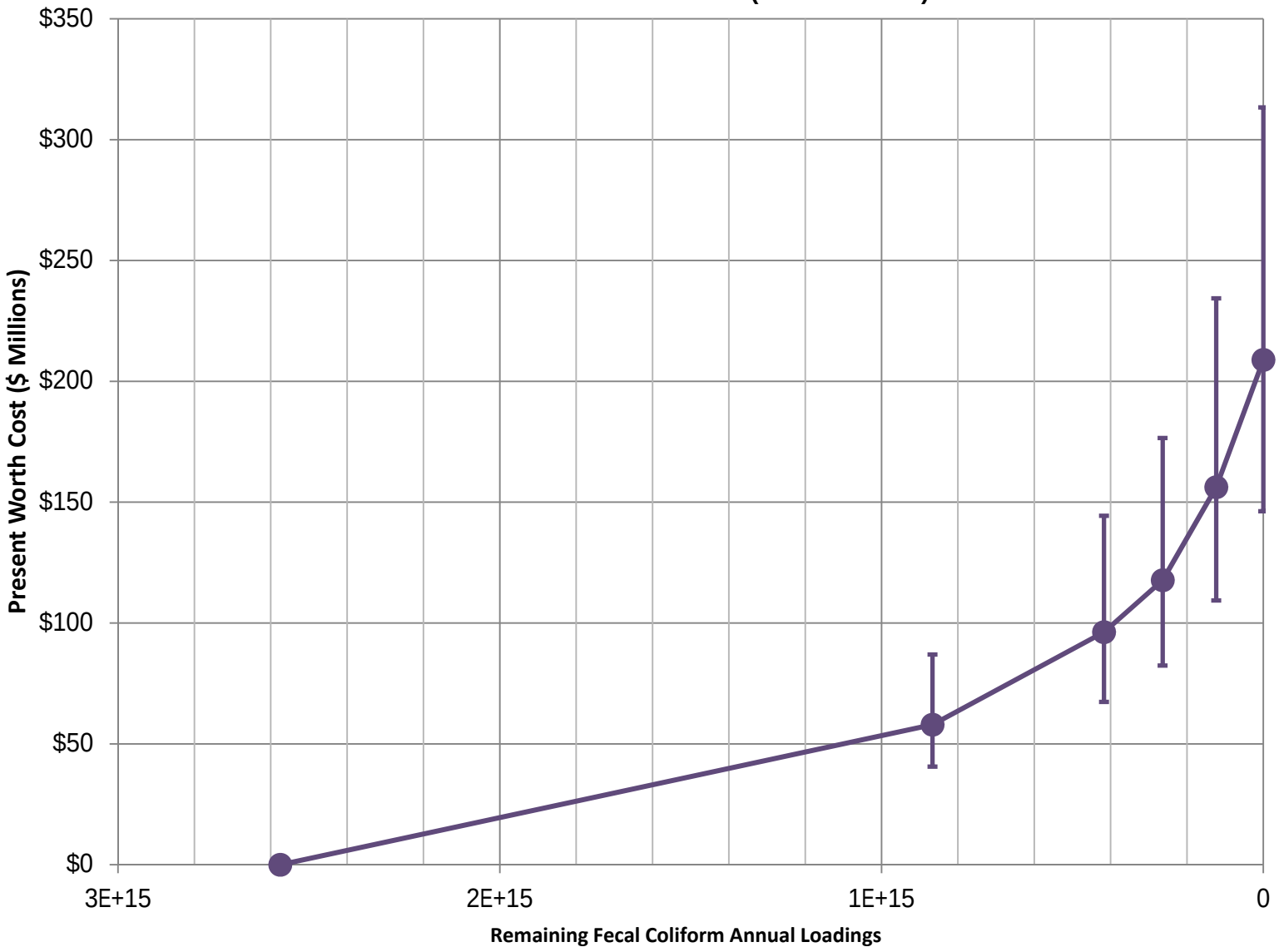


Figure U: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Erie Basin
(System-wide Alternative UA3A)
1993 TY- 2012 Dollars

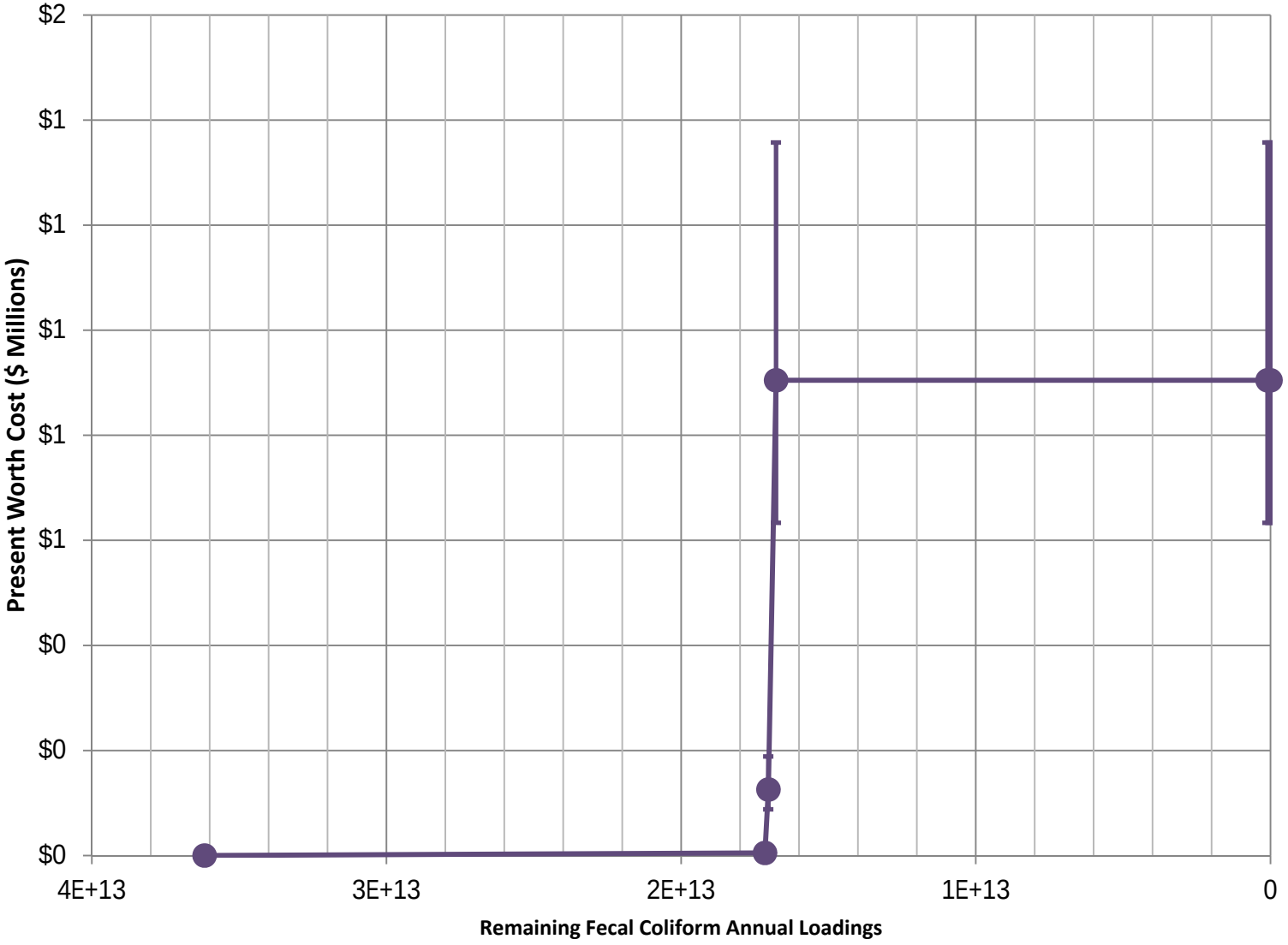
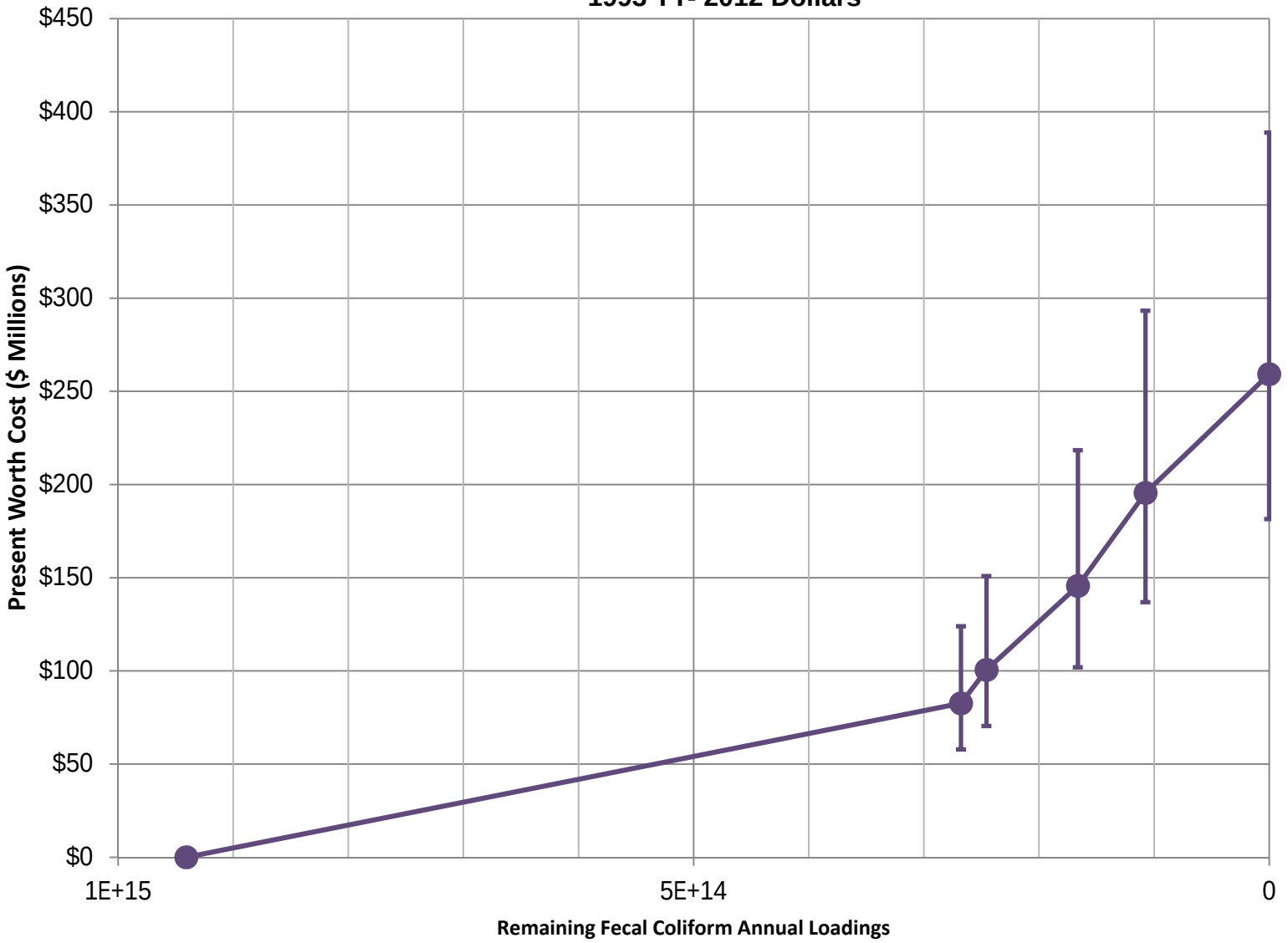


Figure V: Present Worth Costs vs. Remaining Fecal Coliform Annual Loadings for Scajaquada Creek (System-wide Alternative UA3A)
1993 TY- 2012 Dollars



Alternative UA3A Overflow Volume Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	Revised Baseline 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3a 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3a 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3a 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)	UA3a 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Volume (MG)
004	Scajaquada	Black Rock Canal	16.2	11.2	15.5	20.3	5.1	0.1
005	Scajaquada	Black Rock Canal	0.1	0.1	0.1	0.1	0.1	Closed
006	Scajaquada	Black Rock Canal	201.4	198.9	44.4	29.4	14.5	4.1
008	Scajaquada	Black Rock Canal	8.2	6.1	1.1	1.1	0.1	0.1
010	Scajaquada	Black Rock Canal	11.8	11.9	1.7	1.7	0.2	0.1
012	Albany	Black Rock Canal	52.0	52.5	10.5	13.5	6.6	0.3
013	South Central	Black Rock Canal	13.6	6.8	0.5	0.5	0.1	0.0
061	Scajaquada	Black Rock Canal	33.8	31.2	24.1	8.2	7.4	3.0
063	South Central	Black Rock Canal	1.5	0.6	0.0	0.0	0.0	0.0
017	South Central	Buffalo River	101.6	71.3	30.4	32.4	35.0	21.6
022	South Central	Buffalo River	42.7	29.8	0.5	0.5	0.3	0.0
025	South Central	Buffalo River	1.4	1.4	0.3	0.3	0.2	0.0
026	South Central	Buffalo River	146.5	124.2	26.5	26.7	27.2	21.4
027	South Central	Buffalo River	19.4	31.7	29.6	35.9	33.0	14.3
028	South Central	Buffalo River	44.4	45.5	28.8	29.6	20.4	10.1
029	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
032	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
033	South Central	Buffalo River	35.7	37.8	21.9	23.1	18.6	6.6
034	South Central	Buffalo River	0.1	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0.0	0.0	0.0	0.0	0.0	0.0
050	South Central	Buffalo River	4.1	3.2	1.1	1.1	0.8	0.3
051	South Central	Buffalo River	3.7	1.2	1.2	To Storage	To Storage	To Storage
052	South Central	Buffalo River	13.6	10.9	10.9	15.9	14.7	12.3
064	South Central	Buffalo River	27.2	21.1	4.8	4.8	4.5	4.5
066	South Central	Buffalo River	2.5	1.7	0.9	To Storage	To Storage	To Storage
035	South Central	Cazenovia Creek - B	4.8	0.9	1.2	1.2	0.8	0.1
037	South Central	Cazenovia Creek - C	21.2	23.3	12.9	12.9	9.3	4.6
039	South Central	Cazenovia Creek - C	0.0	0.0	0.0	0.0	0.0	0.0
044	South Central	Cazenovia Creek - C	6.5	2.3	0.8	0.8	0.4	0.0
046	South Central	Cazenovia Creek - C	1.1	1.3	0.0	0.0	0.0	0.0
047	South Central	Cazenovia Creek - C	10.4	8.7	2.7	2.7	1.8	0.8
048	South Central	Cazenovia Creek - C	1.5	0.0	0.0	0.0	0.0	0.0
055	Hertel	Cornelius Creek	613.6	601.1	222.0	103.5	65.3	30.9
014	South Central	Erie Basin	25.9	4.2	2.5	3.0	3.9	0.00
015	South Central	Erie Basin	5.7	6.1	1.8	1.9	0.9	0.03
016	South Central	Erie Basin	0.0	0.0	0.0	0.0	0.0	0.00
003	Parish	Niagara River	4.5	0.1	0.1	0.1	0.1	0.1
011	Albany	Niagara River	125.7	134.3	25.3	15.5	9.9	0.2
054	Ontario	Niagara River	0.1	0.0	0.0	0.0	0.0	0.0
053	Scajaquada	Scajaquada Creek	275.0	268.0	74.3	67.9	45.3	29.0
056	Hertel	Scajaquada Creek	0.0	0.0	0.0	0.0	To Storage	To Storage
057	Parish	Scajaquada Creek	0.3	0.0	0.0	0.0	0.0	0.0
058	Parish	Scajaquada Creek	0.0	0.2	0.2	0.2	0.2	0.2
059	Scajaquada	Scajaquada Creek	5.1	2.2	1.3	1.3	1.3	1.3
060	Scajaquada	Scajaquada Creek	2.9	0.7	0.7	0.7	0.6	0.3
Totals			1886	1752	601	457	329	166

Total CSO Combined Only Volume by District (MG)	Albany		177.7	186.8	35.9	29.0	16.5	0.5
	Hertel		613.7	601.1	222.0	103.6	65.3	30.9
	Ontario		0.1	0.0	0.0	0.0	0.0	0.0
	Parish		4.7	0.3	0.3	0.3	0.3	0.2
	Scajaquada		554.7	530.2	163.1	130.7	74.8	37.9
	South Central		535.2	434.0	179.3	193.3	171.7	96.7
Total CSO Combined Only Volume by Receiving Water (MG)		Black Rock Canal	338.7	319.3	97.9	74.8	34.1	7.6
		Buffalo River	442.9	379.7	156.9	170.2	154.6	91.1
		Cazenovia Creek - B	4.8	0.9	1.2	1.2	0.8	0.1
		Cazenovia Creek - C	40.7	35.6	16.4	16.5	11.5	5.4
		Cornelius Creek	613.6	601.1	222.0	103.5	65.3	30.9
		Erie Basin	31.6	10.3	4.3	4.9	4.8	0.03
		Niagara River	130.2	134.4	25.5	15.6	10.0	0.3
		Scajaquada Creek	283.4	271.0	76.5	70.1	47.5	30.7

Alternative UA3A Overflow Frequency Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3a 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3a 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3a 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency	UA3a 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Frequency
004	Scajaquada	Black Rock Canal	7	5	4	6	4	2
005	Scajaquada	Black Rock Canal	0	4	Closed	Closed	Closed	Closed
006	Scajaquada	Black Rock Canal	65	65	8	7	4	0
008	Scajaquada	Black Rock Canal	42	39	8	8	3	2
010	Scajaquada	Black Rock Canal	44	44	8	8	3	2
012	Albany	Black Rock Canal	42	42	5	7	4	1
013	South Central	Black Rock Canal	14	7	1	1	1	0
061	Scajaquada	Black Rock Canal	10	10	9	6	4	4
063	South Central	Black Rock Canal	50	13	1	1	0	0
017	South Central	Buffalo River	55	49	3	3	3	4
022	South Central	Buffalo River	55	49	3	3	2	1
025	South Central	Buffalo River	11	11	2	2	2	0
026	South Central	Buffalo River	61	63	3	3	3	2
027	South Central	Buffalo River	36	36	7	7	5	2
028	South Central	Buffalo River	69	69	6	6	4	3
029	South Central	Buffalo River	0	0	0	0	0	0
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	8	9	4	5	4	2
034	South Central	Buffalo River	5	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0	0	0	0	0	0
050	South Central	Buffalo River	22	14	4	4	2	2
051	South Central	Buffalo River	16	4	4	To Storage	To Storage	To Storage
052	South Central	Buffalo River	11	10	10	5	4	2
064	South Central	Buffalo River	55	56	2	2	2	0
066	South Central	Buffalo River	16	10	5	To Storage	To Storage	To Storage
035	South Central	Cazenovia Creek - B	29	5	3	3	2	2
037	South Central	Cazenovia Creek - C	14	13	6	6	5	2
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	15	7	2	2	2	0
046	South Central	Cazenovia Creek - C	9	1	0	0	0	0
047	South Central	Cazenovia Creek - C	47	44	5	5	3	2
048	South Central	Cazenovia Creek - C	12	0	0	0	0	0
055	Hertel	Cornelius Creek	40	41	10	6	4	3
014	South Central	Erie Basin	17	4	2	2	2	0
015	South Central	Erie Basin	12	12	4	4	2	2
016	South Central	Erie Basin	3	0	0	0	0	0
003	Parish	Niagara River	27	6	6	5	5	3
011	Albany	Niagara River	41	41	10	6	4	2
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	65	65	8	7	4	0
056	Hertel	Scajaquada Creek	5	5	5	5	To Storage	To Storage
057	Parish	Scajaquada Creek	11	0	0	0	0	0
058	Parish	Scajaquada Creek	2	7	7	7	7	7
059	Scajaquada	Scajaquada Creek	17	11	6	6	6	6
060	Scajaquada	Scajaquada Creek	11	5	5	5	5	3

Max Events	Albany		42	42	10	7	4	2
	Hertel		40	41	10	6	4	3
	Ontario		4	0	0	0	0	0
	Parish		27	7	7	7	7	7
	Scajaquada		65	65	8	7	7	7
	South Central		69	69	10	7	5	4
Max Events		Black Rock Canal	65	65	9	8	4	4
		Buffalo River	69	69	10	7	5	4
		Cazenovia Creek - B	29	5	3	3	2	2
		Cazenovia Creek - C	47	44	6	6	5	2
		Cornelius Creek	40	41	10	6	4	3
		Erie Basin	17	12	4	4	2	2
		Niagara River	41	41	10	6	5	3
		Scajaquada Creek	65	65	8	7	7	7

Alternative UA3A Overflow Duration Results for Each CSO

CSO Outfall	District	Receiving Water	2004 Existing Conditions (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	Revised Baseline 1993 Modified(CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3a 12OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3a 6OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3a 4OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)	UA3a 2OF 1993 Modified (CSO Only - Excluding Storm & Creek Flow) Overflow Duration (hours)
004	Scajaquada	Black Rock Canal	12	8	9	14	7	2
005	Scajaquada	Black Rock Canal	5	5	Closed	Closed	Closed	Closed
006	Scajaquada	Black Rock Canal	322	344	71	66	42	0
008	Scajaquada	Black Rock Canal	105	90	11	11	3	2
010	Scajaquada	Black Rock Canal	103	103	11	11	3	2
012	Albany	Black Rock Canal	111	111	13	15	11	1
013	South Central	Black Rock Canal	58	25	8	8	8	0
061	Scajaquada	Black Rock Canal	31	29	26	17	15	9
063	South Central	Black Rock Canal	110	19	2	2	0	0
017	South Central	Buffalo River	166	124	38	36	29	23
022	South Central	Buffalo River	166	124	13	13	9	2
025	South Central	Buffalo River	17	17	17	17	15	0
026	South Central	Buffalo River	232	247	18	17	17	13
027	South Central	Buffalo River	127	131	48	46	36	16
028	South Central	Buffalo River	328	328	57	57	43	19
029	South Central	Buffalo River	0	0	0	0	0	0
032	South Central	Buffalo River	0	0	0	0	0	0
033	South Central	Buffalo River	20	21	38	36	31	15
034	South Central	Buffalo River	8	Closed	Closed	Closed	Closed	Closed
049	South Central	Buffalo River	0	0	0	0	0	0
050	South Central	Buffalo River	47	22	16	16	11	8
051	South Central	Buffalo River	56	14	14	To Storage	To Storage	To Storage
052	South Central	Buffalo River	112	70	70	103	85	62
064	South Central	Buffalo River	166	181	29	22	10	0
066	South Central	Buffalo River	26	17	11	To Storage	To Storage	To Storage
035	South Central	Cazenovia Creek - B	55	9	22	22	17	7
037	South Central	Cazenovia Creek - C	42	40	15	15	13	7
039	South Central	Cazenovia Creek - C	2	0	0	0	0	0
044	South Central	Cazenovia Creek - C	37	12	5	5	3	0
046	South Central	Cazenovia Creek - C	37	1	0	0	0	0
047	South Central	Cazenovia Creek - C	108	94	11	11	8	4
048	South Central	Cazenovia Creek - C	42	0	0	0	0	0
055	Hertel	Cornelius Creek	184	174	78	37	24	16
014	South Central	Erie Basin	61	15	16	16	18	0
015	South Central	Erie Basin	43	43	16	16	10	4
016	South Central	Erie Basin	4	0	0	0	0	0
003	Parish	Niagara River	224	32	34	33	33	18
011	Albany	Niagara River	240	243	36	21	15	2
054	Ontario	Niagara River	4	0	0	0	0	0
053	Scajaquada	Scajaquada Creek	322	344	71	66	42	0
056	Hertel	Scajaquada Creek	8	8	8	8	To Storage	To Storage
057	Parish	Scajaquada Creek	15	0	0	0	0	0
058	Parish	Scajaquada Creek	2	10	10	10	10	10
059	Scajaquada	Scajaquada Creek	45	26	20	20	20	20
060	Scajaquada	Scajaquada Creek	25	11	11	11	11	5

Appendix 11-7: Real Time Control Feasibility Reports

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Buffalo Sewer Authority
Real Time Control Evaluation for Sewer System

FINAL REPORT MARCH 20TH, 2011

PREPARED BY EMNET, LLC

INTRODUCTION

Buffalo Sewer Authority is interested in evaluating the benefits and costs associated with the utilization of Real Time Control (RTC) in its collection system. The objective of RTC technologies is to maximize the utilization of a collection system's storage and conveyance capacities to reduce its combined sewer overflows (CSOs), street and basement flooding, and inflow peaks to the wastewater treatment plant. By using RTC with control structures (gates, pumps, and valves) in the collection system, these benefits can be achieved for a fraction of the costs of other traditional technologies.

Spatial and temporal variations in precipitation, coupled with diverse land permeability and long sewer travel times, enables the RTC to utilize this potential by dynamically storing and controlling flows at key locations. The function of the RTC system is essentially to match the wastewater treatment facility wet weather capacity before CSOs occur. RTC takes advantage of the time and space between rainfall events and across the system to smooth operations, reducing overflows, surcharging, and flooding. In-line and off-line storage assets can be used to equalize and dampen peak flows to allow downstream conveyance assets to transport water to the treatment facility while reducing CSOs. Similarly, conveyance optimization is achieved by ensuring conveyance assets are fully utilized before CSOs occur upstream.

KEYS ELEMENTS OF RTC

Implementing a successful RTC program requires more than gates, valves, and programming. A successful RTC program is built on a sound and transparent RTC strategy based on actual conditions in the field, opportunities in the future, and a practical understanding of what is achievable. A well founded RTC strategy provides the roadmap for an integration process that will take place over several years, as capital projects bring necessary facilities and controls on line. The following is a list some of the key elements for a successful and meaningful RTC evaluation:

- **Access through open source/open architecture design:** EmNet utilizes EPA SWMM compatible models to generate RTC optimization strategies. This means that the optimal RTC strategy is always delivered as a working model. Extensive research into the factors that contribute to the long term success of RTC projects have demonstrated that

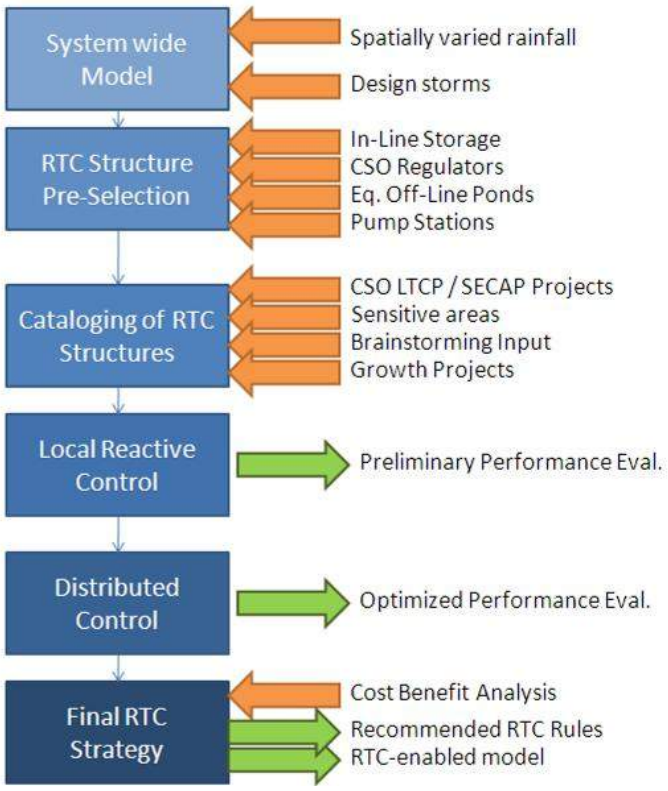
open source/open architecture approaches are more robust and are easier and less expensive to implement that “black box” proprietary approaches.

- **Verifiability through a delivered model:** As a standard deliverable, EmNet will provide back to the Client the EPA SWMM compatible model used to generate RTC optimization strategies. Because the optimal RTC strategy is always delivered as a working model, the Client can verify the operation of the RTC under conditions different that those considered during the original RTC evaluation such as different storm scenarios, recalibrated models, and new structures. Verification can be done in terms of CSO volume reductions, surcharge levels, hydraulic operation of RTC structures, etc.
- **Low implementation and maintenance costs:** Given that the RTC rules are delivered as part of a working model, the rules can be implemented by third party system integrators using standard SCADA solutions. With EmNet’s RTC system, there is no need to use proprietary software or hardware to implement the RTC rules.
- **Meaningful evaluation through collaboration:** A meaningful optimization evaluation can only be achieved with the active participation of the engineering and operators staff. Information such as system growth projection, consent decree objectives, pipe structural integrity, seasonal flooding, and chronic basement backup areas are not always well captured in the hydraulic model.
- **Robustness through the use of distributed control technology:** EmNet’s distributed control approach to RTC relies on collection system monitoring as opposed to weather forecast predictions. Traditional approaches to RTC, such as global predictive optimization, rely heavily on precipitation forecasts up to 6 hours in the future to predict flows in the collection system, leading to proportionately large inaccuracies. The EmNet distributed control system approach relies on measured upstream and downstream flow conditions and an understanding of travel time to determine future flow conditions at the control locations when making control decisions.
- **Transparent RTC operation:** The experience of long time users of RTC systems illustrates that the transparency and easy understanding of the inner works of the RTC system are essential for long term operation. Collection system managers need to understand the RTC rules to be able to trust the system and ultimately manage it optimally. Experience shows that operators tend to disengage the automatic operation of RTC when the rules of the RTC are not explicit or cannot be understood. EmNet’s collaborative approach is to ensure that all stakeholders are involved in the design process.

THE RTC OPTIMIZATION PROCESS

Typically, static structures, like weirs and high overflow pipes, direct flows between a normal flow path to the WWTP and a high flow path to CSO, but the existence of large structures that are underutilized during storm events presents opportunities for RTC. EmNet's RTC process starts by organizing the objectives of the RTC system. The Client's stated objectives are:

1. Maximization of the collection system and wastewater treatment infrastructure utilization throughout a wet weather event. That means to maximize conveyance in water transport assets, maximize storage in ponds, and maximize flows to the WWTP.
2. Minimization of the activation frequency and volume of combined sewer.
3. Enhancement of the operation and maintenance of the collection system, such as minimizing grit deposition, isolating and protecting sensitive areas, and providing information on flow conditions.



These objectives are subject to the following constraints:

1. Maintain surcharge levels below basement elevations (10 ft of freeboard to the surface).
2. Avoid surface flooding due to capacity limitations.
3. Meet the terms and conditions of the Consent Decree.
4. Is cost-effective to implement, operate, and maintain.

EmNet's approach to RTC follows a simple, but detailed, interactive methodology to ensure that all objectives are obtained within the required constraints. Its RTC process utilizes a six step process.

A. **Selection of relevant storms and use of the calibrated hydraulic model.** In this step, the most recently updated and calibrated model is used in combination with selected spatially varied rainfall information. RTC tends to take advantage of spatially and temporally distributed events. At the same time, for regulatory purposes, design storms that tend to be uniformly distributed are typically utilized. EmNet typically uses a number of relevant storms of different intensities and distributions for both practical purposes and

for regulatory reporting. Historic rainfall data from the City's rainfall network is an excellent resource for this step.

B. **Selection of available structures for RTC**. Next, structures that can be dynamically controlled are identified. Existing and planned off-line storage facilities, such as the East Amherst Quarry, fall in this category and are easily cataloged. In-line storage areas are typically identified according to some basic criteria. For example, pipes that have diameters larger than 5ft, a slope of less than 0.015, and have more than 50% of empty wet weather capacity during the peak of the provided storms are selected for consideration. The interceptors and the large trunk sewers will be reviewed for in-line storage opportunities. For improved optimized CSO management, CSO regulators that activate before the downstream lines are surcharged are selected as possible candidates for RTC. The figure below shows some of the existing and planned facilities that may be considered as part of the RTC evaluation.

C. **Cataloging of selected RTC structures.** This step is needed to further filter the selection of RTC sites. Flooding and regulatory constraints are considered here (constraints a-c). Information from engineering staff is very useful here. A brainstorming workshop, is used to capture the wealth of knowledge. Each RTC site is evaluated to determine:

   a. Potential excess storage ability (in-line and off-line assets)
   b. Potential excess conveyance ability (improved conveyance assets)
   c. Maximum surcharge level (in-line and off line assets)
   d. Peak dry weather and wet weather flows (in line assets)
   e. Structural integrity (in line assets)
   f. Nearby sensitive areas
   g. Anecdotal information from sewer crews

D. **Implementation of local reactive control system.** The hydraulic model is outfitted with structures that provide the RTC functionality. Typically, an orifice, which represents a valve, or pump is used to control the flows. In a local reactive mode, each RTC structure is independent from each other (i.e. there is no coordination between the structures). In this step, each control structure is instructed to convey a maximum equivalent to the dry weather flow and store the rest until capacity is reached. When the storage capacity has been reached, the assets will convey any inflows as if there was no RTC system. This is the simplest, most inexpensive form of RTC. While it usually does not maximize the asset utilization, it is useful to evaluate the potential of the RTC site.

E. **Implementation of distributed control scheme.** This step is aimed at satisfying objectives 1 and 2. In a distributed control scheme, each RTC site is given rules that depend on flows and levels upstream and downstream from the RTC site. The main objective of these rules is to provide a time and rate for storage or dewatering of each asset. For example, the storage and dewatering of an in-line storage asset may affect a CSO regulator downstream. The objective of the in-line storage rule is to match the available capacity of the regulator. This provides the flow rate for the in-line site. The

travel time between the in-line storage site and the regulator might be considerable. In this case, the flow rate calculated for the in-line storage location must be predicted. This prediction is based on all flows upstream from the CSO regulator.

F. **Final selection of RTC sites and cost benefit analysis.** Using the provided storm events, each RTC site is evaluated for its ability to reduce CSO volumes and frequencies. It is customary to perform the cost benefit analysis by comparing the RTC implementation cost versus the cost of providing additional storage or conveyance for the difference in CSO volumes. Locations with a cost benefit ratio of more than 66% are typically considered for implementation. This standard step satisfies the cost effectiveness constraint.

ACTIVITIES PERFORMED

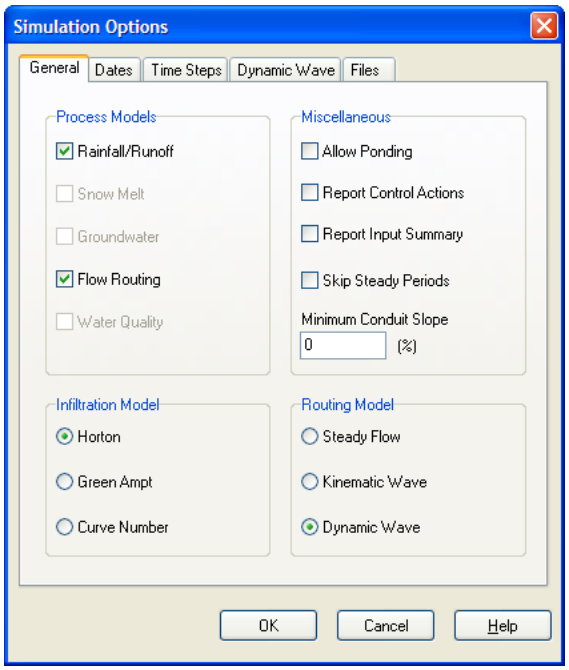
EmNet is in the process of evaluating Buffalo Sewer Authority's Collection System following the steps previously mentioned. Due to the constraints in the maximum number of hours allocated for this project, great emphasis has been given to providing the Client with tangible results that may prompt a follow up to determine details of implementation and fine tuning of the RTC strategy.

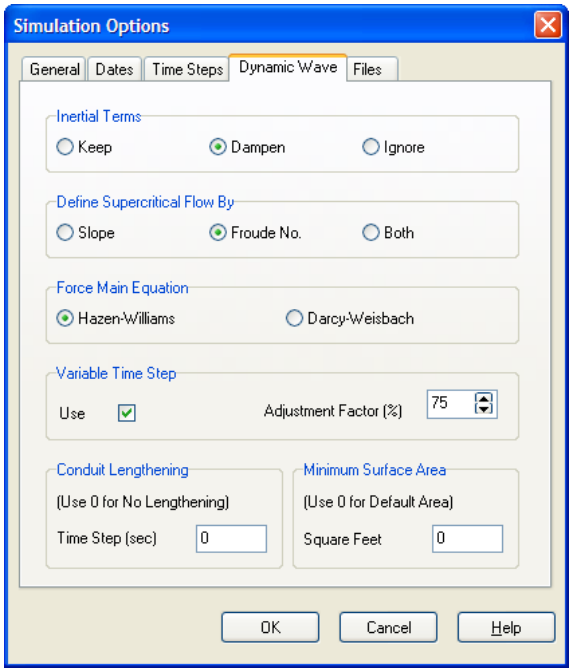
The work performed by EmNet is summarized next:

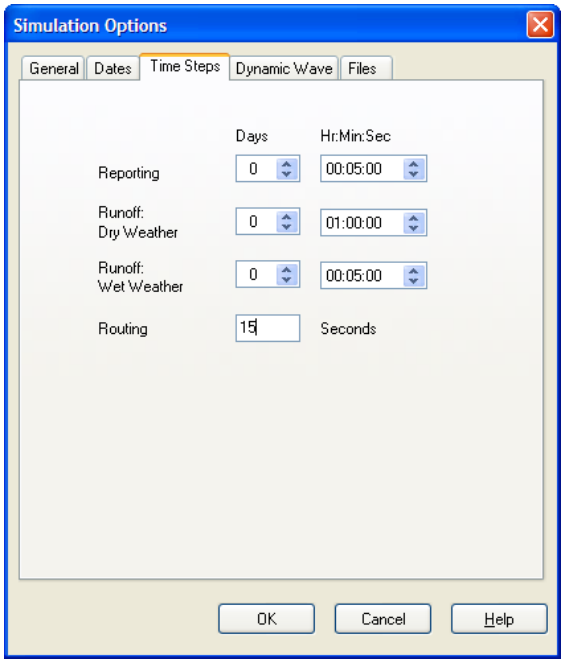
1. **Model preparation.**

   EmNet was provided with the full XP SWMM model of BSA's sewer network. While XP SWMM is a powerful tool for hydraulic and hydrologic simulation and modeling, it is unable to integrate the sophisticated RTC strategies that are required for Distributed Control. EmNet has open source add-ons that can be incorporated with open architecture tools such as EPA SWMM. To perform this RTC study the XP SWMM model was translated into EPA SWMM. The EPA SWMM representing BSA's system has not been simplified, skeletonized, or linearized. Currently the model contains 3430 junction nodes, 3384 conduit links, 1044 subcatchments, and 12 rain gauges.

   While this project does not contemplate further calibration of the model, the EPA SWMM model is able to track the performance of XP SWMM model closely. For the initial run, a 6 month 6 hour design storm was used. In this run, the peak flows (both major and minor peaks) and the time to peak were compared at 12 locations along the interceptors and major trunklines. The peak flows were typically within 3% of those seen in the XP model, with the largest difference being 6%. The time to peak was typically within 15 minutes of those seen in the XP model, with the largest difference being 20 minutes. Based on this comparison, it was determined that the parameters used for the EPA SWMM hydraulic simulation engine were appropriate. The following parameters have been used for the simulation:

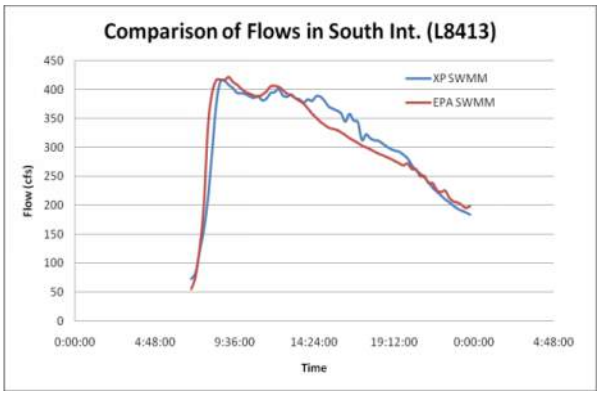




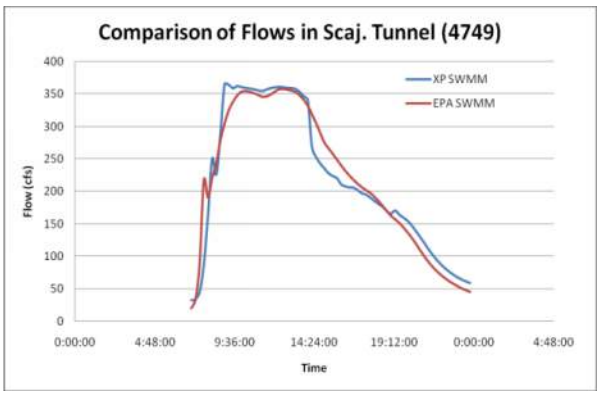


Further verification of the model was obtained by running the typical year in the EPA SWMM and comparing the overflow volumes to those provided by Malcolm Pirnie. A difference in total overflow volume of 3.7% was observed between the models. Differences at each outfall location can be explained through differences between the two simulation engines. This effect can be seen in the BSA system because the interceptors become surcharged so quickly. For example, in one model, one SPP may be able to send its peak flow into the interceptor just before a neighboring SPP

can, causing the neighboring SPP to overflow more water. In the other model, the use of a slightly different, but equally valid, numerical method may result in the opposite happening. When the CSOs are grouped regionally or globally, these differences are minimized. For the purposes of this study, the difference was considered acceptable. Further calibration can be done in subsequent work to lower the difference between the models to provide better tracking. Alternatively, a simplified version of the final RTC algorithms can be implemented in the existing XP SWMM for a direct performance evaluation.



(a)



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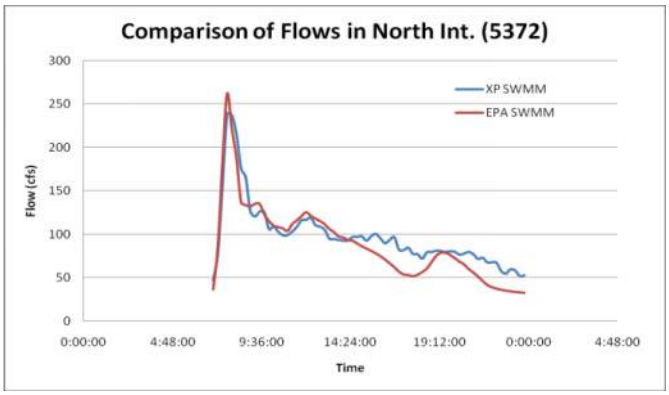


(c)

Comparison of XP SWMM and EPA SWMM for the 6 month, 6 hour design storm

The following table summarizes the results obtained from comparing the original XP SWMM and the EPA SWMM models:

CSO Outfall	Annual OF Volume XP SWMM (MG)	Annual OF Volume EPA SWMM (MG)
001a	0.0	0.0
003	4.4	3.7
004	44.8	26.9
006	526.2	454
008	10.0	12.5
010	13.2	44.4
011	162.1	85.7
012	152.8	128.2
013	25.2	20.4
014	18.8	17.9
015	35.3	116
016	10.4	63
017	315.1	221.9
022	25.2	28.8
025	8.1	6.3
026	340.4	570.5
027	75.0	58.7
028	152.4	134.7
029	1.2	1.2
032	0.0	0
033	90.8	97.3
034	Closed	0
035	23.6	29.4
037	55.5	29.9
039	0.0	0
044	8.3	6
046	2.3	8
047	11.9	11.6
048	0.0	0.1
049	0.1	0
050	8.4	5.6
051	5.0	4.5
052	25.5	15.4
053	456.0	162
054	26.3	29.7
055	949.3	967.5
056	1.6	1.4
057	0.1	0.6
058	12.8	16.3
059	2.2	3.7
060	0.8	0.9

061	65.5	56.7
063	1.8	1.2
064	25.3	110.6
066	123.3	123.9
TOTAL	**3816.8**	**3677.1**

2. Selection of Candidate Structures for RTC.

Structures amenable in BSA for RTC can be classified as follows:

a. Off-Line storage locations: Large, temporary containment areas, such as East Amherst Quarry.

b. In-Line storage locations: Large diameter pipes with excess capacity available during severe storm events

c. CSO discharge line storage: Large diameter pipes used for CSO discharge where overflows can be contained before they reach the environment and bled back into the collection system.

The following structures were identified during this step:

Name	Classification
East Amherst Quarry	Off-Line Storage
North Bailey	In-Line Storage
South Bailey	In-Line Storage
Key	In-Line Storage
Floss	In-Line Storage
Roslyn	In-Line Storage
Hertel North East Line	In-Line Storage
Hertel North West Line	In-Line Storage
Hertel South Line	In-Line Storage
Bird East	In-Line Storage
Bird West	In-Line Storage
Fillmore North	In-Line Storage
Fillmore South	In-Line Storage
Genesee	In-Line Storage
Michigan	In-Line Storage
Gibson	CSO Line Storage
Montgomery	CSO Line Storage
Smith	CSO Line Storage
Louisiana	CSO Line Storage

In-line storage and CSO discharge line storage locations where classified according to the following criteria:

- Minimum pipe diameter of 5 feet
- Maximum pipe slope of 0.015
- Maximum peak level during wet weather (as evaluated during the 6 month 6 hour storm) of 50% of the pipe diameter.
- Minimum pipe length of 1500 feet

Additional considerations used during the selection of in line storage locations included:

- The ground elevation across the usable portion of the structure must be such that it allows the hydraulic grade line to extend from upstream to downstream without danger of surface flooding, especially close to the control point.
- The location of the control point must be such that it maximizes the potential utilization of the asset. This can be done by effectively comparing the ground elevation near the downstream portion of the pipe.
- Connecting structures such as weirs must also be taken into consideration. To avoid causing an increase on overflow in other parts of the system, the surcharge level must be below diversion structures that may create additional overflows or uncontrolled flows.
- For CSO discharge line storage locations, infiltration must be minimal, especially for pipes located below the high tide elevation or the water table.

3. Cataloging of RTC Structures.

Each structure identified in the previous step was evaluated to determine the following:

- Cross Section Area
- Usable Length
- Potential storage capabilities
- Maximum surcharge limiting factor

The following represents the identified RTC Structures:

East Amherst Quarry Storage

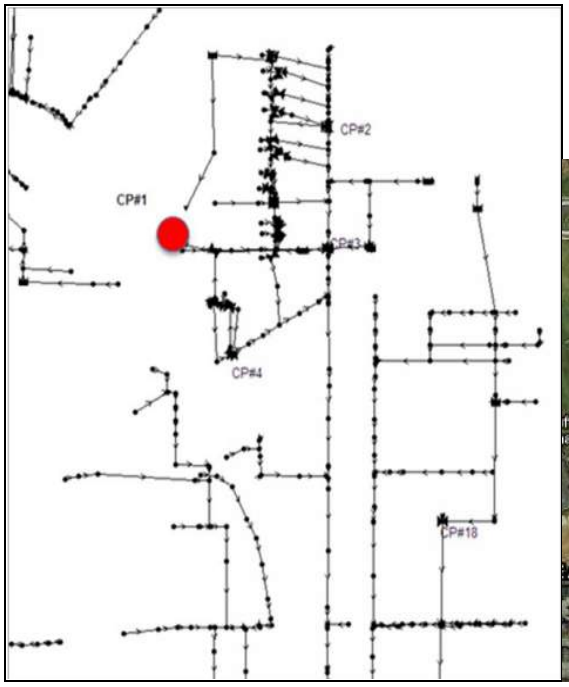
Control Point IDs: CP1, CP3

Capacity: 18 Million Gallons

Cross Section: NA

Usable Length: NA

Surcharge Limiting Factor: Quarry Depth





North Bailey In-Line Storage

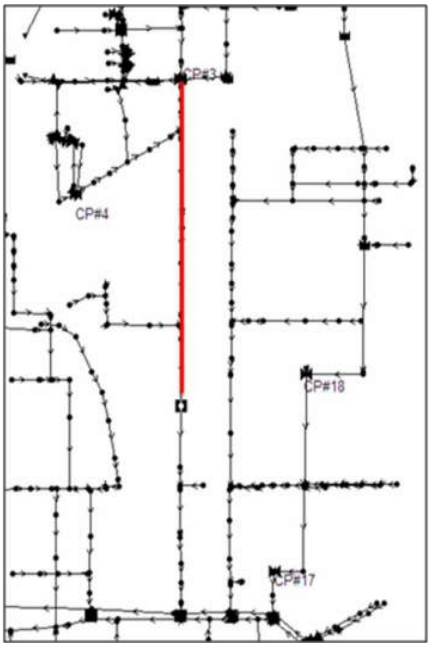
Control Point ID: CP24

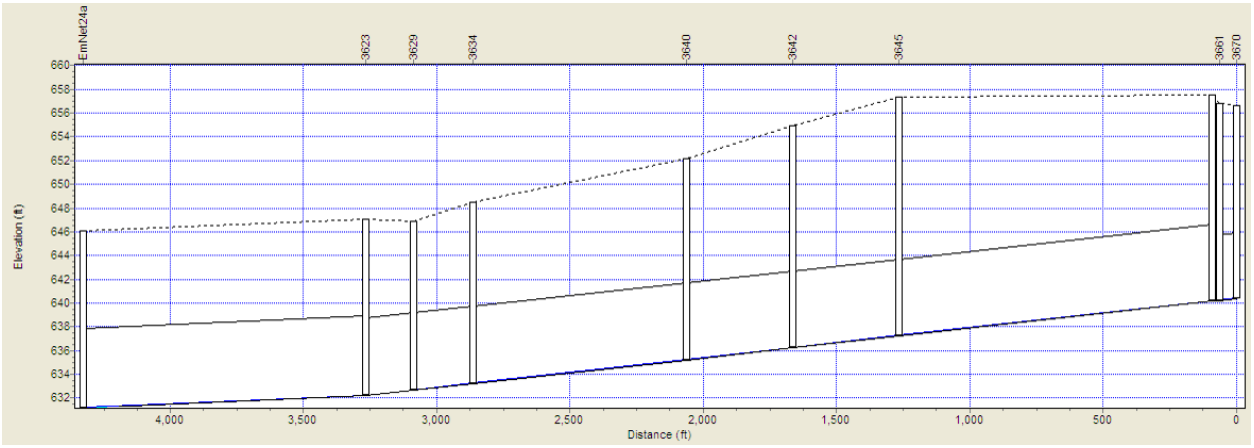
Capacity: 1.1 Million Gallons

Cross Section: 49.5 square feet

Usable Length: 3000 ft

Surcharge Limiting Factor: Pipe crown at control structure





South Bailey In-Line Storage

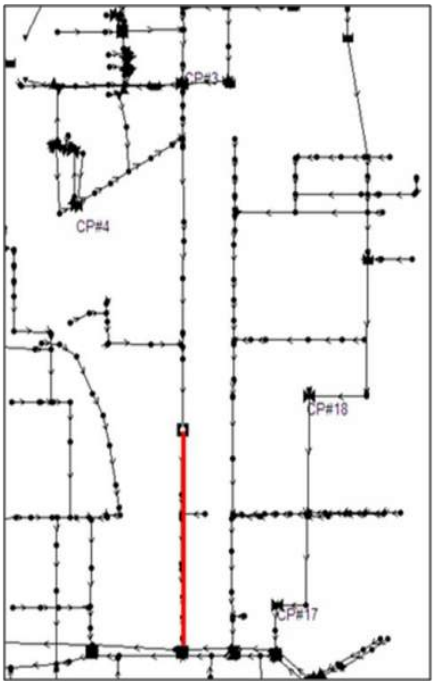
Control Point ID: CP23

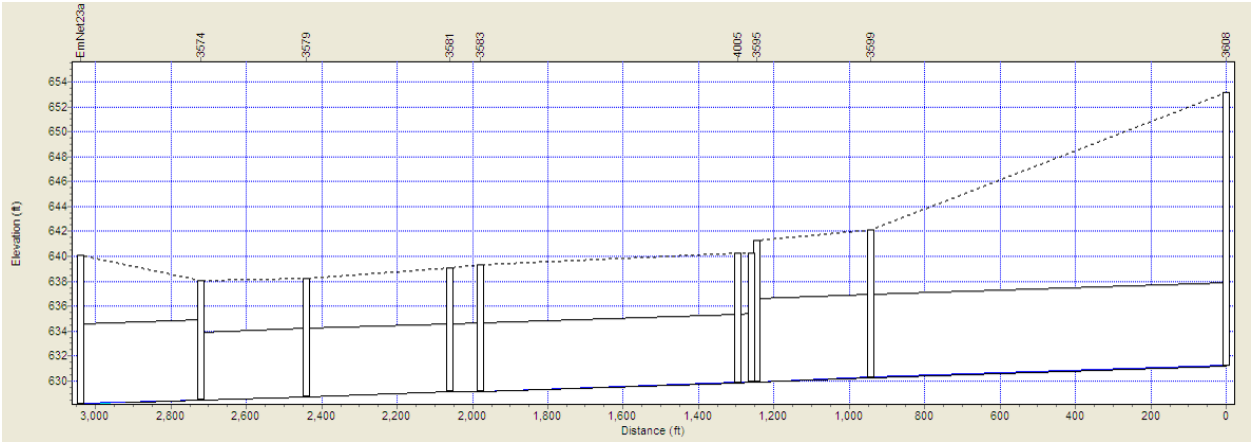
Capacity: 1.0 Million Gallons

Cross Section: 34.2 square feet

Usable Length: 4000 ft

Surcharge Limiting Factor: Pipe crown at control structure





Key In-Line Storage

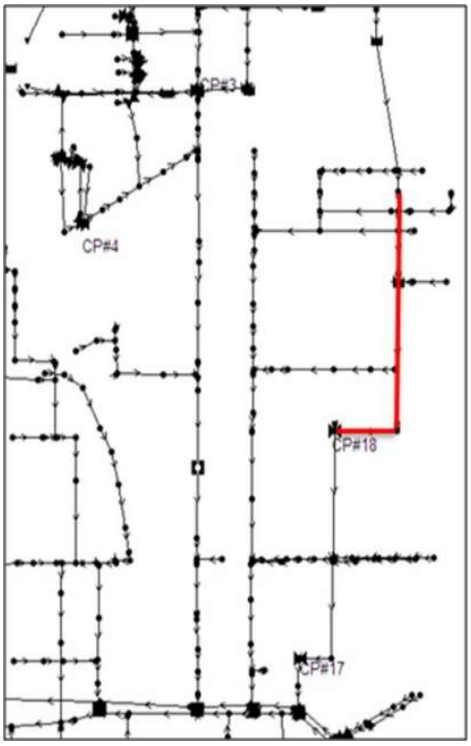
Control Point ID: CP18

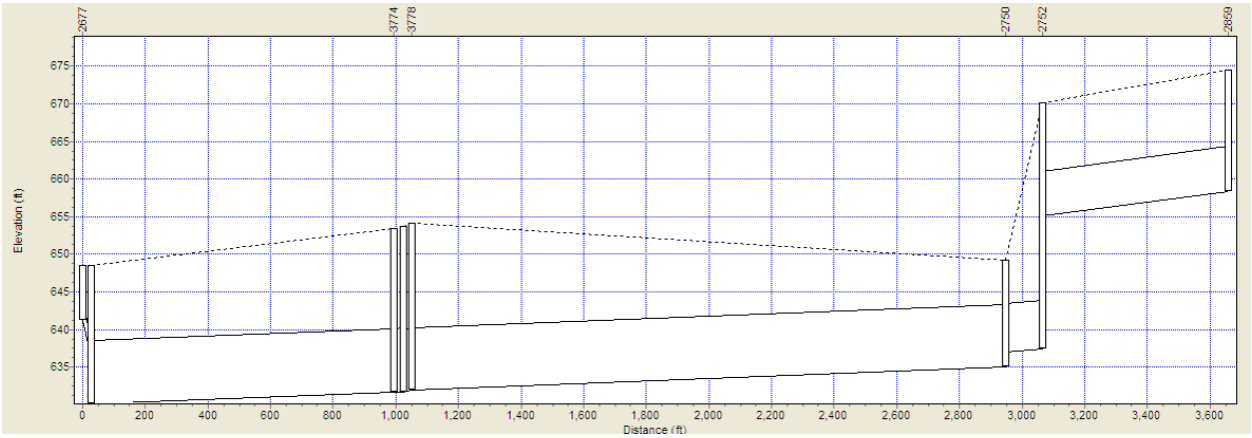
Capacity: 1.1 Million Gallons

Cross Section: 50.2 square feet

Usable Length: 3000 ft

Surcharge Limiting Factor: Pipe crown at control structure





Floss In-Line Storage

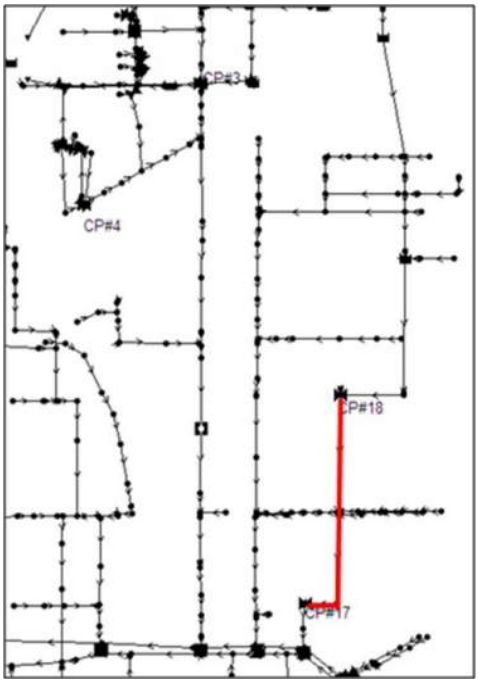
Control Point ID: CP17

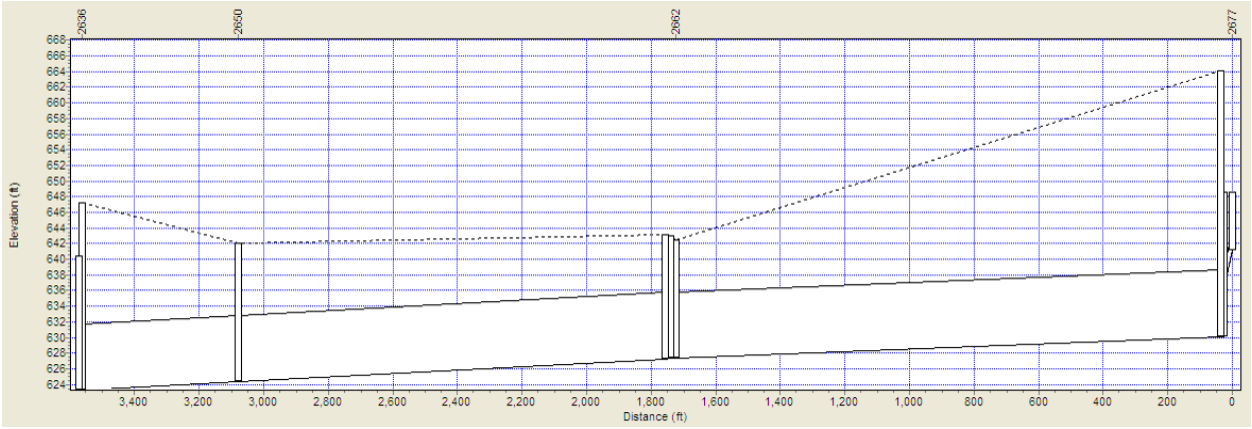
Capacity: 1.4 Million Gallons

Cross Section: 56.8 square feet

Usable Length: 3400 ft

Surcharge Limiting Factor: Pipe crown at control structure





Roslyn In-Line Storage

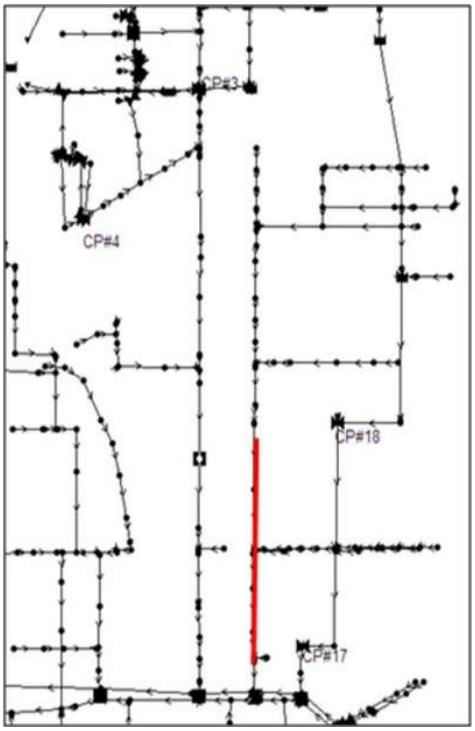
Control Point ID: CP22

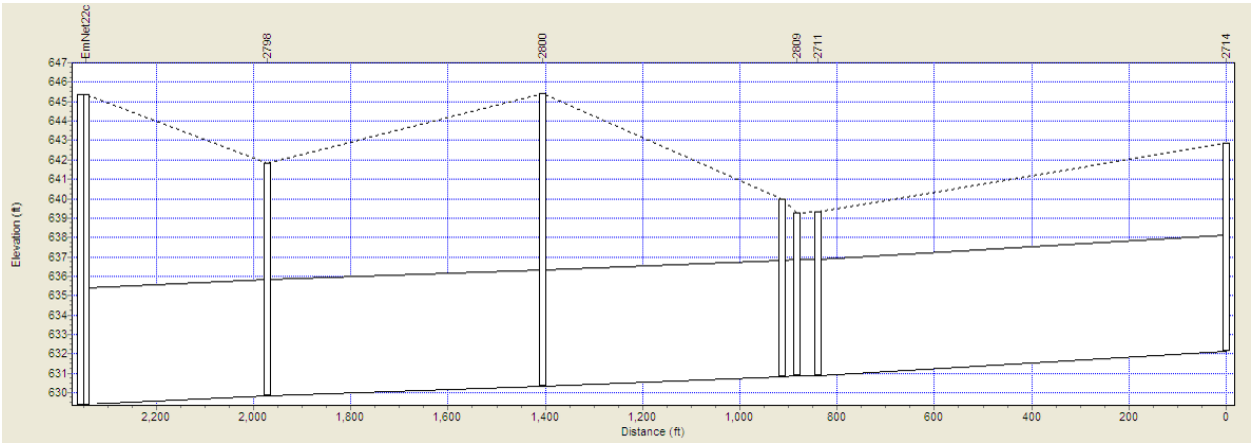
Capacity: 1.8 Million Gallons

Cross Section: 81.0 square feet

Usable Length: 3000 ft

Surcharge Limiting Factor: Pipe crown at control structure





Hertel Ave North East In-Line Storage

Control Point ID: CP5N2

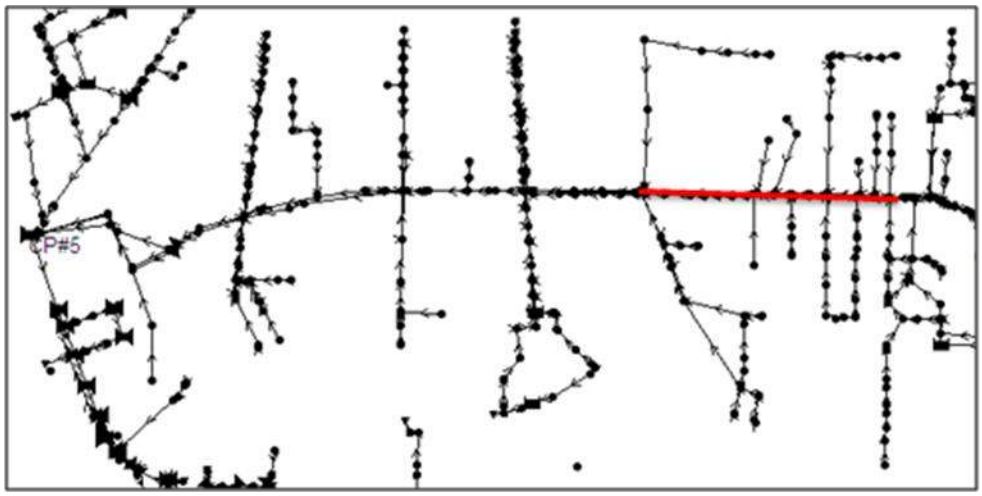
Capacity: 2.2 Million Gallons

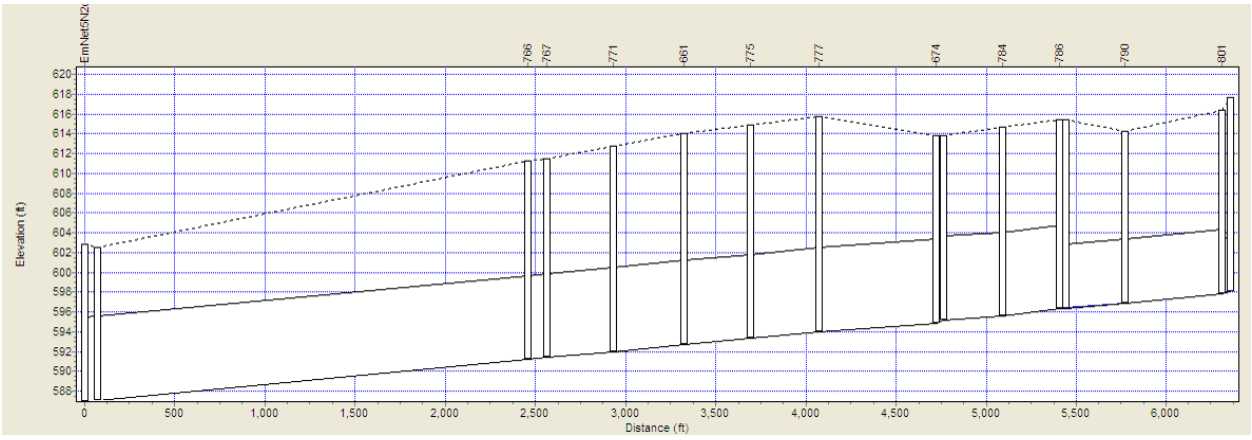
Cross Section: 72.3 square feet

Usable Length: 4000 ft

Surcharge Limiting Factor: ground elevation at Node 747

Note: Area subject to flooding





Hertel Ave North West In-Line Storage

Control Point ID: CP5N

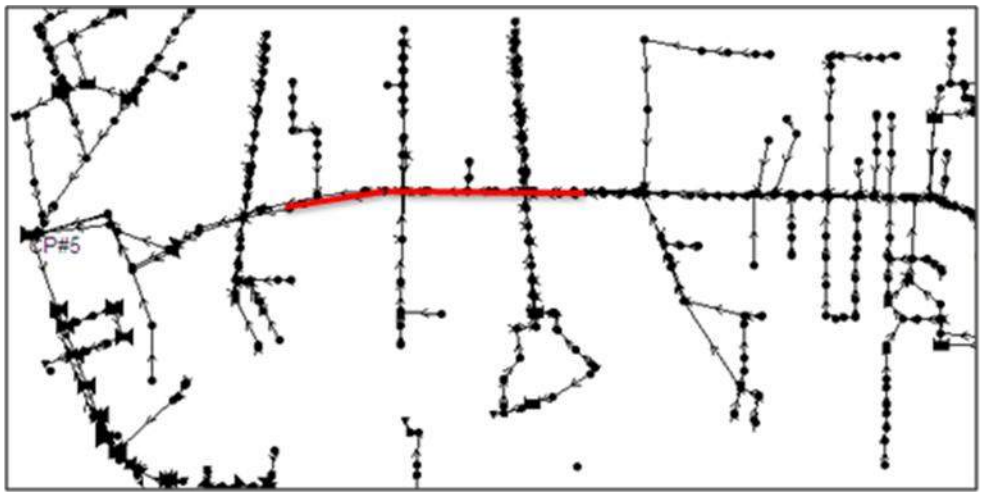
Capacity: 2.2 Million Gallons

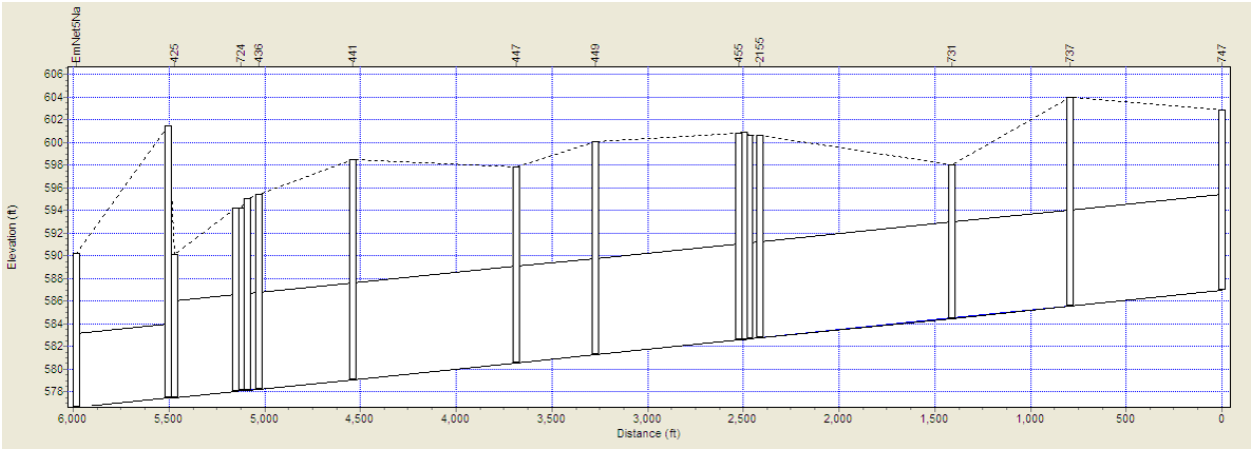
Cross Section: 72.3 square feet

Usable Length: 4000 ft

Surcharge Limiting Factor: ground elevation at Node 424

Note: Area subject to flooding





Hertel Ave South In-Line Storage

Control Point ID: CP5S

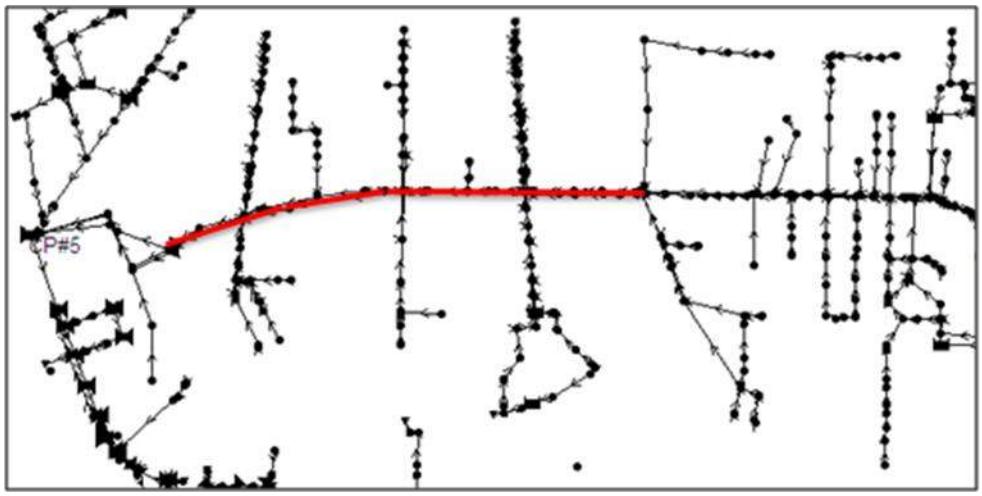
Capacity: 3.3 Million Gallons

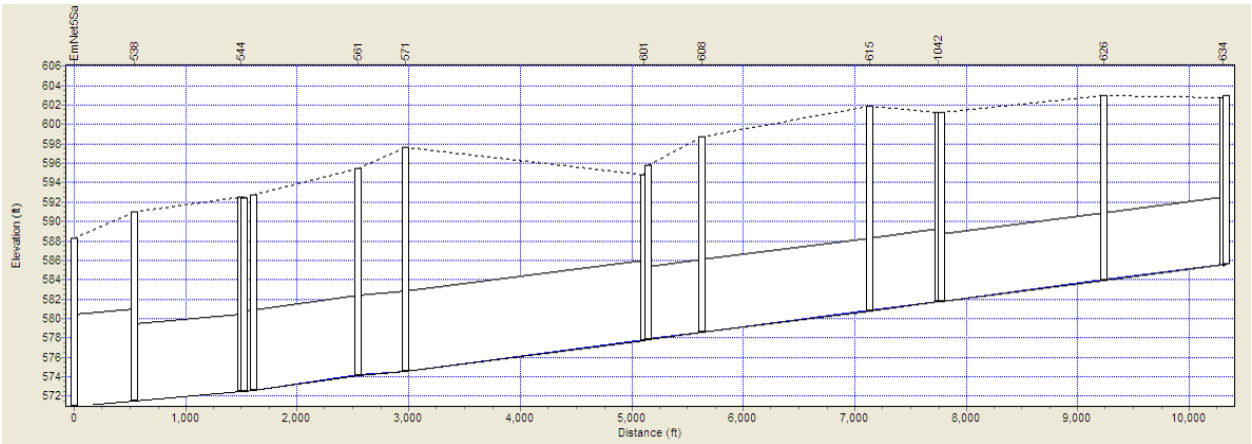
Cross Section: 44.2 square feet

Usable Length: 10,000 ft

Surcharge Limiting Factor: ground elevation at Node d540

Note: Area subject to flooding





Bird East In-Line Storage

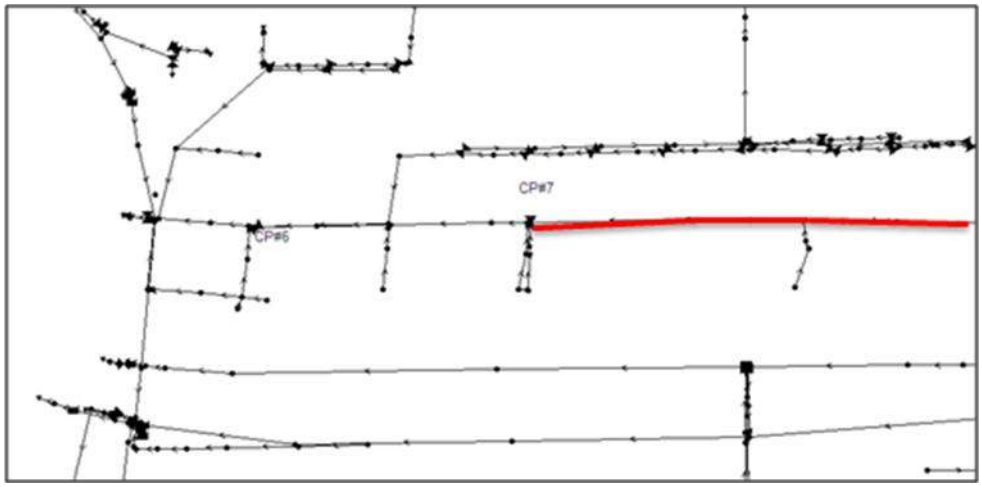
Control Point ID: CP7

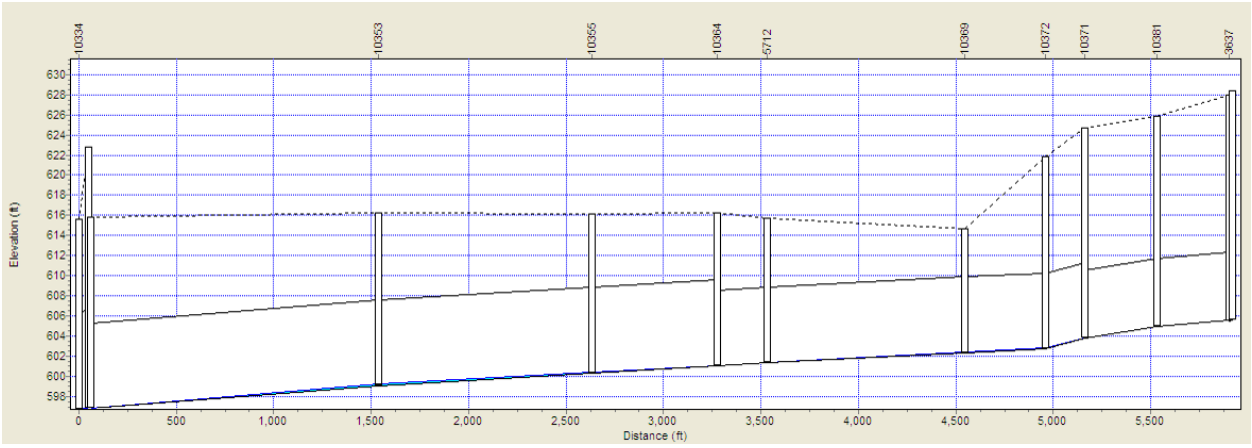
Capacity: 1.7 Million Gallons

Cross Section: 56.8 square feet

Usable Length: 4000 ft

Surcharge Limiting Factor: Crest of weir 95





Bird West In-Line Storage

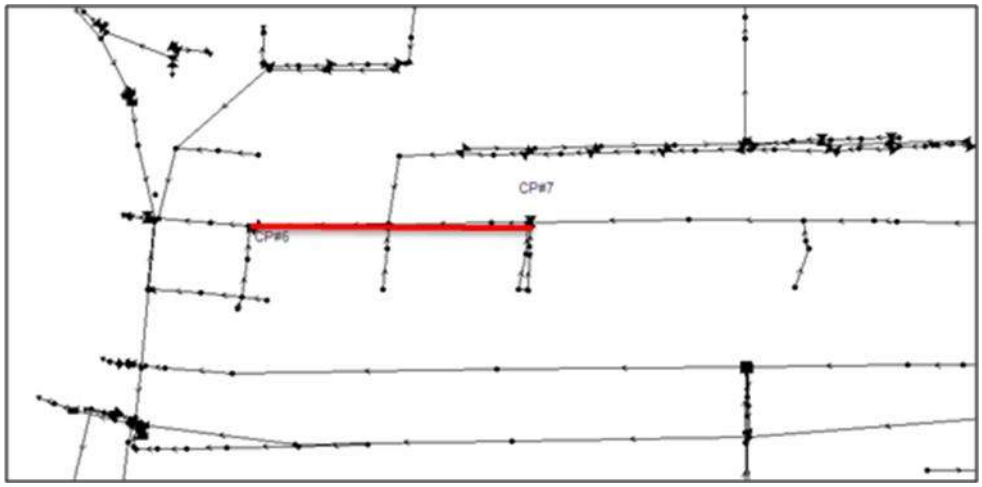
Control Point ID: CP6

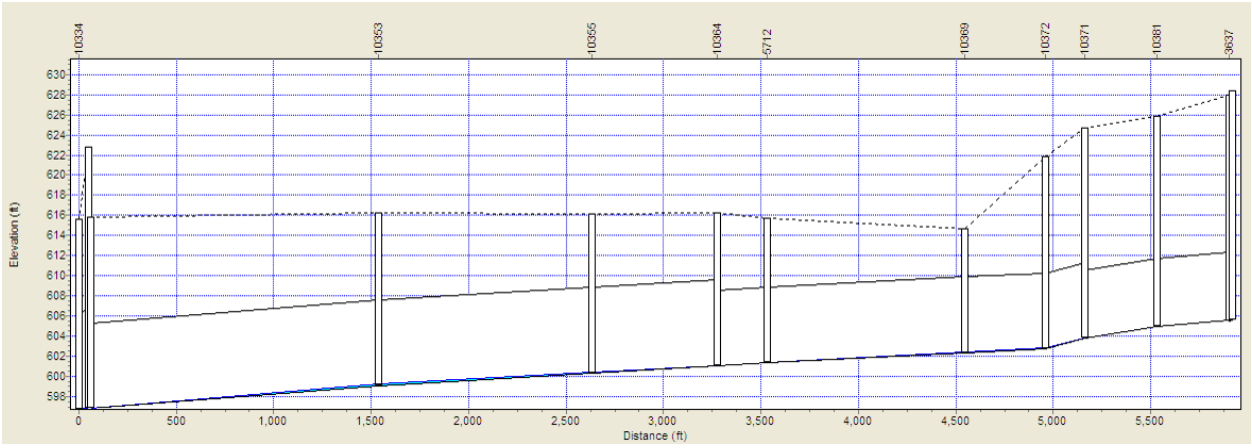
Capacity: 1.1 Million Gallons

Cross Section: 74.7 square feet

Usable Length: 2000 ft

Surcharge Limiting Factor: ground elevation at Node 10332





Fillmore North In-Line Storage

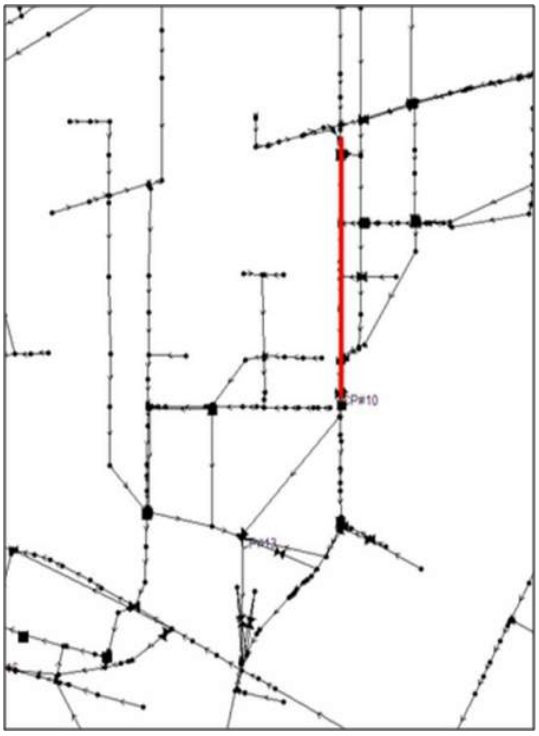
Control Point ID: CP10

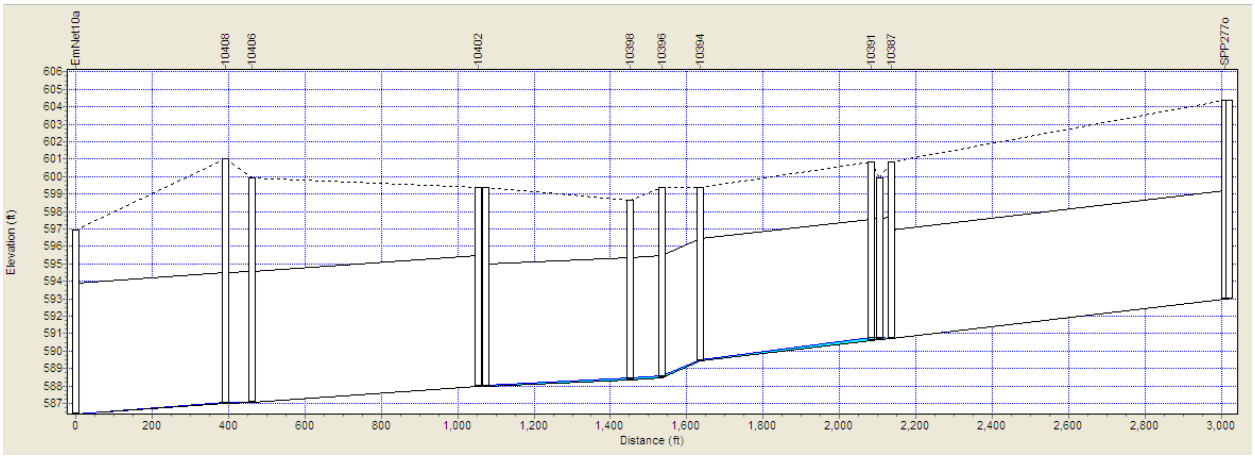
Capacity: 0.8 Million Gallons

Cross Section: 44.2 square feet

Usable Length: 2400 ft

Surcharge Limiting Factor: Crest of weir 15





Fillmore South In-Line Storage

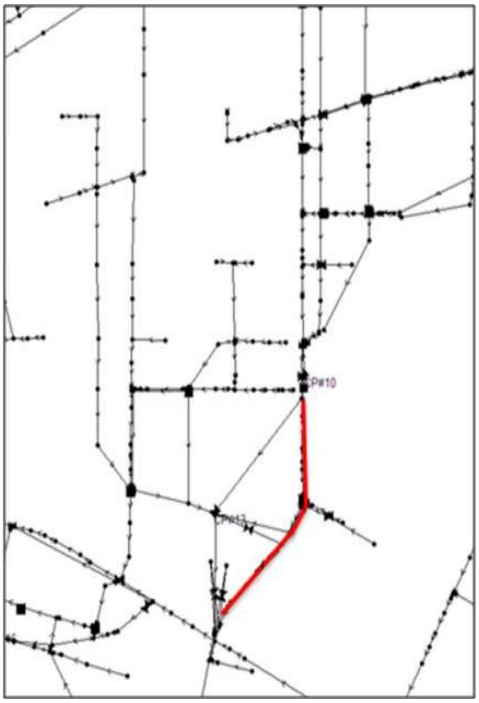
Control Point ID: CP10_2

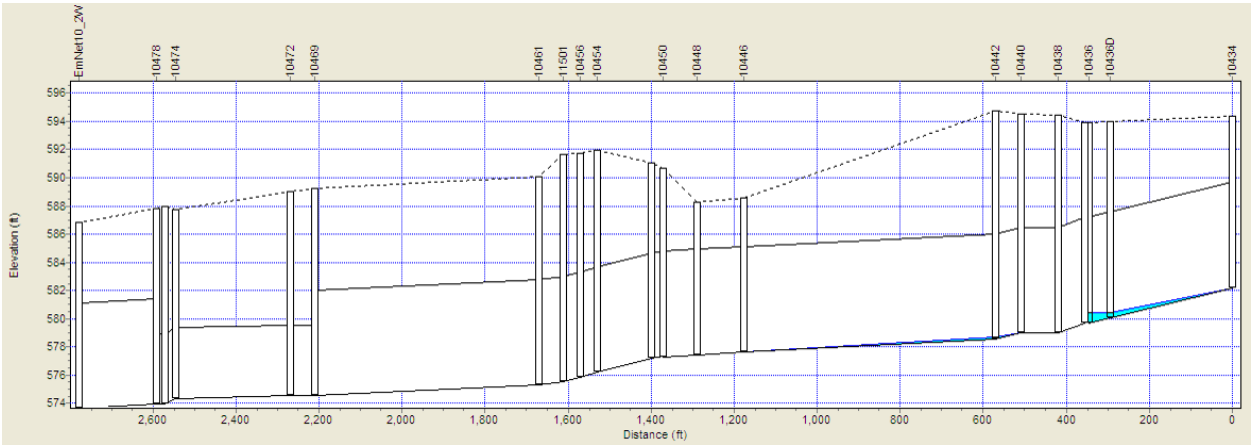
Capacity: 0.9 Million Gallons

Cross Section: 44.2 square feet

Usable Length: 2800 ft

Surcharge Limiting Factor: Pipe crown at control structure





Genesee In-Line Storage

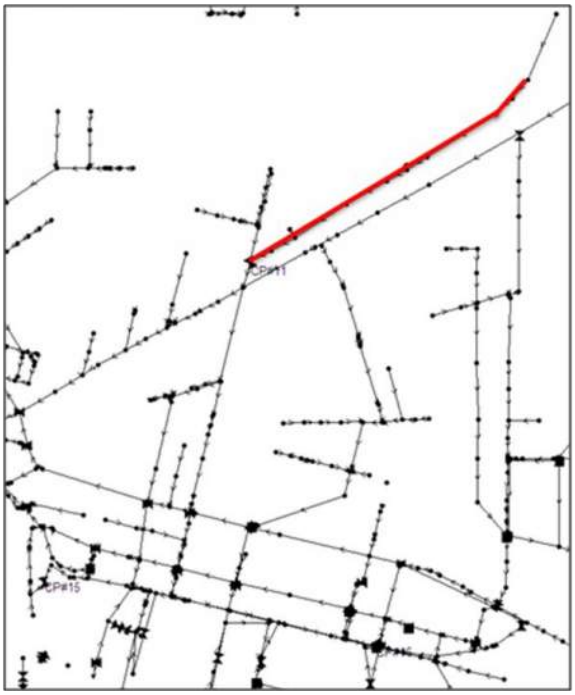
Control Point ID: CP11

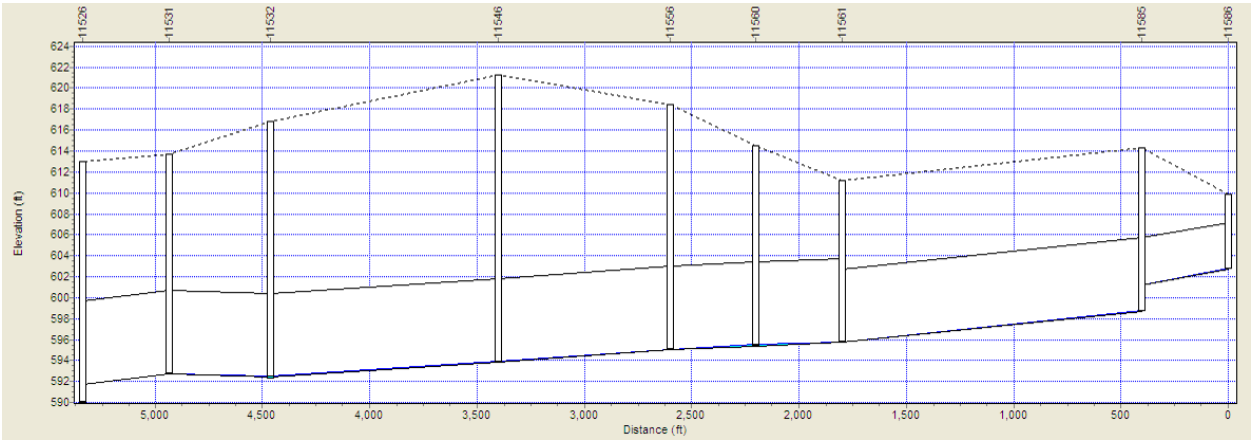
Capacity: 1.1 Million Gallons

Cross Section: 28.3 square feet

Usable Length: 5000 ft

Surcharge Limiting Factor: Pipe crown at control structure





Michigan In-Line Storage

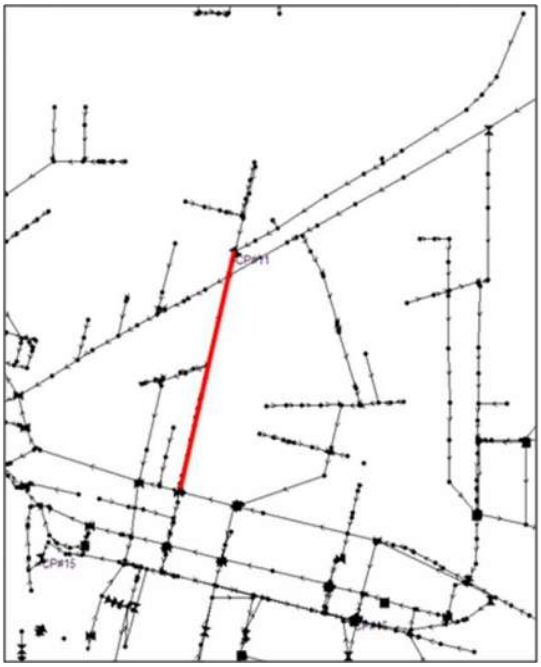
Control Point ID: CP11_2

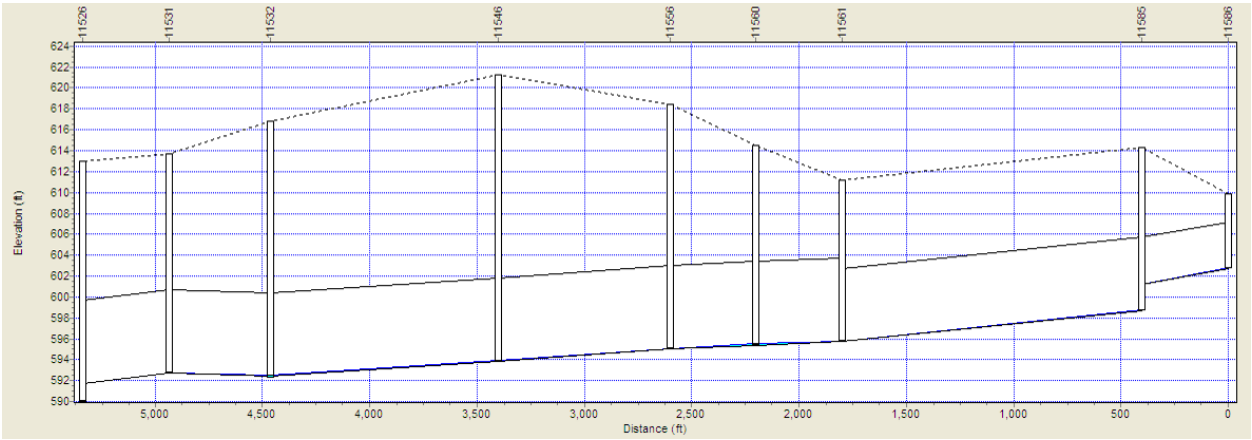
Capacity: 2.3 Million Gallons

Cross Section: 63.6 square feet

Usable Length: 4800 ft

Surcharge Limiting Factor: Pipe crown at control structure





Gibson CSO Line Storage

Control Point ID: CP25

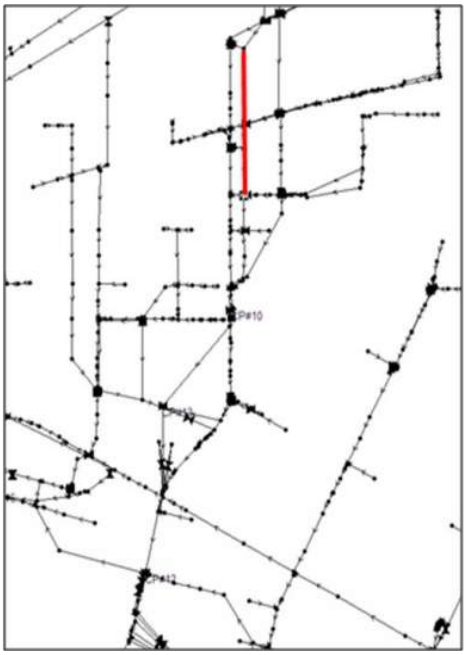
CSO 26 Overflow Line

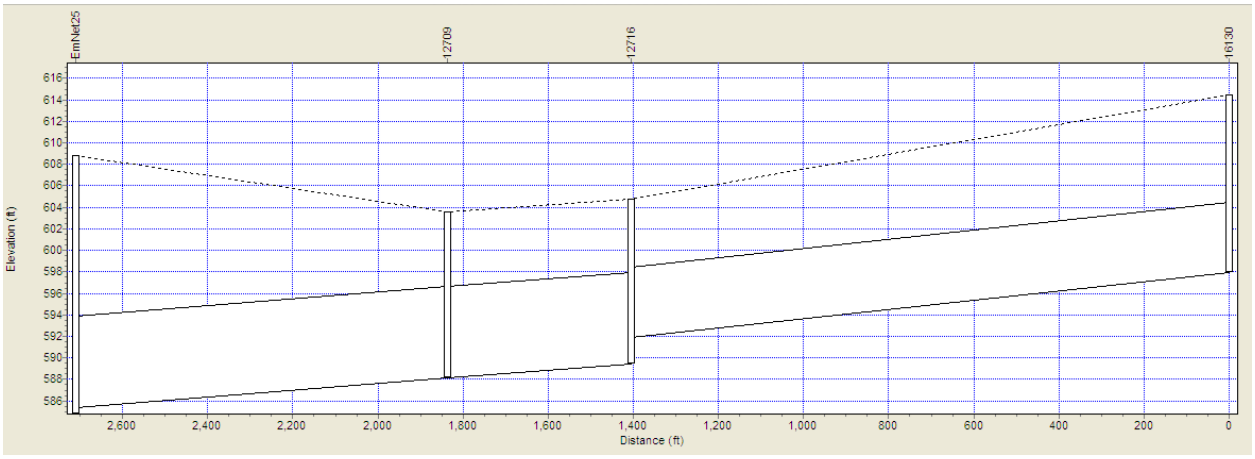
Capacity: 0.8 Million Gallons

Cross Section: 72.3 square feet

Usable Length: 1500 ft

Surcharge Limiting Factor: Crest of weir 18





Montgomery CSO Line Storage

Control Point ID: CP13

CSO 26 Overflow Line

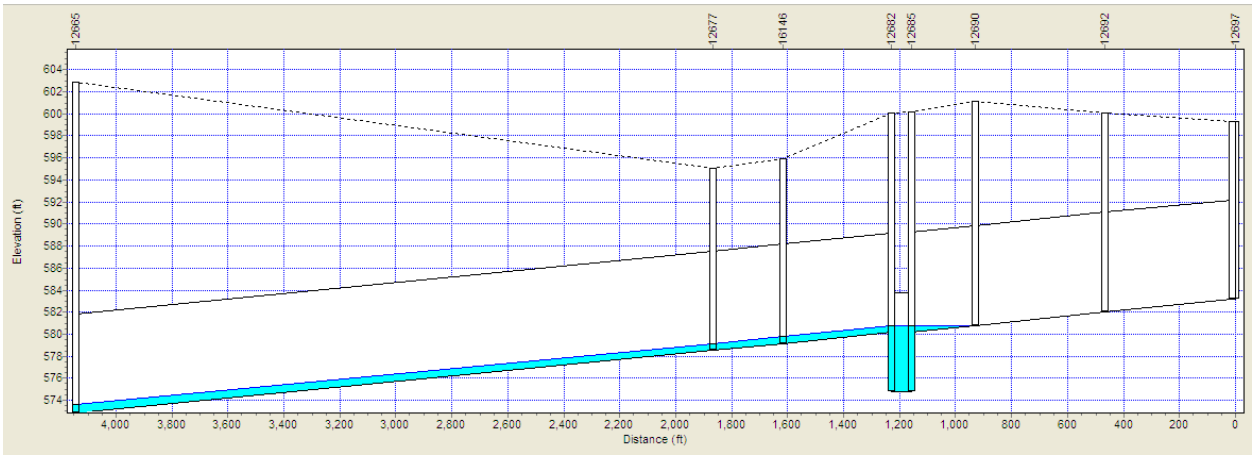
Capacity: 1.8 Million Gallons

Cross Section: 76.5 square feet

Usable Length: 3200 ft

Surcharge Limiting Factor: Crest of weir 39





Smith CSO Line Storage

Control Point ID: CP12

CSO 34 Overflow Line

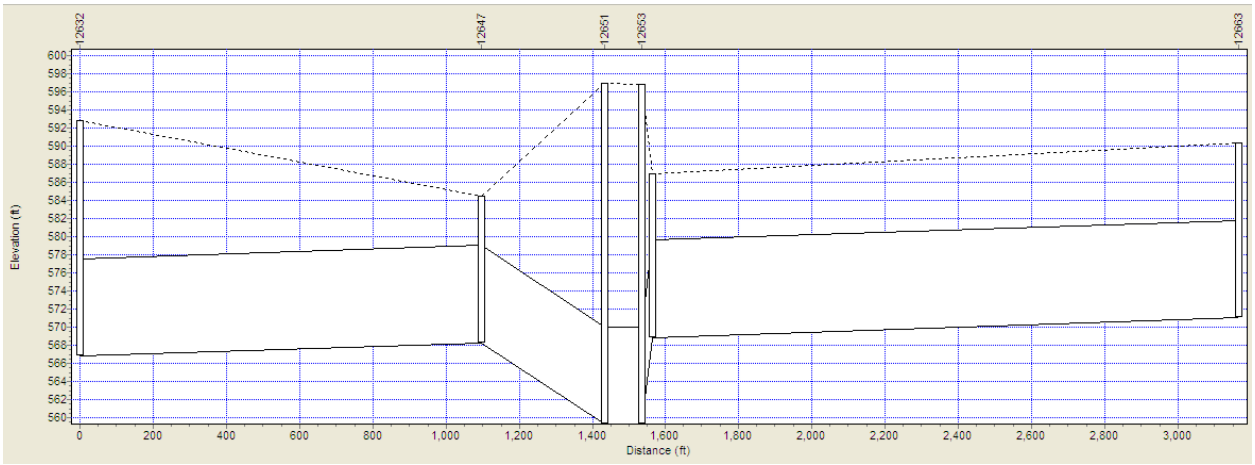
Capacity: 4.1 Million Gallons

Cross Section: 172.0 square feet

Usable Length: 3200 ft

Surcharge Limiting Factor: Crown of pipe at control structure





Louisiana CSO Line Storage

Control Point ID: CP14

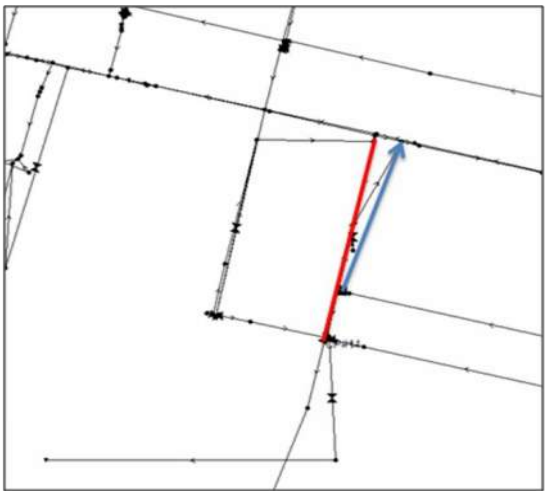
CSO 64 Overflow Line

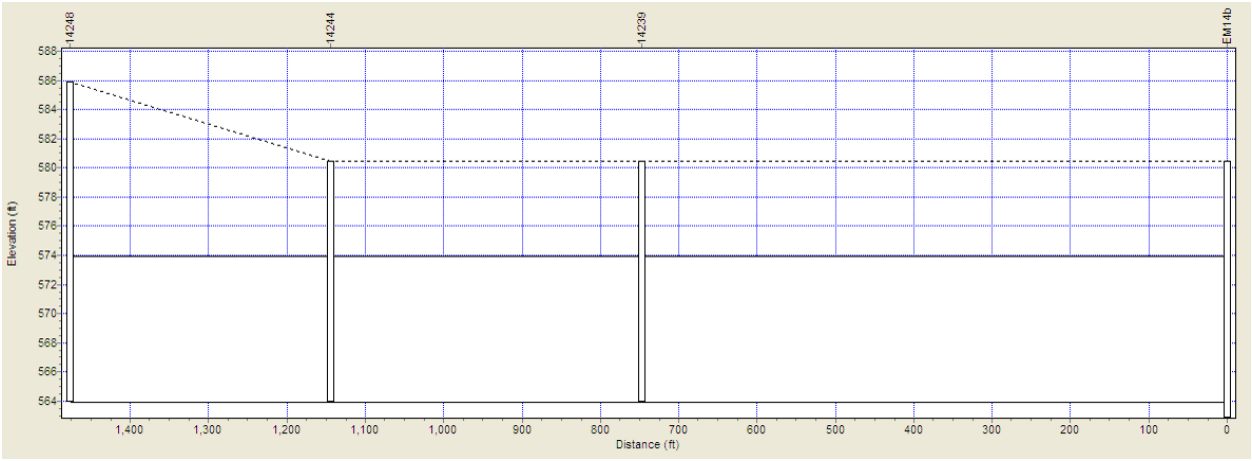
Capacity: 1.4 Million Gallons

Cross Section: 120.0 square feet

Usable Length: 1500 ft

Surcharge Limiting Factor: Crest of weir 11





EmNet's Recommended Locations for RTC – BSA Collection System

Name	Classification	EmNet Control Point Number	Control Location (node name)	Downstream Outfall Node Name	Affected CSO(s)	Overflow Volume Reduction (MG)
East Amherst Quarry	Off-Line Storage	CP1, CP3	4654*, 255DWF1	5708, 5942, 4737	6, 53, 61	45, 23, 19.3, respectively
North Bailey	In-Line Storage	CP24	3608	5708, 5942, 4737	6, 53, 61	45, 23, 19.3, respectively
South Bailey	In-Line Storage	CP23	3567	5708, 5942, 4737	6, 53, 61	45, 23, 19.3, respectively
Key	In-Line Storage	CP18	2670	5708, 5942, 4737	6, 53, 61	45, 23, 19.3, respectively
Floss	In-Line Storage	CP17	2636	5708, 5942, 4737	6, 53, 61	45, 23, 19.3, respectively
Roslyn	In-Line Storage	CP22	2793	5708, 5942, 4737	6, 53, 61	45, 23, 19.3, respectively
Hertel North East Line	In-Line Storage	CP5N2	747	P7	55	62.5
Hertel North West Line	In-Line Storage	CP5N	423	P7	55	62.5
Hertel South Line	In-Line Storage	CP5S	d540	P7	55	62.5
Bird East	In-Line Storage	CP7	10337	10208, 10210	4	14.3
Bird West	In-Line Storage	CP6	10322	10208, 10210	4	14.3
Fillmore North	In-Line Storage	CP10	10410	12611	26	381.8
Fillmore South	In-Line Storage	CP10_2	10478	12611	26	381.8
Genesee	In-Line Storage	CP11	11526	14853	17**	9.9**
Michigan	In-Line Storage	CP11_2	11497	14853	17**	9.9**

Gibson	CSO Line Storage	CP25	12701	12611	26	381.8
Montgomery	CSO Line Storage	CP13	12665	12611	26	381.8
Smith	CSO Line Storage	CP12	12632	12611	26	381.8
Louisiana	CSO Line Storage	CP14	14248	15152	64	9

* In the XP SWMM model, this is modeled as an outfall. In the EPA SWMM model, this was converted to a storage unit to model the East Amherst Quarry.
** CSO 017 collects the overflow from most of the southern half of the BSA system, so the effect of two relatively small storage areas will be lost in the overall flow of this CSO. To quantify the affects of these RTC locations, it is more accurate to examine the flow reduction at node SPP326w. At this node, the typical year overflow reduced from 28.9 MG to 19.0 MG.

Implementation of Local Reactive Control

This level of control offers a first cut at the potential benefits of RTC. Local Reactive Control is the simplest form of control, consisting mainly of controlling flows based on local hydraulic parameters, such as level or flows. The advantages of this level of control are:

- Robust to degraded operation due to equipment malfunction or communication failure. Each control site operates completely independently from other control sites. This means that lack of communication of the failure of any one control site does not affect the rest of the system.
- Can be used to evaluate the performance of the RTC system for regulatory purposes. Coordination between distinct RTC sites is mostly needed when temporal and spatially distributed precipitation is present. Typically, for regulatory purposes, a uniform precipitation pattern is used. In this case, most structures are exposed to flow peaks at roughly the same time. Coordination between the control sites may marginally increase the performance of the RTC.
- Inexpensive implementation and operation. Local reactive rules are simple to understand, implement, and maintain.

The main disadvantage of this control is that it does not fully optimize the performance of the RTC during temporal and spatially distributed rainfall events. The costs associated with operating a coordinated system must be evaluated against the benefits of a local reactive control system.

The rules implemented for each structure are presented below:

Off-Line Storage Areas:

The rules implemented for off-line storage areas are directed to maximize the utilization of the available storage when CSO regulators are close to being activated. In a local reactive system, an off-line storage starts storing water when the flow at the diversion point is greater than the regular dry weather flows. Dewatering strategies are aimed at conveying water to the collection system as fast as it possible without creating additional overflows. Levels at the nearest large downstream conveyance system is used to determine if it is safe to release water.

East Amherst Quarry Storage

Control Point IDs: CP1, CP3

CP3: Allow up to 2 cfs through SPP255.2, all additional flows diverted to Quarry.

Dewatering Strategy: dewater quarry at 27.3 cfs if depth at node 4784 is below 1.5 feet.

In-Line Storage Areas:

Similar to off line storage areas, in-line storage locations must time the storage and dewatering actions to maximize the performance of the RTC system. However, these structures must be able to simultaneously store and convey to prevent surface flooding. A local reactive in-line storage system will not store water until it detects that the flow is above the normal dry weather flow. Upon detecting the presence of significant wet weather flows and while the water level does not exceed the maximum surcharge levels, the structure will only allow flow values approximately equivalent to dry weather conditions. If the maximum surcharge level is reached, the system must convey flows to prevent exceeding the maximum surcharge level. This action produces flows that are essentially equivalent to flows seen without the RTC structure, but at that point, the structure would have captured its target volume. Once the water level recedes from the maximum allowed, the structure will dewater at a rate equivalent to dry weather flows.

North Bailey In-Line Storage

Control Point ID: CP24

CP24: Allow up to 20 cfs through node 3608 until depth exceeds 6.75 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 20 cfs.

South Bailey In-Line Storage

Control Point ID: CP23

CP23: Allow up to 20 cfs through node 3567 until depth exceeds 6.5 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 20 cfs.

Key In-Line Storage

Control Point ID: CP18

CP18: Allow up to 15 cfs through node 2670 until depth exceeds 8.5 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 25 cfs.

Floss In-Line Storage

Control Point ID: CP17

CP17: Allow up to 15 cfs through node 2636 until depth exceeds 8.5 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 25 cfs.

Roslyn In-Line Storage

Control Point ID: CP22

CP22: Allow up to 0.8 cfs through node 2793 until depth exceeds 6 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 0.8 cfs.

Hertel Ave North East In-Line Storage

Control Point ID: CP5N2

CP5N2: Allow up to 12 cfs through node 747 until depth exceeds 8.5 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 12 cfs.

Hertel Ave North West In-Line Storage

Control Point ID: CP5N

CP5N: Allow up to 200 cfs through node 423 until depth exceeds 10 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 200 cfs.

Hertel Ave South In-Line Storage

Control Point ID: CP5S

CP5S: Allow up to 100 cfs through node d540 until depth exceeds 9.5 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 100 cfs.

Bird East In-Line Storage

Control Point ID: CP7

CP7: Allow up to 27 cfs through node 10337 until depth exceeds 9 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 27 cfs.

Bird West In-Line Storage

Control Point ID: CP6

CP6: Allow up to 35 cfs through node 10322 until depth exceeds 9.8 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 35 cfs.

Fillmore North In-Line Storage

Control Point ID: CP10

CP10: Allow up to 20 cfs through node 10410 until depth exceeds 4 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 20 cfs.

Fillmore South In-Line Storage

Control Point ID: CP10_2

CP10_2: Allow up to 20 cfs through node 9394 until depth exceeds 7.5 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 20 cfs.

Genesee In-Line Storage

Control Point ID: CP11

CP11: Allow up to 25 cfs through node 11526 until depth exceeds 13.1 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 25 cfs.

Michigan In-Line Storage

Control Point ID: CP11_2

CP11_2: Allow up to 37 cfs through node 11497 until depth exceeds 14 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: dewater structure at no more than 37 cfs.

CSO Line Storage Areas:

The objective of CSO storage areas is to store water before the release point to the environment. They behave similarly to in-line storage locations in the sense that they are required to convey water if the water level threatens to cause surface flooding. Additionally, the level must be kept below the lowest weir crest upstream from the control structure. This prevents overflows from weirs with higher crest elevations from reentering the system through weirs with lower crest elevations. CSO Line Storage Areas also behave like off-line storage locations in the sense once the storm event has receded, they are not required to continue conveying water, but instead, they must be dewatered in such a way that they do not cause problems downstream from the control structure.

Gibson CSO Line Storage

Control Point ID: CP25

CP25: If node 8625 depth exceeds 8 feet, all flows upstream of node 12701 are stored until depth exceeds 9 feet. If level exceeds 9 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 8625 depth retreats to less than 6 feet, the structure is dewatered at a flow rate of 10 cfs.

Montgomery CSO Line Storage

Control Point ID: CP13

CP13: If node 8625 depth exceeds 8 feet, all flows upstream of node 12665 are stored until depth exceeds 9 feet. If level exceeds 9 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 8625 depth retreats to less than 6 feet, the structure is dewatered at a flow rate of 20 cfs.

Smith CSO Line Storage

Control Point ID: CP12

CP12: If node 8625 depth exceeds 8 feet, all flows upstream of node 12632 are stored until depth exceeds 10.75 feet. If level exceeds 10.75 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 8625 depth retreats to less than 6 feet, the structure is dewatered at a flow rate of 40 cfs. Dewatering flows are re-entered to the South Interceptor Line at node 8629.

Louisiana CSO Line Storage

Control Point ID: CP14

CP14: If node 14262 depth exceeds 7 feet, all flows upstream of node 14248 are stored until depth exceeds 7 feet. If level exceeds 7 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 14262 depth retreats to less than 0.5 feet, the structure is dewatered at a flow rate of 40 cfs. Dewatering flows are re-entered to the South Interceptor Line through the Hamburg Pump Station at node 14262.

Results of Local Reactive Control

The aforementioned Local Reactive Control strategy was utilized to evaluate the hydraulic performance of the system. The provided typical year rain data was used for the evaluation. To expedite the results, the number of dry days was reduced according to the following rules:

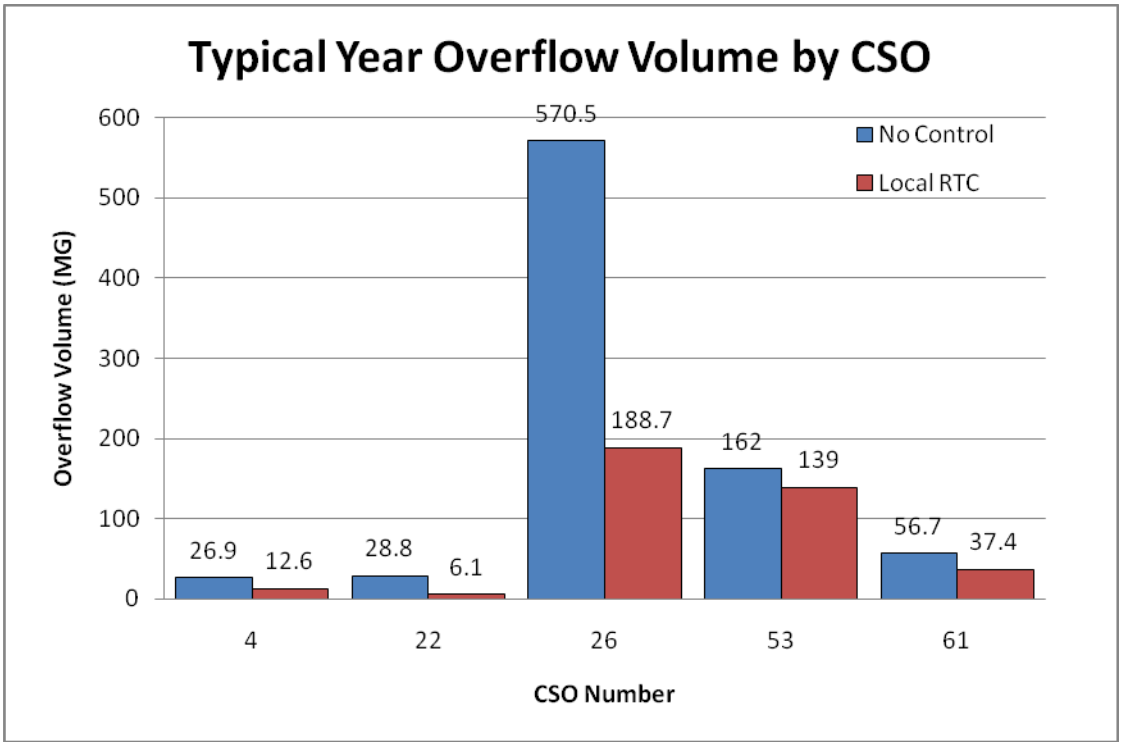
- Storm events with a total accumulation of less than 0.05" in 24 hours were removed, because they were unlikely to cause overflows.
- Storm events with total accumulations of 0.05" to 0.15" were followed by 24 hours of dry weather or by the time until the next storm event, whichever was less.
- Storm events with total accumulations of 0.16" to 0.25" were followed by 30 hours of dry weather or by the time until the next storm event, whichever was less.
- Storm events with total accumulations of 0.26" to 0.35" were followed by 36 hours of dry weather or by the time until the next storm event, whichever was less.
- Storm events with total accumulations of 0.36" and over were followed by 48 hours of dry weather or by the time until the next storm event, whichever was less.

To account for the large snowfalls that Buffalo receives during the winter months, the typical year was simulated using rain data from March through November. The results were multiplied by 4/3 to account for the missing months. In the EPA SWMM simulations, it was most convenient to split the March through November time period into four sections and sum the results. The following table summarizes the results:

CSO Outfall	Annual OF Volume EmNet SWMM without Control (MG)	Annual OF Volume EmNet SWMM with RTC (MG)	Difference in volume (MG)	Reduction (%)
001a	0	0	0	0%
003	3.73	3.6	0.13	3%
004	26.9	12.6	14.3	53%
006	454	409	45	10%

008	12.5	12.2	0.3	2%
010	44.4	43.9	0.5	1%
011	85.7	91.6	-5.9	-7%
012	128.2	128.2	0	0%
013	20.4	20.4	0	0%
014	17.9	17	0.9	5%
015	116	116.1	-0.1	0%
016	63	63	0	0%
017	221.9	234.6	-12.7	-6%
022	28.8	6.1	22.7	79%
025	6.3	6.3	0	0%
026	570.5	188.7	381.8	67%
027	58.7	59.5	-0.8	-1%
028	134.7	134.6	0.1	0%
029	1.2	1.2	0	0%
032	0	0	0	0%
033	97.3	97.5	-0.2	0%
034	0	0	0	0%
035	29.4	29.3	0.1	0%
037	29.9	29.9	0	0%
039	0	0	0	0%
044	6	5.9	0.1	2%
046	8	8.1	-0.1	-1%
047	11.6	11.6	0	0%
048	0.1	0.1	0	0%
049	0	0	0	0%
050	5.6	5.6	0	0%
051	4.5	4.5	0	0%
052	15.4	15.4	0	0%
053	162	139	23	14%
054	29.7	29.7	0	0%
055	967.5	905	62.5	6%
056	1.4	1.4	0	0%
057	0.6	0.6	0	0%
058	16.3	16.3	0	0%
059	3.7	2.1	1.6	43%
060	0.9	0.9	0	0%
061	56.7	37.4	19.3	34%
063	1.2	1.2	0	0%
064	110.6	101.6	9	8%
066	123.9	124	-0.1	0%
TOTAL	**3677.1**	**3115.7**	**561.43**	**15%**

The system reduction in overflow volume was approximately 560 MG, or 15% of the total, and reductions of up to 79% were seen on a per CSO basis (see graphs below).



Overflow Volume Reduction by CSO

4. Implementation of Coordinated or Distributed Control

In this phase, the control sites are able to control flows not only based on local levels, but also on the actions of other control sites and remote monitoring locations. This type of control has the biggest impact during spatially and temporally distributed storms. The concept behind Distributed Control is that since non-uniform precipitation does not affect the entire system simultaneously, there will be areas with hydraulic constraints while others will have available conveyance and/or storage capacity. By utilizing these areas with available capacity at the right time, areas with hydraulic constraints will be relieved.

For this work, a spatially and temporally distributed storm was chosen to compare the performance of the Distributed Control versus the Local Reactive Control. Note that the distributed control only has a measurable performance difference with the Local Reactive Control under spatially and temporally distributed storm scenarios. Ideally, a number of “statistically relevant” spatially and temporally distributed storms would be used to provide more meaningful conclusions. The characterization of statistically relevant storms falls outside the scope of this work. However, a real storm was chosen to evaluate the performance of the control system. To provide more

meaningful results, the intensity of the storm was varied while keeping the spatial and temporal distribution. The storm chosen corresponds to an actual storm event that hit the City of Buffalo, NY on July 23, 2009. It was chosen because this storm varies both spatially and temporally to a large extent. This variation is necessary to test the robustness and effectiveness of the control algorithms. This storm event was then multiplied by 0.5, 1.0, and 2.0 to create a series of realistic storm events with different levels of intensity. The storms have the following parameters:

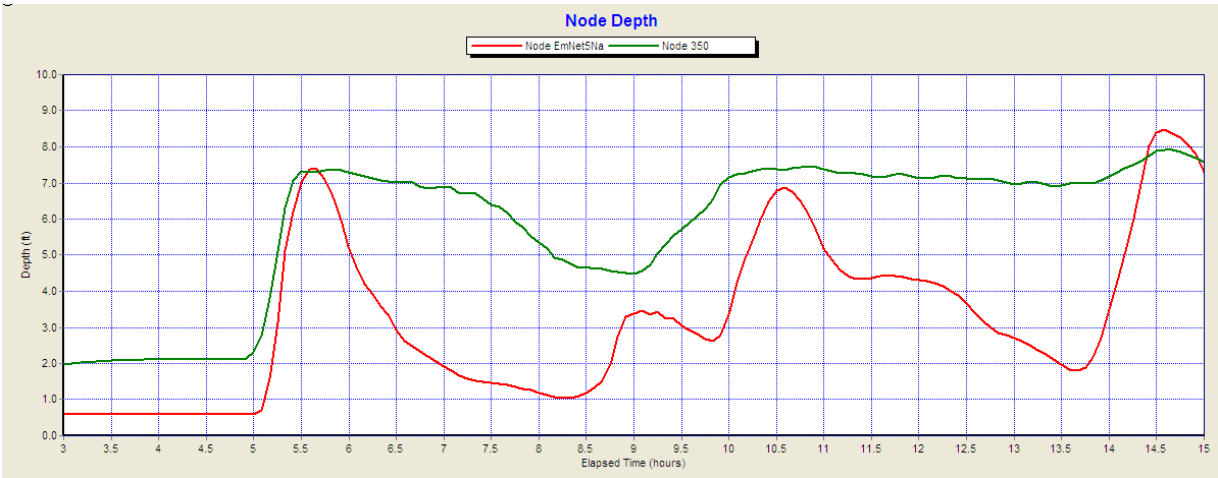
Name	Description	Duration (hrs)	Max. Intensity (in/hr)	Total Precipitation (in)
Storm 1	July 23, 2009 storm event x 0.5, approx. a 2 month design storm	23.5	0.20 – 0.72	0.43 – 1.14
Storm 2	July 23, 2009 storm event x 1.0, approx. a 6 month design storm	23.5	0.40 – 1.44	0.85 – 2.27
Storm 3	July 23, 2009 storm event x 2.0, approx. a 24 month design storm	23.5	0.80 – 2.88	1.70 – 4.54

Since the most important parameter of design is timing, it is natural to expect that travel times would be critical. The first step in the design of the Distributed Control is to determine the closest critical hydraulic structure. This structure is typically a CSO control structure. The closest hydraulic structure is by definition the closest hydraulic structure that will be affected by the control point decision to store or dewater. Travel times are then estimated for each control system. To calculate travel times, a mean flow velocity of 4 feet per second was assumed.

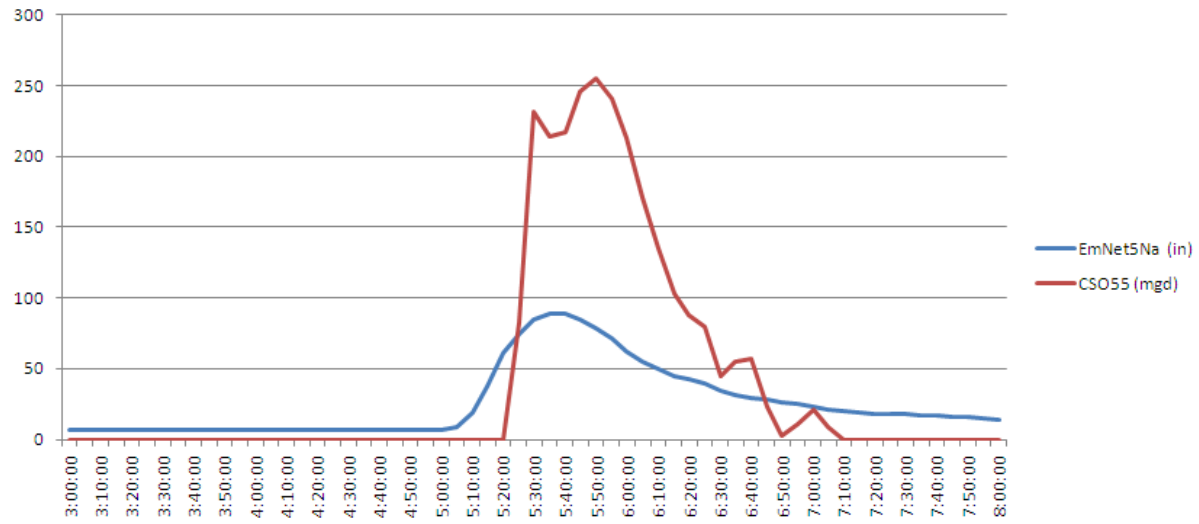
Control System ID	Control Points in System	Critical Point (SWMM ID)	CSO Structure(s)	Travel Time (min)
3	3, 24, 23	Weir#128	6, 53, 61	1
17	18, 17	Weir#130	6, 53, 61	3
22	22	Weir#129	6, 53, 61	3
5N	5N2, 5N	Outfall P7	55	34
5S	5S	Outfall P7	55	19
7	7, 6	Outfalls 10208, 10210	4	5
10	10, 10_2	Weir#9, Outfall 14853	26	5
11	11, 11_2	Outfall 15752	14	21

12	25, 13, 12	Outfall 12611, SPP77w, 78w	26	0
14	14	Outfall BR1.00	64	0

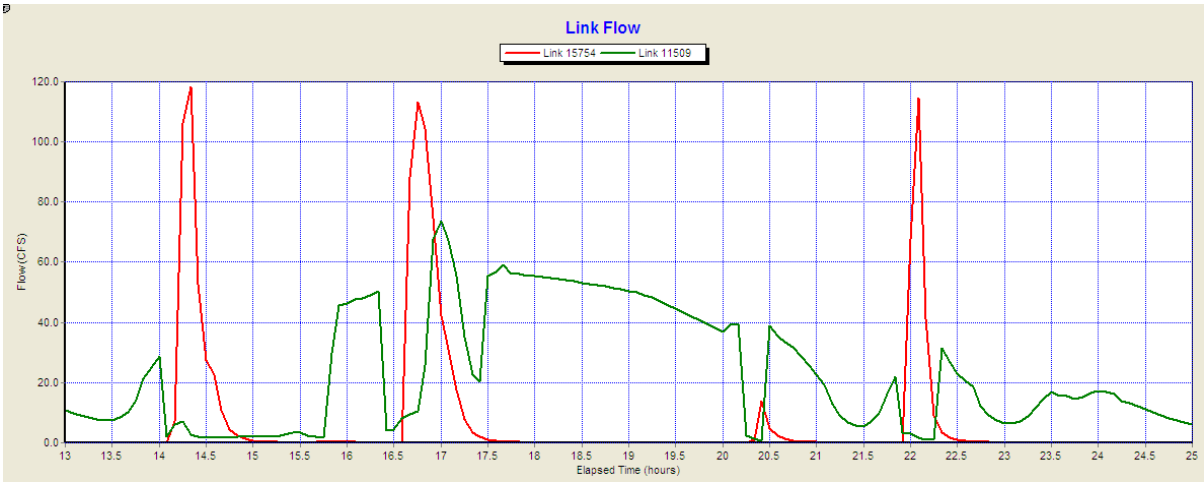
From the above table, it becomes obvious that there are only 3 control systems with larger travel times, namely Control System 5N (Hertel Ave North), 5S (Hertel Ave South), and 11 (Genesee-Michigan Ave). Both the North and South Hertel Ave control systems operate in an area with relatively large inflows. The following graph depicts the node depth right upstream of the control point 5N (in red) and immediately upstream of the CSO control structure (in green – overflow level is 8.5ft),



It can be observed that the level behind the weir increases before the storage location sees an increase in flow. This due to large inflows occurring between the control point and the CSO structure. Furthermore, in the following graph, it can be observed that the control structure stores before the CSO structure begins overflowing and dewaters quickly after the CSO structure has ceased from overflowing. This indicates that the use of coordination between the events occurring at the CSO structure and the control system is not needed as the control system stores and dewaters at approximately the required times.



The situation for Control System 11 (Genesee-Michigan Ave) is different. The actual overflow point immediately downstream from this system is Weir#38. Under local reactive control, this overflow point does not get activated during the storm due to the large in-line storage capacity available in the trunk line. However, it was observed that CSO14, a relief point for the South Interceptor line overflows during peak flows. By providing the appropriate threshold level trigger at CSO14, it was possible to provide advanced notice to Control System 11 of an upcoming CSO activation. From the graph depicted below, it can be seen that the flow coming from Control System 11 (green) is almost reduced to zero between 15 and 20 minutes before CSO14 (red) activates. This can be further refined by providing monitoring upstream from the control point and/or adding a trigger on rate of change of flow. This added feature, however, does not seem to greatly increase the performance of the system.



All the other Control Systems have travel times that are 5 minutes or smaller negating the need for complex flow prediction schemes. The Distributed Control strategy only depends on the immediate status of the associated critical hydraulic structure. Fine tuning of the trigger levels and or flows is done on an iterative process that ensures that the control point only starts storing when the critical hydraulic

structure has reached its capacity and is dewatered as quickly and safely as possible. Next is a compilation of control rules for the Distributed Control scheme.

Off-Line Storage Areas:

East Amherst Quarry Storage

Control Point IDs: CP1, CP3

CP3: Allow up to 5 cfs through SPP255.2, all additional flows diverted to Quarry.

Dewatering Strategy: dewater quarry at 27.3 cfs if depth at node 4784 is below 1.5 feet.

In-Line Storage Areas:

North Bailey In-Line Storage

Control Point ID: CP24

CP24: Allow up to 30 cfs through node 3608 until depth exceeds 6.75 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-6.25)*200,0)

Dewatering Strategy: dewater structure at no more than 30 cfs.

South Bailey In-Line Storage

Control Point ID: CP23

CP23: Allow up to 35 cfs through node 3567 until depth exceeds 6.5 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-6)*200,0)

Dewatering Strategy: dewater structure at no more than 35 cfs.

Key In-Line Storage

Control Point ID: CP18

CP18: Allow up to 5 cfs through node 2670 until depth exceeds 8.5 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-8)*100,0)

Dewatering Strategy: dewater structure at no more than 5 cfs.

Floss In-Line Storage

Control Point ID: CP17

CP17: Allow up to 12 cfs through node 2636 until depth exceeds 8.5 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-8)*200,0)

Dewatering Strategy: dewater structure at no more than 12 cfs.

Roslyn In-Line Storage

Control Point ID: CP22

CP22: Allow up to 10 cfs through node 2793 until depth exceeds 6 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-5.8)*150,0)

Dewatering Strategy: dewater structure at no more than 10 cfs.

Hertel Ave North East In-Line Storage

Control Point ID: CP5N2

CP5N2: Allow up to 10 cfs through node 747 until depth exceeds 8.5 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-6)*533,0)

Note that this location has flooding issues. The above maximum allowed excess flow might be larger than the conveyance capacity of the line. It is understood that the maximum allowable flow is limited by the maximum conveyance capacity of the line. This means that the line is capable of surcharging and causing surface flooding even under uncontrolled conditions.

Dewatering Strategy: dewater structure at no more than 10 cfs.

Hertel Ave North West In-Line Storage

Control Point ID: CP5N

CP5N: Allow up to 225 cfs through node 423 until depth exceeds 10 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-8)*533,0)

Note that this location has flooding issues. The above maximum allowed excess flow might be larger than the conveyance capacity of the line. It is understood that the maximum allowable flow is limited by the maximum conveyance capacity of the line. This means that the line is capable of surcharging and causing surface flooding even under uncontrolled conditions.

Dewatering Strategy: dewater structure at no more than 225 cfs.

Hertel Ave South In-Line Storage

Control Point ID: CP5S

CP5S: Allow up to 110 cfs through node d540 until depth exceeds 9.5 feet, all excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-8.5)*1066,0)

Dewatering Strategy: dewater structure at no more than 110 cfs.

Bird East In-Line Storage

Control Point ID: CP7

CP7: Disabled due to line surcharging.

Bird West In-Line Storage

Control Point ID: CP6

CP6: Disabled due to line surcharging.

Fillmore North In-Line Storage

Control Point ID: CP10

CP10: Allow up to 50 cfs through node 10410 until depth exceeds 5.5 feet unless level at node 10492 (overflow point at interceptor line) is greater than 2.8 feet. If level at node 10492 is greater than 2.8 feet then allow no flow unless level at node 10410 is greater than 5.5 feet. All excess flows

are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-5)*140,0)

Dewatering Strategy: dewater structure at no more than 50 cfs.

Fillmore South In-Line Storage

Control Point ID: CP10_2

CP10_2: Allow up to 60 cfs through node 9394 until depth exceeds 7.5 feet unless level at node 10492 (overflow point at interceptor line) is greater than 2.8 feet. If level at node 10492 is greater than 2.8 feet then allow no flow unless level at node 9394 is greater than 7.5 feet. Excess flows are conveyed to the CSO line at node 12654. All excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-7.5)*400,0)

Dewatering Strategy: dewater structure at no more than 60 cfs.

Genesee In-Line Storage

Control Point ID: CP11

CP11: Allow up to 55 cfs through node 11526 until depth exceeds 13.1 feet unless level at node 6778 (overflow point at interceptor line) is greater than 8 feet. If level at node 6778 is greater than 8 feet then allow no flow unless level at node 11526 is greater than 13.1 feet. All excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-12.6)*200,0)

Dewatering Strategy: dewater structure at no more than 55 cfs.

Michigan In-Line Storage

Control Point ID: CP11_2

CP11_2: Allow up to 55 cfs through node 11497 until depth exceeds 14 feet unless level at node 6778 (overflow point at interceptor line) is greater than 8 feet. If level at node 6778 is greater than 8 feet then allow no flow unless level at node 11497 is greater than 14 feet. All excess flows are conveyed to maintain maximum surcharge level. The maximum allowed excess flow conveyed follows the formula:

Flow=max((Level-13.5)*140,0)

Dewatering Strategy: dewater structure at no more than 55 cfs.

CSO Line Storage Areas:

Gibson CSO Line Storage

Control Point ID: CP25

CP25: Flows are stored upstream of node 12701 until depth exceeds 9 feet. If level exceeds 9 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 8625 (overflow line in interceptor) depth retreats to less than 10 feet, the structure is dewatered at a flow rate of 10 cfs.

Montgomery CSO Line Storage

Control Point ID: CP13

CP13: Flows are stored upstream of node 12665 until depth exceeds 9 feet. . If level exceeds 9 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 8625 depth retreats to less than 10 feet, the structure is dewatered at a flow rate of 20 cfs.

Smith CSO Line Storage

Control Point ID: CP12

CP12: Flows are stored upstream of node 12632 until depth exceeds 10 feet. If level exceeds 10 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 8625 (overflow line in interceptor) depth retreats to less than 10 feet, the structure is dewatered at a flow rate of 60 cfs. Dewatering flows are re-entered to the South Interceptor Line at node 8629.

Louisiana CSO Line Storage

Control Point ID: CP14

CP14: If node 14262 depth exceeds 2 feet, all flows upstream of node 14248 until depth exceeds 7 feet. If level exceeds 7 feet, all excess flows are conveyed to maintain maximum surcharge level.

Dewatering Strategy: If node 14262 depth retreats to less than 0.5 feet, the structure is dewatered at a flow rate of 40 cfs. Dewatering flows are re-

entered to the South Interceptor Line through the Hamburg Pump Station at node 14262.

Results of Distributed Control

To properly compare the results of the Distributed or Coordinated Control, the collection system was tested using Local Reactive Control. The following tables detail the overflow volumes for each CSO outfall using the previous Local-Reactive Control for each of the three storms evaluated. The overflow volumes are compared against the original model with no control.

Original vs. Local Reactive RTC, Storm 1 (intensity factor =0.5)

CSO	Outfall node	Original Volume (MG)	RTC, Local (MG)	Volume Reduction (MG)	Percentage Reduction (%)
1	WWTPOF	0.0	0.0	0.0	0%
3	5494	0.0	0.0	0.0	0%
4	10208	0.0	0.0	0.0	0%
	10210				
6	5708	0.0	0.0	0.0	0%
8	5904	0.3	0.3	0.0	0%
10	5551	1.2	1.2	0.0	0%
11	6717	0.0	0.0	0.0	0%
12	6366	1.3	1.3	0.0	0%
	6370				
13	9866	0.0	0.0	0.0	0%
14	15752	0.0	0.0	0.0	0%
15	15762	3.2	3.2	0.0	0%
16	15760	1.2	1.2	0.0	0%
	BR0.00				
17	14853	1.9	1.9	0.0	0%
22	14690	0.0	0.0	0.0	0%
	15439				
25	15467	0.0	0.0	0.0	0%
26	12611	7.3	0.1	7.2	99%
27	10058	0.0	0.0	0.0	0%
28	7509a	0.6	0.6	0.0	0%
	7509b				
29	7731	0.0	0.0	0.0	0%
32	7449w	0.0	0.0	0.0	0%

33	14405	0.2	0.2	0.0	0%
34	BR7.00	0.4	0.4	0.0	0%
35	7258	0.2	0.2	0.0	0%
37	7073	0.0	0.0	0.0	0%
39	7526	0.0	0.0	0.0	0%
44	8117	0.0	0.0	0.0	0%
46	7630	0.1	0.1	0.0	0%
47	8195a	0.0	0.0	0.0	0%
	8195b				
48	7830OUT	0.0	0.0	0.0	0%
49	7579	0.0	0.0	0.0	0%
50	7140	0.0	0.0	0.0	0%
51	6894	0.0	0.0	0.0	0%
52	7743	0.0	0.0	0.0	0%
53	5942	0.0	0.0	0.0	0%
54	14	0.5	0.5	0.0	0%
55	P7	11.2	9.5	1.7	15%
56	2601	0.0	0.0	0.0	0%
57	N34	0.0	0.0	0.0	0%
58	6888	0.4	0.4	0.0	0%
59	10251	0.0	0.0	0.0	0%
60	5778	0.0	0.0	0.0	0%
61	4737	0.0	0.0	0.0	0%
63	16136	0.0	0.0	0.0	0%
64	15152	1.8	1.8	0.0	0%
	BR1.00				
66	14961	1.1	1.1	0.0	0%
TOTAL		**33.0**	**24.1**	**8.9**	**27%**

Original vs. Local Reactive RTC, Storm 2 (intensity factor = 1)

CSO	Outfall node	Original Volume (MG)	RTC, Local (MG)	Volume Reduction (MG)	Percentage Reduction (%)
1	WWTPOF	0.0	0.0	0.0	0%
3	5494	0.2	0.2	0.0	-1%
4	10208	0.1	0.1	0.0	0%
	10210				
6	5708	0.0	0.0	0.0	0%
8	5904	0.6	0.6	0.0	3%
10	5551	2.3	2.2	0.1	3%
11	6717	3.9	5.5	-1.6	-40%
12	6366	7.2	7.2	0.0	0%
	6370				
13	9866	0.4	0.4	0.0	-1%
14	15752	0.0	0.0	0.0	0%
15	15762	4.3	4.3	0.0	0%
16	15760	2.5	2.5	0.0	0%
	BR0.00				
17	14853	4.2	4.0	0.2	4%
22	14690	0.2	0.2	0.0	-1%
	15439				
25	15467	0.1	0.1	0.0	-2%
26	12611	10.9	0.3	10.6	97%
27	10058	0.0	0.0	0.0	0%
28	7509a	1.7	1.7	0.0	0%
	7509b				
29	7731	0.0	0.0	0.0	0%
32	7449w	0.0	0.0	0.0	0%
33	14405	0.4	0.4	0.0	0%
34	BR7.00	0.8	0.8	0.0	0%
35	7258	0.4	0.4	0.0	0%
37	7073	0.0	0.0	0.0	0%
39	7526	0.0	0.0	0.0	0%
44	8117	0.0	0.0	0.0	0%
46	7630	0.1	0.1	0.0	0%
47	8195a	0.1	0.1	0.0	0%
	8195b				
48	7830OUT	0.0	0.0	0.0	0%

49	7579	0.0	0.0	0.0	0%
50	7140	0.0	0.0	0.0	0%
51	6894	0.0	0.0	0.0	0%
52	7743	0.1	0.1	0.0	0%
53	5942	0.3	0.3	0.0	-8%
54	14	1.4	1.4	0.0	0%
55	P7	60.1	57.5	2.5	4%
56	2601	0.0	0.0	0.0	0%
57	N34	0.0	0.0	0.0	0%
58	6888	0.8	0.8	0.0	0%
59	10251	0.0	0.0	0.0	0%
60	5778	0.0	0.0	0.0	0%
61	4737	0.5	0.0	0.5	100%
63	16136	0.1	0.1	0.0	0%
64	15152	3.9	3.9	0.0	0%
	BR1.00				
66	14961	2.4	2.4	0.0	0%
TOTAL		**109.8**	**97.6**	**12.2**	**11%**

Original vs. Local Reactive RTC, Storm 3 (intensity factor =2)

CSO	Outfall node	Original Volume (MG)	RTC, Local (MG)	Volume Reduction (MG)	Percentage Reduction (%)
1	WWTPOF	0.0	0.0	0.0	0%
3	5494	1.6	1.6	0.0	-1%
4	10208	7.5	7.5	0.0	0%
	10210				
6	5708	32.9	33.5	-0.6	-2%
8	5904	1.4	1.3	0.1	8%
10	5551	5.0	4.9	0.1	2%
11	6717	23.5	26.3	-2.7	-12%
12	6366	36.6	36.6	0.0	0%
	6370				
13	9866	6.3	6.3	0.0	0%
14	15752	2.7	2.8	-0.1	-4%
15	15762	7.5	7.5	0.0	0%
16	15760	6.3	6.3	0.0	0%
	BR0.00				
17	14853	22.5	22.1	0.4	2%
22	14690	1.5	1.3	0.2	13%
	15439				
25	15467	1.1	1.1	0.0	0%
26	12611	26.8	7.7	19.1	71%
27	10058	12.9	13.4	-0.5	-4%
28	7509a	8.3	8.3	0.0	0%
	7509b				
29	7731	0.0	0.0	0.0	0%
32	7449w	0.0	0.0	0.0	0%
33	14405	4.9	5.0	-0.1	-2%
34	BR7.00	2.4	2.4	0.0	0%
35	7258	1.2	1.2	0.0	0%
37	7073	2.0	2.0	0.0	0%
39	7526	0.0	0.0	0.0	0%
44	8117	0.0	0.0	0.0	0%
46	7630	0.3	0.3	0.0	0%
47	8195a	0.5	0.5	0.0	0%
	8195b				
48	7830OUT	0.0	0.0	0.0	0%

49	7579	0.0	0.0	0.0	0%
50	7140	0.1	0.1	0.0	-1%
51	6894	0.1	0.1	0.0	0%
52	7743	3.1	3.1	0.0	0%
53	5942	3.6	3.5	0.1	3%
54	14	6.6	6.6	0.0	0%
55	P7	186.7	183.4	3.3	2%
56	2601	0.2	0.2	0.0	-6%
57	N34	0.2	0.2	0.0	-1%
58	6888	1.6	1.6	0.0	0%
59	10251	0.8	1.0	-0.2	-29%
60	5778	0.1	0.1	0.0	0%
61	4737	12.8	8.3	4.5	35%
63	16136	0.5	0.5	0.0	0%
64	15152	9.8	10.9	-1.1	-11%
	BR1.00				
66	14961	5.0	5.0	0.0	0%
TOTAL		**447.0**	**424.6**	**22.3**	**5%**

The following tables detail the overflow volumes for the Distributed or Coordinated Control scheme. As with the Local Reactive, the percentage reductions with respect to the original control are shown.

Original vs. Distributed RTC, Storm 1 (intensity factor = 0.5)

CSO	Outfall node	Original Volume (MG)	RTC, Dist. (MG)	Volume Reduction (MG)	Percentage Reduction (%)
1	WWTPOF	0.0	0.0	0.0	0%
3	5494	0.0	0.0	0.0	0%
4	10208	0.0	0.0	0.0	0%
	10210				
6	5708	0.0	0.0	0.0	0%
8	5904	0.3	0.3	0.0	0%
10	5551	1.2	1.2	0.0	0%
11	6717	0.0	0.0	0.0	0%
12	6366	1.3	1.3	0.0	0%
	6370				
13	9866	0.0	0.0	0.0	0%
14	15752	0.0	0.0	0.0	0%
15	15762	3.2	3.2	0.0	0%
16	15760	1.2	1.2	0.0	0%
	BR0.00				
17	14853	1.9	1.9	0.0	0%
22	14690	0.0	0.0	0.0	0%
	15439				
25	15467	0.0	0.0	0.0	0%
26	12611	7.3	0.1	7.2	99%
27	10058	0.0	0.0	0.0	0%
28	7509a	0.6	0.6	0.0	0%
	7509b				
29	7731	0.0	0.0	0.0	0%
32	7449w	0.0	0.0	0.0	0%
33	14405	0.2	0.2	0.0	0%
34	BR7.00	0.4	0.4	0.0	0%
35	7258	0.2	0.2	0.0	0%
37	7073	0.0	0.0	0.0	0%
39	7526	0.0	0.0	0.0	0%
44	8117	0.0	0.0	0.0	0%

46	7630	0.1	0.1	0.0	0%
47	8195a	0.0	0.0	0.0	0%
	8195b				
48	7830OUT	0.0	0.0	0.0	0%
49	7579	0.0	0.0	0.0	0%
50	7140	0.0	0.0	0.0	0%
51	6894	0.0	0.0	0.0	0%
52	7743	0.0	0.0	0.0	0%
53	5942	0.0	0.0	0.0	0%
54	14	0.5	0.5	0.0	0%
55	P7	11.2	9.5	1.7	15%
56	2601	0.0	0.0	0.0	0%
57	N34	0.0	0.0	0.0	0%
58	6888	0.4	0.4	0.0	0%
59	10251	0.0	0.0	0.0	0%
60	5778	0.0	0.0	0.0	0%
61	4737	0.0	0.0	0.0	0%
63	16136	0.0	0.0	0.0	0%
64	15152	1.8	1.8	0.0	0%
	BR1.00				
66	14961	1.1	1.1	0.0	0%
TOTAL		**33.0**	**24.1**	**8.9**	**27%**

Original vs. Distributed RTC, Storm 2 (intensity factor = 1)					
CSO	Outfall node	Original Volume (MG)	RTC, Dist. (MG)	Volume Reduction (MG)	Percentage Reduction (%)
1	WWTPOF	0.0	0.0	0.0	0%
3	5494	0.2	0.2	0.0	-3%
4	10208	0.1	0.1	0.0	0%
	10210				
6	5708	0.0	0.0	0.0	0%
8	5904	0.6	0.6	0.0	3%
10	5551	2.3	2.2	0.1	3%
11	6717	3.9	5.6	-1.7	-43%
12	6366	7.2	7.2	0.0	0%
	6370				
13	9866	0.4	0.4	0.0	-1%
14	15752	0.0	0.0	0.0	0%
15	15762	4.3	4.3	0.0	0%
16	15760	2.5	2.5	0.0	0%
	BR0.00				
17	14853	4.2	4.0	0.1	4%
22	14690	0.2	0.2	0.0	-1%
	15439				
25	15467	0.1	0.1	0.0	-2%
26	12611	10.9	0.3	10.6	97%
27	10058	0.0	0.0	0.0	-105%
28	7509a	1.7	1.7	0.0	0%
	7509b				
29	7731	0.0	0.0	0.0	0%
32	7449w	0.0	0.0	0.0	0%
33	14405	0.4	0.4	0.0	0%
34	BR7.00	0.8	0.8	0.0	0%
35	7258	0.4	0.4	0.0	0%
37	7073	0.0	0.0	0.0	0%
39	7526	0.0	0.0	0.0	0%
44	8117	0.0	0.0	0.0	0%
46	7630	0.1	0.1	0.0	0%
47	8195a	0.1	0.1	0.0	0%
	8195b				

48	7830OUT	0.0	0.0	0.0	0%
49	7579	0.0	0.0	0.0	0%
50	7140	0.0	0.0	0.0	0%
51	6894	0.0	0.0	0.0	0%
52	7743	0.1	0.1	0.0	0%
53	5942	0.3	0.2	0.1	35%
54	14	1.4	1.4	0.0	0%
55	P7	60.1	57.5	2.5	4%
56	2601	0.0	0.0	0.0	0%
57	N34	0.0	0.0	0.0	0%
58	6888	0.8	0.8	0.0	0%
59	10251	0.0	0.0	0.0	0%
60	5778	0.0	0.0	0.0	0%
61	4737	0.5	0.0	0.5	100%
63	16136	0.1	0.1	0.0	0%
64	15152	3.9	3.9	0.0	0%
	BR1.00				
66	14961	2.4	2.4	0.0	0%
TOTAL		**109.8**	**97.6**	**12.2**	**11%**

Original vs. Distributed RTC, Storm 3 (intensity factor =2)					
CSO	Outfall node	Original Volume (MG)	RTC, Dist. (MG)	Volume Reduction (MG)	Percentage Reduction (%)
1	WWTPOF	0.0	0.0	0.0	0%
3	5494	1.6	1.7	0.0	-2%
4	10208	7.5	7.5	0.0	0%
	10210				
6	5708	32.9	30.6	2.3	7%
8	5904	1.4	1.3	0.1	8%
10	5551	5.0	4.9	0.1	2%
11	6717	23.5	26.4	-2.8	-12%
12	6366	36.6	36.6	0.0	0%
	6370				
13	9866	6.3	6.3	0.0	0%
14	15752	2.7	2.6	0.1	3%
15	15762	7.5	7.4	0.1	1%
16	15760	6.3	6.3	0.0	0%
	BR0.00				
17	14853	22.5	18.9	3.6	16%
22	14690	1.5	1.3	0.2	13%
	15439				
25	15467	1.1	1.1	0.0	0%
26	12611	26.8	10.9	15.9	59%
27	10058	12.9	13.5	-0.7	-5%
28	7509a	8.3	8.3	0.0	0%
	7509b				
29	7731	0.0	0.0	0.0	0%
32	7449w	0.0	0.0	0.0	0%
33	14405	4.9	5.0	0.0	-1%
34	BR7.00	2.4	2.4	0.0	0%
35	7258	1.2	1.2	0.0	0%
37	7073	2.0	2.0	0.0	0%
39	7526	0.0	0.0	0.0	0%
44	8117	0.0	0.0	0.0	0%
46	7630	0.3	0.3	0.0	0%
47	8195a	0.5	0.5	0.0	0%
	8195b				

48	7830OUT	0.0	0.0	0.0	0%
49	7579	0.0	0.0	0.0	0%
50	7140	0.1	0.1	0.0	-1%
51	6894	0.1	0.1	0.0	0%
52	7743	3.1	3.1	0.0	0%
53	5942	3.6	3.2	0.4	11%
54	14	6.6	6.6	0.0	0%
55	P7	186.7	183.4	3.3	2%
56	2601	0.2	0.2	0.0	-5%
57	N34	0.2	0.2	0.0	-1%
58	6888	1.6	1.6	0.0	0%
59	10251	0.8	1.0	-0.2	-22%
60	5778	0.1	0.1	0.0	0%
61	4737	12.8	8.9	4.0	31%
63	16136	0.5	0.5	0.0	0%
64	15152	9.8	10.8	-1.0	-10%
	BR1.00				
66	14961	5.0	5.0	0.0	0%
TOTAL		**447.0**	**421.7**	**25.2**	**6%**

Final Observations:

1. The Distributed or Coordinated Control offers marginal benefits over the Local Reactive Control in particular during Storm 3 a 1% of overflow reduction was observed. This is due to a variety of factors, mainly that BSA's collection system consists of relatively independent service areas that do not interfere with each other until they reach the corresponding interceptor lines. These interceptor lines become rapidly surcharged and do not allow much additional conveyance capacity even during small storms.
2. It is important to observe that CSO11 experiences an increase of CSO volumes. This is due to an increment in the flow pushed into the South Interceptor line as a result of the control system attempting to reduce CSO volumes upstream. This CSO structure is located approximately 0.5 miles south of wastewater treatment plant and underlines the constraints in conveyance capacity in the interceptor lines. The performance of a control system can be further enhanced by improving the conveyance capacity of the "last mile".
3. Similarly to CSO11, CSO61 observes a decrease in CSO volume reduction as a result of the control system attempting to push more water through the North Interceptor line. In this case, the Distributed Control scheme attempts to push more water through this line resulting on an apparent reduction of performance as compared to the Local-Reactive Control.
4. From all studied areas, the one location that sees the largest reduction of overflows is CSO26 with reduction percentages from 100% to 59%. This is due to available storage capacity in both the trunk lines and CSO lines. Note that the distributed control seems to have a reduction of approximately 3MG less than the local-reactive control. These 3MG are shifted from CSO26 to CSO17 resulting on equivalent total volume reductions.
5. The used storm events are based on the existing 12 rain gauge data distributed throughout the service area. Questions remain as to the relevance, accuracy, and granularity of the storm data being used. However, given the small differences observed between CSO volume reductions for equivalent uniform storms, the improvements on the control scheme are expected to render marginal results.

Conclusions:

1. Real Time Control systems can offer substantial reductions of CSO volumes (15% per year or 560 Mgallons) at a fraction of the cost of traditional alternatives.
2. The largest opportunities for Real Time Control exist in the form of in-line storage structures located upstream of the interceptor lines. Improved conveyance does not seem to be viable due to the rapid surcharging of the interceptor lines. Planned improvements on interceptor lines should require an update of the Real Time Control strategy as new opportunities may arise.
3. Two Real Time Control strategies where evaluated: Local Reactive Control and Distributed Control. Due to BSA's collection system configuration, Distributed Control could only be applied in a small percentage of locations rendering marginal improvements according to the model. Local Reactive Control is usually preferred due to its simplicity, reduced cost, and operational robustness. However, Distributed Control tends to be more robust to modeling discrepancies due to the increased control feedback.
4. CSO 26 offers the largest reduction of CSO volumes (in excess of 59% reduction). A first phase of Real Time Control implementation should consider this location as a strong candidate.

Recommendations:

This Real Time Control study offers a first view of the opportunities to Real Time Control for the reduction of CSO volumes. Prior to the physical implementation a number of tasks are recommended:

1. Validation of the observations through more in depth monitoring. It is recommended that an extensive monitoring program is implemented to validate the observations that resulted from this study. The monitoring system should investigate the areas corresponding to the control points. The data obtained from these locations will further increase the understanding of available capacity and other hydraulic parameters in in-line storage locations during actual storms and provide in-sight into the optimization of the control scheme and model.
2. Assessment of the different actuators (inflatable dams, knife gates, movable weirs, etc). A detailed study to evaluate the implementation cost and maintenance requirements offered by various technologies should be considered. In particular, the operation and maintenance of these structures must be well suited for BSA's existing operation strategies. The characteristics of the actuator chosen for a particular structure may vary the way that the control point is modeled.
3. Inventory of control point locations. A more in depth study of the location of the control points is required to better determine the feasibility of control strategy, actuator technology, and maintenance requirements.
4. Identification of an implementation phased schedule. The advantage of Local Reactive Control and Distributed Control schemes is that they can be implemented gradually. An incremental implementation that starts with one or a few control locations is highly recommended as a way to evaluate the operational and maintenance requirements of the system as well as a way to evaluate the benefits of Real Time Control.
5. Implementation of the control schemes in XP SWMM for validation and long term planning. The control schemes implemented in this study were done in EPA-SWMM. These control schemes can be easily incorporated into XP SWMM.

Buffalo Sewer Authority
Real Time Control Evaluation for Sewer System

CAPITAL COST ADDENDUM

The Buffalo Sewer Authority (BSA) is examining the potential of Real Time Control (RTC) to reduce the frequency and severity of its CSO events. In the course of its study, EmNet, LLC identified twenty potential RTC control points, which utilize a combination of inline storage, offline storage, and CSO overflow line storage. These control points are expected to prevent over 560 MG (15% of the total volume) from overflowing in a typical year.

As part of its analysis, EmNet developed the expected capital costs for implementing the twenty control sites. The cost estimation process was based on the process used in BSA's 2004 Long Term Control Plan Draft. In this document, ten locations in the Scajaquada Creek and Black Rock Canal Basins were identified as potential inline storage locations. The cost of the inflatable dam, site work, vault & equipment cost, and installation were then calculated and included in Table 4-14 in Appendix 8-1.

This same cost analysis was performed on each of the twenty locations that EmNet identified. The cross sectional area of the control location was calculated and then used to determine the diameter of an equivalent round pipe, which is the standard configuration for an inflatable dam. This size was then compared against the dimensions of the locations listed in Table 4-14, and most similarly sized dam was used to estimate the cost. If the required dam size was significantly smaller than any dam shown in Table 4-14, then the cost of the inflatable dam was estimated using the City of Indianapolis, IN's Long Term Control Plan. If the required dam size was significantly larger than any dam shown in the table, the largest dam in the table was used. It was assumed that throttling these largest pipes down slightly at the control location would not interfere with the pipe's conveyance requirements.

The same vault & equipment costs and site work costs from the table were also used in this analysis. In addition to these values, an additional cost for instrumentation and control equipment was included at allow for additional monitoring upstream and downstream of the control location. Since the East Amhurst Quarry would utilize its existing infrastructure for RTC, only the cost of instrumentation and control was included for this site. All of these costs were totaled, and it was assumed that the cost of installation would be equivalent to the sum of the material costs. An engineering cost equal to 20% of the cost of materials and installation was also included. Please note that all values were calculated in 2004 dollars in order to be consistent with the LTCP and then converted to 2011 dollars for comparison purposes. A Engineering News-Record Capital Costs Index (ENR CCI) of 7115 was used for 2004, and an ENR CCI of 8998 was used for 2011.

A total capital cost for the twenty RTC locations was determined to be $22.9M, which is equivalent to $0.04 per gallon of overflow prevented.

Capital Costs for Potential RTC Locations

Location	Purpose	Pipe Cross Section Area (ft^2)	Equivalent Diameter for Round Pipe (in)	Size of Inflatable Dam Used (in)	Capital Cost for Inflatable Dam	Vault & Equipment Cost	Inst. and Controls Cost	Site Work	Subtotal	Installation Factor, Including Profit	Engineering Costs (20% of Project Cost)	Total Capital Cost (2004 dollars)	Total Capital Cost (2011 dollars)
E Amhurst and Ericson	Divert additional water to the Quarry	12	46.9	48	138,000	64,000	15,000	75,000	292,000	1	$116,800	700,800	$886,268
E Amhurst Quarry	Store water and pump back into collection system	NA	NA		NA	NA	25,000	NA	25,000	1	$10,000	60,000	$75,879
North Bailey	Inline Storage	49.5	95.3	96	248,160	64,000	15,000	75,000	402,160	1	$160,864	965,184	$1,220,622
South Bailey	Inline Storage	34.2	79.2	84	211,200	64,000	15,000	75,000	365,200	1	$146,080	876,480	$1,108,442
Key	Inline Storage	50.2	95.9	96	248,160	64,000	15,000	75,000	402,160	1	$160,864	965,184	$1,220,622
Floss	Inline Storage	56.8	102.0	96	248,160	64,000	15,000	75,000	402,160	1	$160,864	965,184	$1,220,622
Roslyn	Inline Storage	81	121.9	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725
Hertel Northern Line, East	Inline Storage	72.3	115.1	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725
Hertel Northern Line, West	Inline Storage	72.3	115.1	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725
Hertel South Line	Inline Storage	44.2	90.0	84	211,200	64,000	15,000	75,000	365,200	1	$146,080	876,480	$1,108,442

Bird Ave, East	Inline Storage	56.8	102.0	96	248,160	64,000	15,000	75,000	402,160	1	$160,864	965,184	$1,220,622
Bird Ave, West	Inline Storage	74.7	117.0	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725
Fillmore North	Inline Storage	44.2	90.0	84	211,200	64,000	15,000	75,000	365,200	1	$146,080	876,480	$1,108,442
Fillmore South	Inline Storage	44.2	90.0	84	211,200	64,000	15,000	75,000	365,200	1	$146,080	876,480	$1,108,442
Genesee	Inline Storage	28.3	72.0	72	205,500	64,000	15,000	75,000	359,500	1	$143,800	862,800	$1,091,142
Michigan	Inline Storage	63.6	108.0	96	248,160	64,000	15,000	75,000	402,160	1	$160,864	965,184	$1,220,622
Gibson	CSO Line Storage	72.3	115.1	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725
Montgo-mery	CSO Line Storage	76.5	118.4	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725
Smith	CSO Line Storage	172	177.6	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725
Louisiana	CSO Line Storage	120	148.3	120	269,280	64,000	15,000	75,000	423,280	1	$169,312	1,015,872	$1,284,725

TOTAL= $22,867,966

BPR CSO

The leader in urban water control & systems optimization



Buffalo Sewer Authority

Preliminary Assessment of RTC Potential

FINAL DRAFT VERSION

May 12, 2011
Revision 1

Buffalo Sewer Authority

Preliminary Assessment of RTC Potential

FINAL DRAFT VERSION

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GLOSSARY OF TERMS

Dry Weather Flow

Dry weather flow is the combination of the base flow and sanitary sewage from domestic and trade (ICI) sources during dry weather.

Combined Trunk Sewer

Combined trunk sewers collect discharges from local combined sewers and carry both sanitary sewage and storm runoff. A portion of flows in combined trunks are intercepted and sent to the treatment plant, while flows exceeding the interception capacity can be diverted to another sewer or to the receiving waters.

Combined Sewer Overflow

Combined sewer overflow (CSO) is flow originating from a combined sewer that exceeds the interceptor capacity and is conveyed to receiving waters.

Combined Sewer Overflow Outfalls

These outfalls convey a mix of CSOs and storm outflows from the storm relief sewers.

Intercepted WWF

Intercepted WWF refers to all wet weather flow (not including dry weather flow) that is intercepted into an interceptor or sanitary trunk sewer that will be conveyed to a wastewater treatment plant with no chance of overflowing.

Interception Factor

The interception factor is a value referencing the amount of intercepted flow into an interceptor or trunk with respect to a given benchmark; in most cases it is the DWF.

Interception Rate (Threshold and Maximum)

Threshold interception rate is the ratio of intercepted flow to total flow into an interceptor or trunk as overflow or bypass begins. (The maximum interception rate is the ratio of the total intercepted flow to the total flow into an interceptor or trunk.)

Sewer Patrol Point

General term that refers to all types of hydraulic structures whose purpose is to control flow between different trunk sewers or interceptors by diversion, interception, or overflow.

Wet Weather Flow

Wet weather flow (WWF) refers to all flow that is generated from stormwater runoff.

ABBREVIATIONS

BMP	Best Management Practices
BSA	Buffalo Sewer Authority
DSS	Decision Support System
DWF	Dry Weather Flow
CPI	Cost performance Indicator
CSO	Combined Sewer Overflow
CTS	Combined Trunk Sewer
GOP	Global and Optimal Control
HGL	Hydraulic Grade Line
HMI	Human Machine Interface
LTCP	Long Term Control Plan
MG	Million gallons
MGD	Million gallons per day
NI	North Interceptor
O&M	Operation and Maintenance
PLC	Programmable Logic Controller
RTC	Real Time Control
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SI	South Interceptor
SPP	Sewer Patrol Point
SPDES	State Pollutant Discharge Elimination Permit
STI	Scajaquada Tunnel Interceptor
USEPA	United States Environmental Protection Agency
UPS	Uninterrupted Power Supply
WWF	Wet Weather Flow
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This preliminary assessment of real time control potential for the Buffalo's combined sewer system identifies the following main benefits:

- Maximize the utilization of existing infrastructure;
- Reduce the volume of combined sewer overflows (CSO) system-wide by 20% annually;
- Reduce discharges at specific CSO sites.

The improvements also support operators, helping to optimize and standardize operations during wet weather events.

Study Objective and Scope of Work

The Buffalo Sewer Authority (BSA) operates and maintains the City's public sewage collection and wastewater treatment system. The system includes 850 miles of sewer mains and collectors, most of which are combined storm and sanitary sewers, as well as ten outlying pumping stations, and the Bird Island Wastewater Treatment Plant (WWTP).

The BSA learned about the remarkable savings on capital improvements that other communities have achieved by integrating real time control (RTC) into their Combined Sewer Overflow (CSO) Long-Term Control Plan (LTCP) to meet regulatory requirements and address water quality concerns. As a leading provider of wet weather management technologies in RTC, BPR CSO has been asked to provide specialized engineering services and technical support to Malcolm Pirnie, Inc. to evaluate the feasibility and benefits of the RTC technology as applied to the BSA's existing combined sewer system before approving additional capital expenditures for new infrastructures. The main goals of the study are to identify potential control opportunities, to quantify combined sewer overflow reduction, and to provide a conceptual cost-benefit analysis.

The project team conducted a detailed review and analysis of flow management and operations through the review of documentation, hydraulic models in XP-SWMM, and technical workshops with the BSA in order to gain a better understanding of the system and its hydraulic conditions. Potential control opportunities were identified for each of the three main sewer districts (North, Scajaquada, and South-Central) and performance on overflow reduction from these opportunities was evaluated and confirmed through hydraulic simulations. Conceptual construction and implementation cost were estimated for each potential control site, including operation and maintenance considering a 40-year life cycle.

Current System Performance

Under the LTCP, a hydrologic and hydraulic model representing the current system's operational and overflow conditions was developed and calibrated in the XP-SWMM platform. As the BSA is making continuous improvements to its sewer system, projects built and committed under phase 1 of the LTCP are included in the latest 2010 XP-SWMM model provided by Malcolm Pirnie, and defined as the baseline conditions for the purposes of this RTC feasibility study.

Sewer District	Number of active CSO Outfalls	1986 Reference 9-Month Overflow Volume (MG)	% of Total
North	7	748	26%
Scajaquada	8	838	29%
South-Central	27	1,278	45%
TOTAL		**2,863**	

The simulation results for the 9-month seasonal period from the 1986 reference year show that the top 10 CSOs contribute to over 85% of the total

system-wide overflow volume. While the North district has the largest CSO site (CSO 055), the South-Central district contributes the most in terms of CSO volume and occurrences.

Four reference rainfall events (5-min time steps) were selected to provide a better appreciation of the system responses for more frequent events that cause overflows while residual conveyance and storage capacities could still be present within the system. They represent four return periods of 1-week, 2-week, 1-month and 3-month respectively. The performance results from the four selected reference events are used to extrapolate CSO reduction results over all events within the 9-month control period from the 1986 typical year through a regression fit methodology.

Rank	CSO Outfall ID	Sewer District	1986 Reference 9-Month Overflow Volume (MG)	% of Total
1	55	North	712	24.9%
2	6	Scajaquada	395	13.8%
3	53	Scajaquada	342	11.9%
4	26	South-Central	255	8.9%
5	17	South-Central	236	8.3%
		TOP 5 CSOS SUBTOTAL		**68%**

Evaluation of Potential RTC sites

A review of the key network components, along with the results of the overall simulation of baseline conditions, was conducted in order to identify opportunities and constraints related to:

- Increasing regulated inflows to the interceptors (STI, SI, and NI);
- Making use of in-line storage capacities in the main trunk sewer system while meeting safety requirements; and
- Making use of existing underutilized off-line storage.

Sewer District	CSO with RTC potential		Non-Controlled CSO		All CSO Volume (MG)
	CSO Volume (MG)	% of System-Wide Total	CSO Volume (MG)	% of System-Wide Total	
North	712	25%	36	1%	748
Scajaquada	820	29%	18	1%	838
South-Central	728	25%	550	19%	1,278
System-Wide	2,259	79%	604	21%	2,863

The analysis focuses on the top CSOs that account for the majority of overflow volumes.

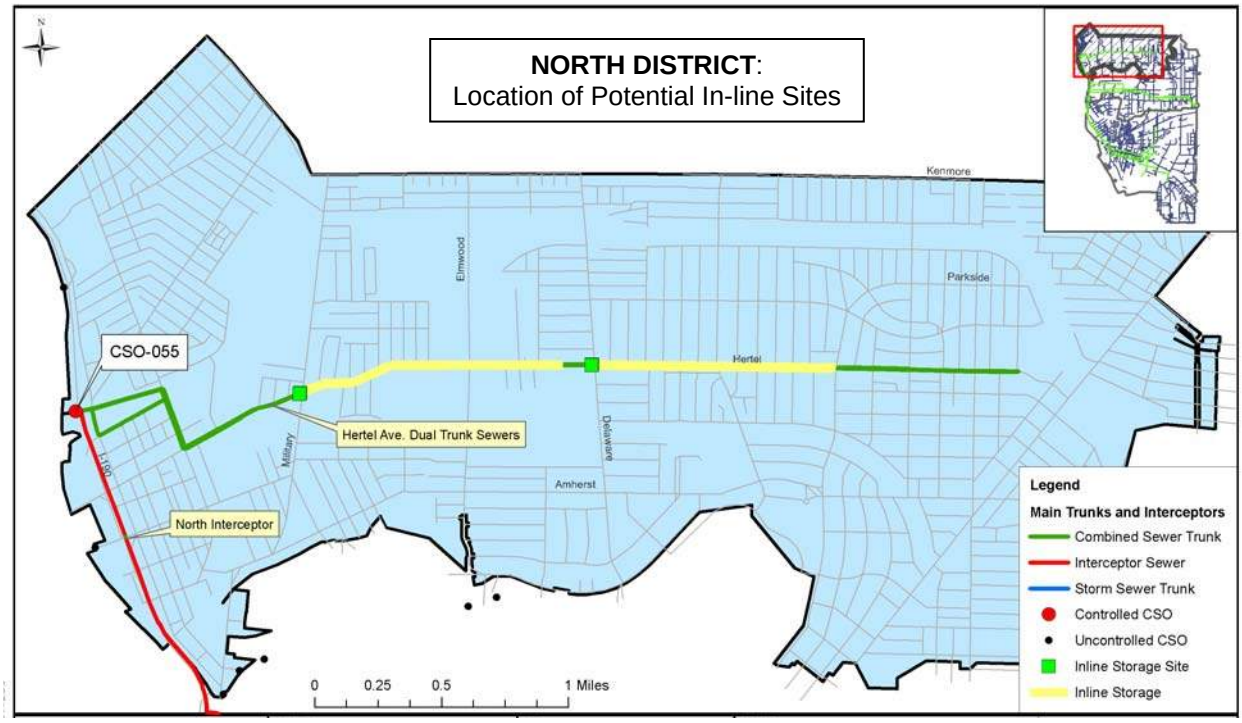
Since the three sewer districts are relatively independent from one another, each is analyzed and presented separately.

North Sewer District

The majority of the North Sewer District is served by a set of large inter-linked combined trunk sewers (Hertel Avenue Dual Trunks), which convey considerable flows to SPP 001. From this point, intercepted flows are conveyed by the North Interceptor (NI) and excess flow overflows at CSO 055. The capacity of NI is far less than that of the incoming trunks and is a significant hydraulic bottleneck in that district. The current weir at CSO 055 is already near the pipe crown, therefore, increased interception at SPP 001 to reduce overflow at CSO 055 is not possible under the baseline condition. However, 4 potential in-line storage branches along the Hertel Avenue Dual Trunks have been identified, with a total estimated volume of 5 MG that can be applied to eliminate and/or reduce overflows at CSO 055 for events larger

Rainfall Frequency	Baseline	RTC with In-line Storage	
	CSO Volume (MG)	New CSO Volume (MG)	Percent Reduction
1-week	0.20	0.20	0%
2-week	3.10	0.39	87%
1-month	39.17	34.23	13%
3-month	78.52	73.58	6%
Extrapolated 9-month District CSO Volume for 1986 Typical Year	747.75	**669.12**	**11%**

than the typical 1-week return period. This RTC intervention leads to a *conservative* seasonal district CSO volume reduction of approximately 11% for the typical year.



Scajaquada District

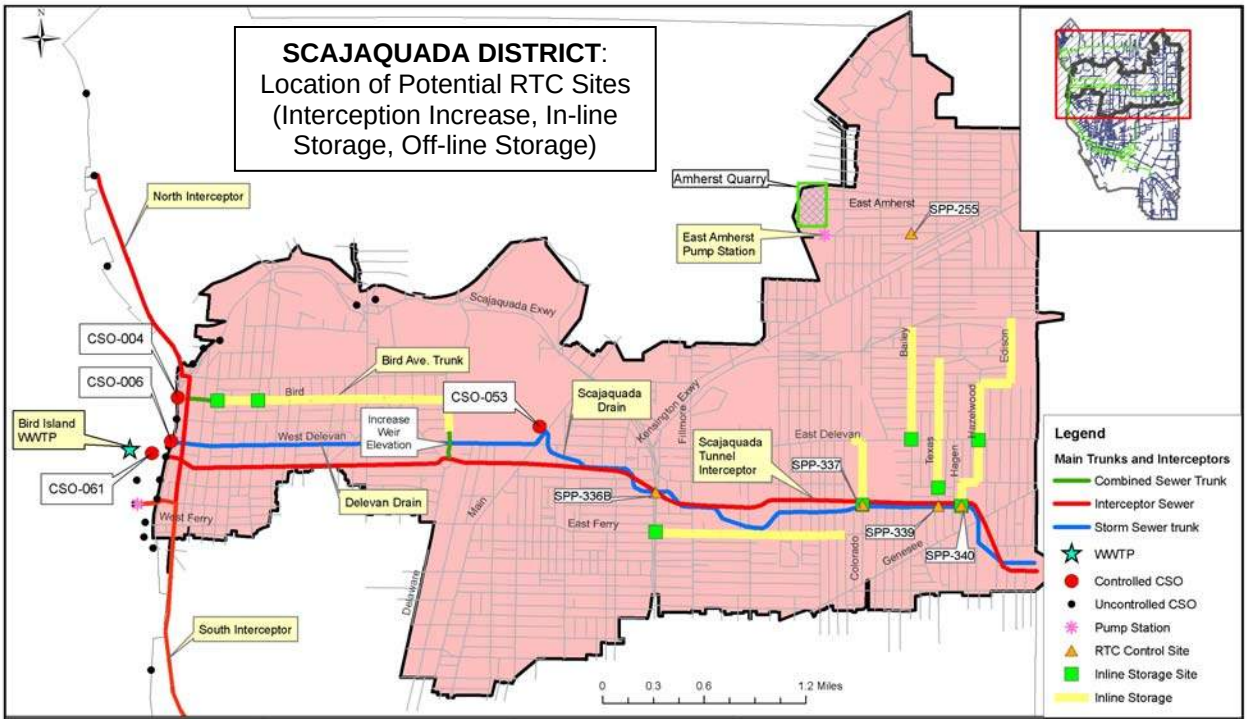
The Scajaquada Sewer District is served by the STI and the Bird Avenue Trunk, both of which drain into the NI. One particularity of this sewer district is that the intercepted flows and the overflows can take different paths depending on the rainfall event characteristics and dual regulation. The baseline overflow analysis shows that a small number of SPPs and CSO outfalls are responsible for the greatest discharge volumes due to low threshold interception rates. Increased interception at 4 SPPs leads to a potential seasonal CSO reduction of 12% for the control period of the typical year.

Rainfall Frequency	Baseline	RTC at SPPs 336B, 337, 339 & 340; In-line Storage at 7 sites; and Off-line Storage at Amherst Quarry	
	CSO Volume (MG)	New CSO Volume (MG)	Percent Reduction
1-week	1.1	0.4	59.3%
2-week	10.4	5.0	51.6%
1-month	27.8	15.0	46.1%
3-month	56.9	48.1	15.5%
Extrapolated 9-month District CSO Volume for 1986 Typical Year	787	**556.8**	**29.3%**

The LTCP already identified certain trunks for in-line storage and additional sites were assessed and selected during this study. Altogether, 7 potential sites with a total volume of 6.3 MG provide a conservative seasonal district CSO reduction of 11%.

The Amherst Quarry is currently a stormwater retention and flocculation treatment facility. Its potential to serve as a possible off-line storage site for CSO control was evaluated. For the 1-week and 2-week

events, since there is sufficient interception and in-line storage capacity downstream of the Quarry, diverting flows to the Quarry is not recommended. However, during the larger 1-month and 3-month events, storing flows in the Quarry has a more significant benefit in reducing overflow at downstream outfalls (e.g. CSO 053). This implies that the use of the Quarry should perhaps be limited to dynamic management that favors usage during only less frequent events to avoid retention and pumping flows that could otherwise be captured by downstream control sites. Off-line storage at the Quarry could provide a seasonal district CSO reduction of approximately 6%. Overall, a conservative estimate of the CSO volume reduction in the Scajaquada district, considering the use of all RTC sites, is approximately 30% for the typical year.



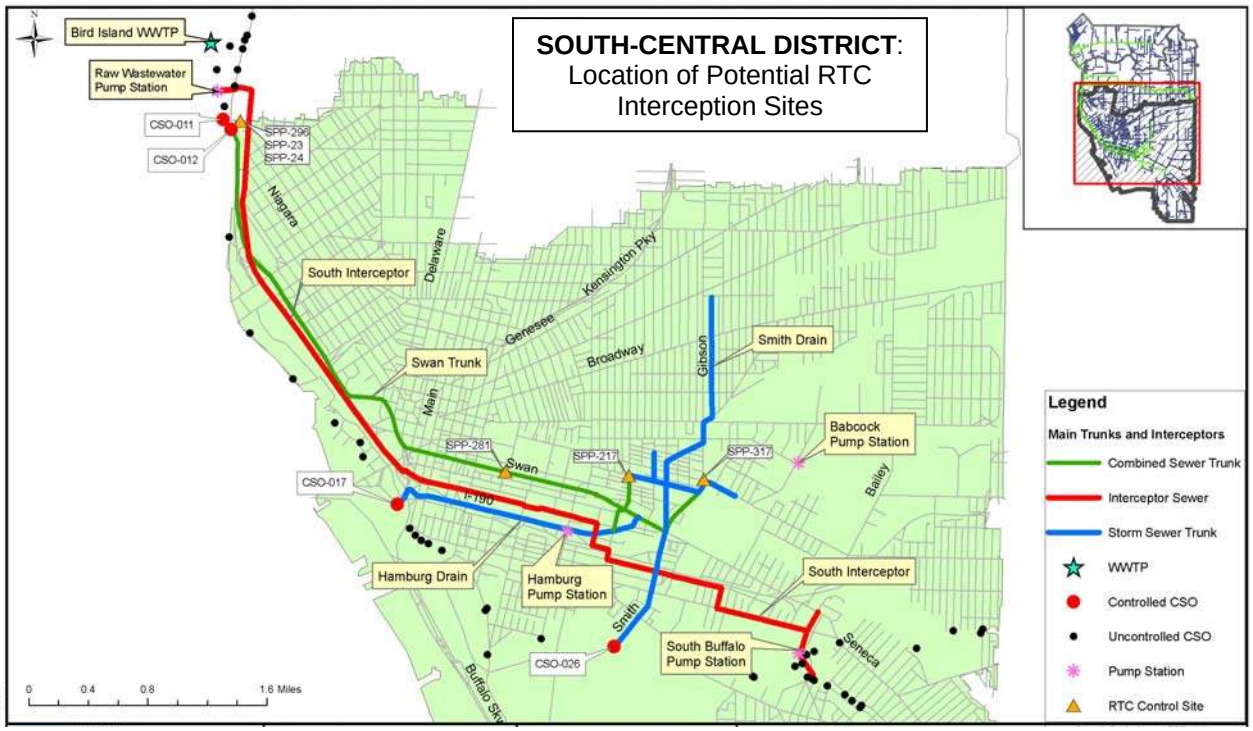
South-Central District

The South-Central Sewer District is the most complex district within the BSA system with several different flow paths for interception and overflow. It is served by the South Interceptor (SI) and the Swan Trunk that are somewhat interconnected through relief points.

The SI is capable of conveying up to 450 cfs, and residual capacity is available for the more frequent events when overflow occurs downstream. The interception rates at three key regulators in the downstream portion of the system could be increased without exceeding the total conveyance capacity. For three additional regulators further upstream, however, the capacity limitations of the Swan Trunk are such that the interception rates cannot be increased without creating additional downstream capacity. This would need to be achieved by regulating the transfer connections between the Swan Trunk and the SI, taking advantage of the significant flow travel time lag between the three regulators and the downstream end of the SI. Together, these two sets of RTC interventions have the potential to provide a seasonal district CSO volume reduction of approximately 20%.

There is no significant in-line storage potential within the district. Although the Hamburg Drain was initially identified as a potential off-line storage site for CSO capture, it was not evaluated further during this study as there is an on-going study by the BSA and its consultant investigating various options.

Rainfall Frequency	Baseline	RTC at CSOs 011 & 012 RTC at SPPs 281, 217, & 317	
	CSO Volume (MG)	New CSO Volume (MG)	Percent Reduction
1-week	2.5	2.4	7%
2-week	14.1	9.2	34.6%
1-month	29.0	16.4	43.6%
3-month	50.4	43.1	14.5%
Extrapolated 9-month District CSO Volume for 1986 Typical Year	1,088	**876**	**19.5%**



Overall System-wide RTC Potential

Validation test simulations confirm hydraulic conditions of RTC regulation and performance of overflow sites for each of the four selected events using the base control functionality of XP-SWMM allowing for reactive control and variation of weir and orifice heights based on adjacent water elevations. The results show a system-wide seasonal CSO volume reduction of approximately 24% based on the extrapolated CSO results from the typical 1986 year.

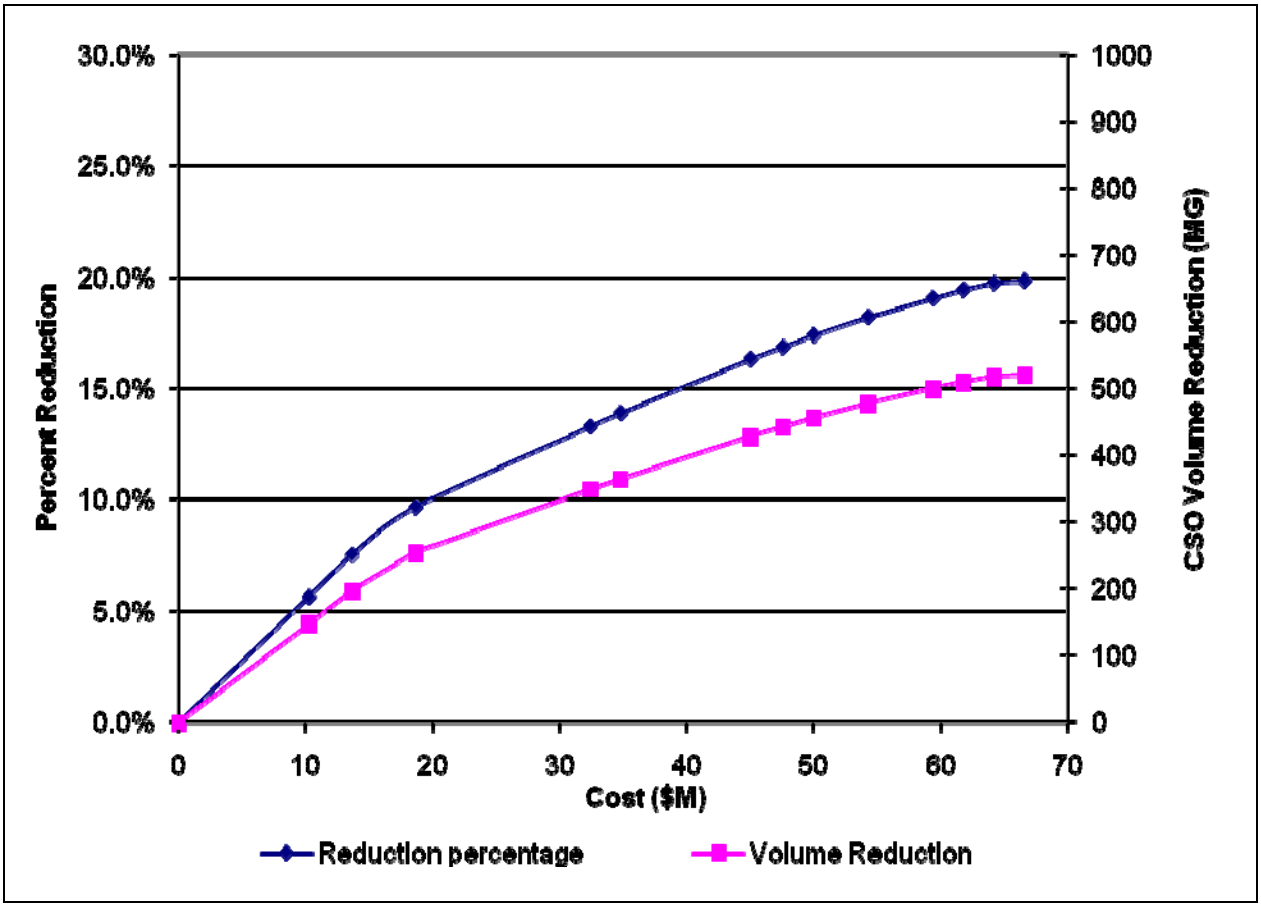
Sewer District	Baseline	RTC Results			Simulated RTC Validation Results		
	Extrapolated 9-mth District CSO Volume for 1986 Typical Year (MG)	CSO Volume (MG)	CSO Reduction		CSO Volume (MG)	CSO Reduction	
			Volumetric (MG)	Percent (%)		Volumetric (MG)	Percent (%)
North	748	669	79	11%	580	168	22%
Scajaquada	787	557	230	29%	558	229	29%
South-Central	1088	876	212	19%	854	233	21%
System Total	2622	2102	521	20%	1995	628	**24%**

Note: Typical year CSO volumes presented are based on the extrapolated results

Conceptual Level Cost Estimates and Cost-Benefit Analysis

A description of RTC technology, system architecture and components is presented in Section 5 of this report. The conceptual cost estimates are based on typical RTC installations in the context of similar projects in Louisville, KY, Wilmington, DE, Ottawa, ON, Hamilton, ON, Montreal, QC, and Quebec City, QC. The cost estimates include construction costs, construction contingencies, engineering services, utilities impacts/relocations, project management, administration and inspection budget for the BSA, and a total project contingency. The conceptual RTC cost estimates represent an "opinion of probable cost" from the most current information available to help guide the BSA's evaluation for future planning. A description of civil instrumentation and control requirements for each proposed RTC site are presented in the report. The operation and maintenance (O&M) costs are estimated on an annual basis taking into consideration the replacement costs for a 40-year life cycle. The total construction and engineering costs for all of the proposed RTC sites are estimated to be $66.5 M, with an annual O&M cost of approximately $500,000.

A cost-benefit analysis was completed for individual RTC sites using cost performance indicators (CPI) presented in $/1000 gallons, which are calculated by dividing the individual cost of each RTC site by the corresponding CSO volume reduction. The lowest CPI corresponds with the most cost-effective sites, which the analysis determined to be the RTC interception sites at SPPs 296, 023, 024 that reduce overflows at CSOs 011 and 012 (Albany). A "knee-of-the-curve" analysis compares the cost of RTC with CSO reduction potentials to demonstrate that certain potential sites offer better CSO volume reduction performance than others. Identified sites that are located at the end of curve could be discarded from further analysis when considering the preferred alternatives since they offer limited benefits.



Integration of RTC with the LTCP

The current study shows only the benefits of RTC on the existing system. As the LTCP progresses and recommends alternatives such as adding new sewers and additional treatment facilities, the capacity and hydraulic conditions of the sewer system would invariable change from the existing conditions and thus create new opportunities for additional RTC sites and new potential for a greater level of control, such as a RTC system with predictive and optimization capabilities to manage a more complex system. Such potential and associated benefits should be evaluated in conjunction with the FINAL DRAFTization of the LTCP. Following this preliminary RTC assessment, the next step should be the integration of RTC into the LTCP to optimize the design of new infrastructures and select preferred alternatives.

Other implementation recommendations include a possible pilot implementation with local control sites providing the largest CSO reduction benefits, along with the implementation of SCADA to provide centralized supervisory control for the operators in addition to performance data for planning and engineering evaluation purposes.

Progressively, as more facilities are built and additional RTC sites become automated, a decision support system would be essential to coordinate the various sites by providing dynamic control of flows at critical junctions where the flow control strategy would adjust depending on priorities, facility status, hydraulic conditions and rainfall flow forecasts. Real-time supervision through monitoring and efficient data management is one of the most important ways to acquire and make use of in-depth knowledge of assets to provide continuous system improvements and value for the capital investments.

1. INTRODUCTION

The Buffalo Sewer Authority (BSA) and their engineering consultants have developed a combined sewer overflow (CSO) long-term control plan (LTCP) in response to regulatory requirements to reduce overflows from the permitted CSO's into the local waterways. In the process of updating and FINAL DRAFTizing the LTCP, the Buffalo Sewer Authority requested that BPR CSO to conduct a preliminary assessment of the potential of real time control (RTC) for its existing service area network system.

RTC technology can be defined as the dynamic management of a sewer network. Unlike static management, dynamic management allows for the distribution of flow in time and space throughout the network. Recognizing and accounting for the temporal and spatial variability of rainfall, of the various runoff responses of sub-catchments, or of the significant travel time between control sites, RTC allows flow regulators, such as pump stations and sluice gates, and interceptor sewers to operate more efficiently and, in turn, maximize the utilization of existing conveyance, treatment and storage capacities. Operational results of successfully implemented RTC systems show that such intervention can effectively optimize overall wastewater system operational performance and minimize the extent of new capital works required to meet the same environmental objectives.

The primary objective of the Real Time Control Feasibility Study is to outline and demonstrate the benefits of implementing RTC in order to reduce the volume and occurrences of combined sewer overflows for the existing collection system. Through performance results and cost-benefit analyses, the demonstrated benefits will have an important impact on the development of future green and grey infrastructure alternatives required to meet the overall CSO abatement objectives of the State Pollutant Discharge Elimination Permit (SPDES) and the United States Environmental Protection Agency (USEPA) CSO Control Policy within the BSA's LTCP.

The main BSA stakeholders participated in a project kick-off meeting during which the attendees presented their objectives and project expectations. The project team conducted a detailed review and analysis of the system's flow management and operations by reviewing the operational data, documentation, and hydraulic models in order to gain an understanding of the hydraulic and operational conditions of the system.

Following that review, a second technical meeting was held with the BSA staff that included management, engineering and operation, along with the BSA's technical consultants, to gather further information with regards to system operation, wet weather conditions, system constraints, control options, and future planning. The project team gained a better understanding of the current operational procedures that are applied under wet weather conditions as well as valuable knowledge and information on the system conditions and responses. An analysis was performed on the configuration and hydraulic capacities of the various major facilities for the three main sewer districts (North, Scajaquada, and South-Central). Next, improvements to the systems and their operations were identified and some of these control opportunities were assessed through hydraulic simulations. FINAL DRAFTly, the study was completed with a cost-benefit analysis and recommendations on potential improvements to the current systems.

The next section of this report provides an overview of the collection system, its baseline overflow conditions, and reference rainfall events (Section 2). The following two sections present an evaluation of the potential for more efficient flow management and an assessment of the potential improvements to the collection system with regards to CSO reduction (Sections 3 and 4). The next two sections present RTC system requirements and conceptual level cost estimates (Sections 5 and 6). The report concludes with a summary of study findings and recommendations for implementation (Section 7).

2. BASELINE CONDITIONS ASSESSMENT

2.1 STUDY AREA

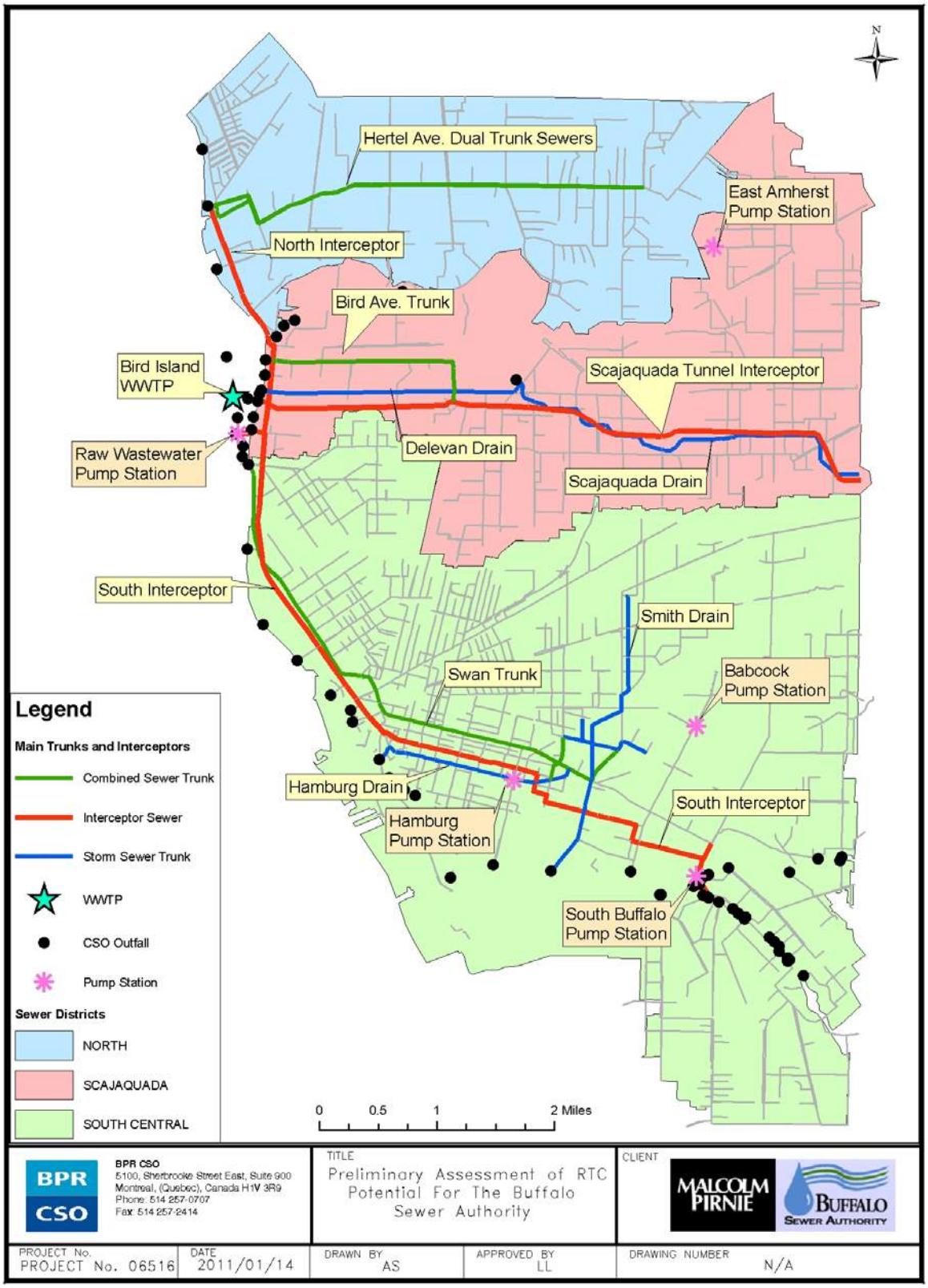
The study area boundaries are equivalent to the Buffalo city limits and encompass a large combined sewer system interspersed with separate sanitary and separate storm sewer areas owned and operated by the BSA. Also within the study area is the Bird Island Wastewater Treatment Plant (WWTP), whose sewershed covers primarily the City of Buffalo, but also extends beyond the study area to serve the towns of Cheektowaga, West Seneca, and Lancaster, as well as the villages of Sloan, Depew and Lancaster.

Two main intercepting sewers convey DWF and a portion of WWF to the Bird Island WWTP: the South Interceptor (SI) and the North Interceptor (NI). Located within the South-Central sewer district, the SI receives the majority of its flows from the Babcock Street sewer, the South Buffalo Pump Station, the Swan Trunk, the Hamburg Street Pump Station, and the Kelly Island Pump Station. Prior to the construction of the SI in the 1930s, the Swan Trunk Interceptor conveyed all wastewater from the southern portion of the City. Currently, the Swan Trunk acts as a combined trunk sewer (CTS) whose flow is either intercepted into the SI or overflows via several possible CSO outfalls. Serving both the North and Scajaquada sewer districts, the NI receives the majority of its flows from the Hertel Avenue dual trunk sewer, the Bird Avenue sewer and the Scajaquada Tunnel Interceptor (STI).

The network contains approximately 250 regulators (also referred to as sewer patrol points (SPP) that convey DWF and a portion of WWF (generally 2-3 times the DWF) to the WWTP via the main interceptor sewers. Excess WWF at the SPPs is diverted to either other trunk sewers or directly to one of 52 permitted CSO outfalls that discharge to 6 receiving waters; namely: the Buffalo River, Niagara River, Scajaquada Creek, Black Rock Canal, Erie Basin, and Cazenovia Creek. Three of the four main pumping stations are located in the South-Central district, namely: Babcock, South Buffalo, and Hamburg. The East Amherst Pump Station is located in the north corner of the Scajaquada district and is responsible for dewatering the Amherst Quarry.

Figure 2-1 on the following page presents the study area, the three main sewer districts (North, Scajaquada, and South), the location of the major interceptors and trunks, the local sewer network, as well as the location of all modeled CSO outfalls, and pump stations. Figure A-1 in Appendix A shows the location of all CSO outfalls and SPPs.

Figure 2-1: Study Area and Location of Main Network Infrastructure



2.2 XPSWMM MODEL

The development and use of a calibrated hydraulic model was an essential element in defining baseline CSO conditions leading to the development of alternatives for the LTCP. Over the past few years, since the LTCP report was submitted to the BSA in 2004, the original model has been improved, upgraded and validated to reflect recent changes and modifications made to the network. For the purposes of this RTC feasibility study, the baseline conditions represent the current state of the sewer network as defined and represented in the latest 2010 XP-SWMM model provided by Malcolm Pirnie:

"BSA_v2010_2009Update_v4_Baseline_wFuture_Ph1_LTCP_Projects_.xp"

This study utilizes the model as is, with the assumption that it is adequately calibrated and sufficiently representative of the real hydraulic behavior of the system.

2.3 BASELINE CSO RESULTS

2.3.1 Updated Typical Year Baseline Overflow Results

The BSA is making continuous improvements to its sewer system; therefore, the overflow results from the 2004 LCTP report are based on an older model version that are no longer valid as a basis of comparison for the current study upon which the potential RTC alternatives are evaluated. Consequently, Malcolm Pirnie re-simulated the 9-month control period (March to November, inclusively) using the 1986 hourly rainfall data and provided the updated annual overflow summary results.

Table 2-1 summarizes the overflow results for the 9-month control period for each district and system-wide. Table A-1 in Appendix A presents the overflow results for the 9-month control period ranked by overflow volume within each sewer district. It should be noted however, that overflow results for individual events were not made available, and thus not included in the tabular summaries.

As shown in the results table, the 9-month control period overflow volume for the entire study area is 2,863 MG. The South-Central district accounts for 45% of the 9-month overflow volumes, followed by the Scajaquada and North districts at 29% and 26%, respectively.

Table 2-1: Typical Year Overflow Volumes (9-month Period) by District

Sewer District	1986 Overflow Volume (9-month period) (MG)	% of System Total
North	748	26%
Scajaquada	838	29%
South-Central	1,278	45%
System TOTAL:	**2,863**	**100%**

Table 2-2 summarizes the top 10 CSO outfalls ranked by overflow volume for the 9-month control period. It should be noted that over 85% of the CSO discharge volume during this period is attributed to only 20% of the CSO outfalls.

Table 2-2: Top 10 CSO Outfalls by Discharge Volume for Typical Year (9-month Period)

Rank (by Volume)	CSO Outfall ID	Location	Sewer District	9-Month Overflow Volume (MG)	% of System Total
1	055	Cornelius Creek	North	712	24.9%
2	006	Delevan Drain	Scajaquada	395	13.8%
3	053	Scajaquada Drain	Scajaquada	342	11.9%
4	026	Smith Drain	South-Central	255	8.9%
5	017	Hamburg Drain	South-Central	236	8.3%
6	011	Albany	South-Central	122	4.2%
7	012	Albany	South-Central	115	4.0%
8	028	Boone	South-Central	114	4.0%
9	066	S. Ogden	South-Central	92	3.2%
10	033	Bailey	South-Central	68	2.4%
			Top 10 Subtotal:	**2,452**	**85.6%**

2.3.2 Selection of Reference Rainfall Events

The typical rainfall year selected and used for the LCTP is 1986. However, the data for the 1986 year is in one-hour intervals and is evenly distributed across the study area. For the purposes of evaluating RTC potential (most effective during more frequent events), using spatially invariable hourly data is not necessarily ideal since peak flows and volumes may be over or under estimated. Alternatively, four equivalent rainfall events whose characteristics were matched to specific return periods from the 1986 typical year were selected from a more recently acquired dataset from the 2009 monitoring campaign, which utilized 11 rain gauges throughout the study area at 5-minute data intervals.

An initial and relative assessment of potential CSO volume reductions from various RTC alternatives can be effectively accomplished by simulating a limited number of rainfalls and then inferring the results of those assessments in determining the CSO reduction for each of the other rainfalls in the annual series. This methodology is applied to extrapolate the overflow volumes of a discrete number of design rainfall events into typical seasonal overflow volumes. Furthermore, the methodology is based on the observation that it is possible to obtain a very good and representative fit of either the volume of overflow per event according to the rainfall depth or the reduction in overflow (volumetric or %) for a RTC approach according to the original volume of overflow for the baseline condition.

The effectiveness of this methodology and the development of the representative fit relationships are explained by the following trends:

- The rainfall depth and overflow volume are very much correlated;
- A minimum reduction in overflow (volumetric or %) is normally obtained for each event. The reduction in overflow tends to be rather constant and similar for events with overflow originally much higher than this reduction. More specifically, this reduction tends to be a little less for shorter events and more significant for events of long duration;
- The application of RTC generates a comparable reduction in overflow volume for all rainfall events that are similar in depth and other characteristics (intensity, duration).

At this initial stage of analysis, it was agreed that simulation results from four representative/design rainfall events were sufficient to identify the minimum reduction in overflow volume that can be generated by the different RTC approaches for all other rainfall events in the typical 1986 year.

The first step was to analyze the rainfall characteristics of the 1986 data in order to identify rainfall events that are representative of various frequencies. These events were selected on the basis of representing return frequencies of 3-months, 1-month, 2-weeks and 1-week per control period. This represents a cross-section of different events that range from a small rainfall occurring frequently to larger events occurring less frequently.

To make the selection and matching of the design events between the two data sources, all of the events within the seasonal 9-month control period between March 1 and November 30 are characterized using the following criteria:

- Duration of actual rainfall (hr);
- Total rainfall depth (inches);
- Maximum 1-hour intensity (inches/hr);

The compiled rainfall data is then sorted and ranked in decreasing order based on the cumulative rainfall depth, as presented in Appendix B (Table B-1 for the 1986 data and Table B-2 for the 2009 data). It should be noted that the since the 2009 data includes 11 rain gauges, the compiled data is averaged for each event (the XP-SWMM model utilizes all rain gauges).

Using the 1986 compiled rainfall data the following associations are made to determine the four required event frequencies:

- 3rd event in 9-month control period for the 3-month event;
- 9th event in 9-month control period for the 1-month event;
- 18th event in 9-month control period for the 2-week event;
- 36th event in 9-month control period for the 1-week event.

In order to determine representative characteristics for each frequency, the average value for each of the criteria listed above was calculated for the events surrounding the rank in the table, as presented in the following tables:

Table 2-3: Average Event Characteristics – 3-month Event

Event		Cumulative Event Depth (in)	Event Duration (h)	Max 1hr Intensity (in/h)
Rank	**Date**			
1	19/05/1986 7:00	3.63	30	1.71
2	03/10/1986 6:00	1.73	13	0.66
3	**15/08/1986 12:00**	**1.5**	**4**	**0.9**
4	01/06/1986 14:00	1.07	10	0.53
5	30/09/1986 3:00	1.02	17	0.74
Average values:		1.79	14.8	0.91

Table 2-4: Average Event Characteristics – 1-month Event

Event		Cumulative Event Depth (in)	Event Duration (h)	Max 1hr Intensity (in/h)
Rank	Date			
7	26/11/1986 5:00	1	20	0.16
8	05/06/1986 9:00	0.99	14	0.62
9	**16/04/1986 1:00**	**0.98**	**25**	**0.16**
10	20/04/1986 13:00	0.8	19	0.13
11	15/09/1986 7:00	0.8	16	0.2
Average values:		0.91	18.8	0.25

Table 2-5: Average Event Characteristics – 2-week Event

Event		Cumulative Event Depth (in)	Event Duration (h)	Max 1hr Intensity (in/h)
Rank	Date			
16	01/08/1986 6:00	0.55	6	0.23
17	07/08/1986 2:00	0.54	12	0.17
18	**10/08/1986 16:00**	**0.54**	**7**	**0.27**
19	05/04/1986 6:00	0.52	24	0.2
20	23/09/1986 2:00	0.52	6	0.17
Average values:		0.53	11.0	0.21

Table 2-6: Average Event Characteristics – 1-week Event

Event		Cumulative Event Depth (in)	Event Duration (h)	Max 1hr Intensity (in/h)
Rank	Date			
34	12/03/1986 23:00	0.28	10	0.07
35	18/03/1986 23:00	0.27	11	0.07
36	**07/06/1986 23:00**	**0.26**	**3**	**0.15**
37	22/06/1986 20:00	0.26	3	0.22
38	27/06/1986 11:00	0.26	5	0.09
Average values:		0.27	6.4	0.12

The average values are then compared and matched with similar events taken from the 2009 rainfall chronology. The event closest to the average characteristics is selected as the most representative event for that frequency. Table 2-7 summarizes the selected events and their characteristics (averaged over 11 rain gauges).

Table 2-7: Selected 2009 Reference Rainfall Events for RTC Study

Applied Event Frequency	Event Start Date	Cumulative Event Depth (in)	Max 1hr Event Intensity (in/hr)	Event Duration (hr)
3-month	23/10/2009	1.44	0.52	22.3
1-month	17/07/2009	0.92	0.42	24.3
2-week	28/08/2009	0.55	0.32	11.8
1-week	28/04/2009	0.34	0.18	6.3

Hyetographs (rainfall intensity in/hour over time) for each of the design rainfall events are presented in the following four figures. All four selected events represent a typical temporal distribution with one or two main peaks of intensity.

Figure 2-2: Hyetograph: 3-month Event (23/10/2009)

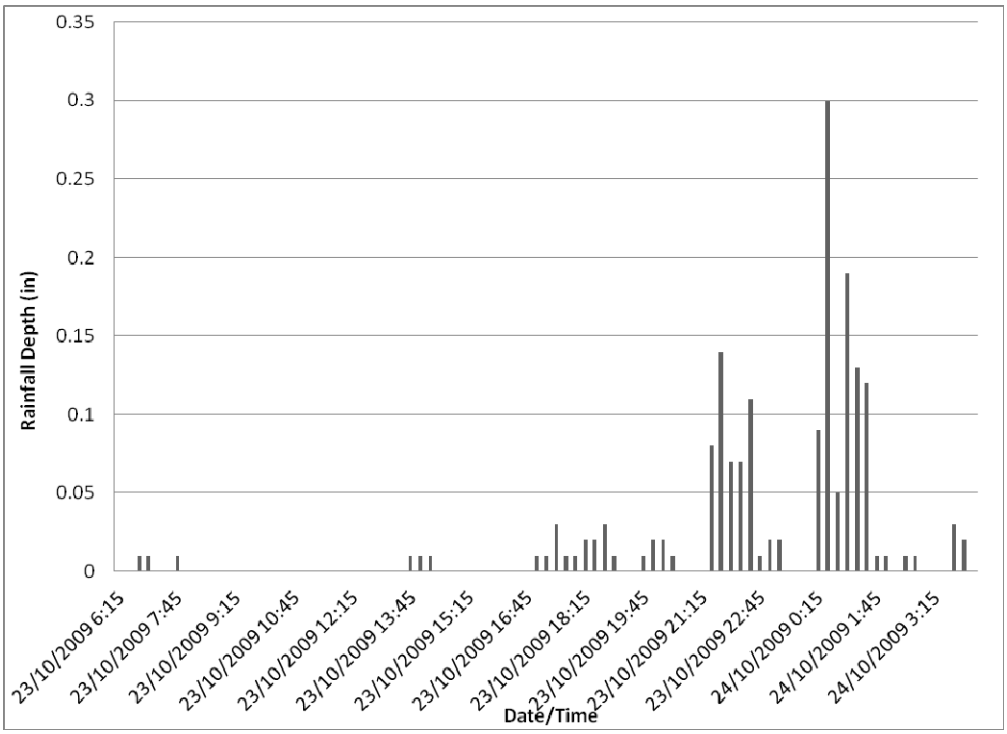


Figure 2-3: Hyetograph: 1-month Event (17/07/2009)

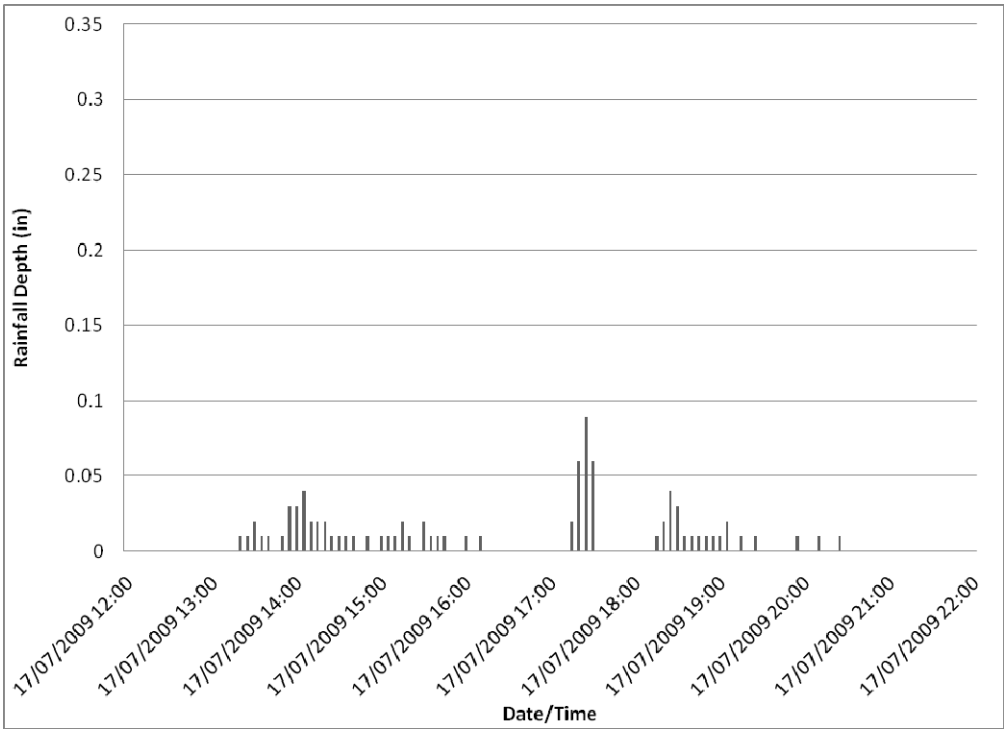


Figure 2-4: Hyetograph: 2-week Event (28/08/2009)

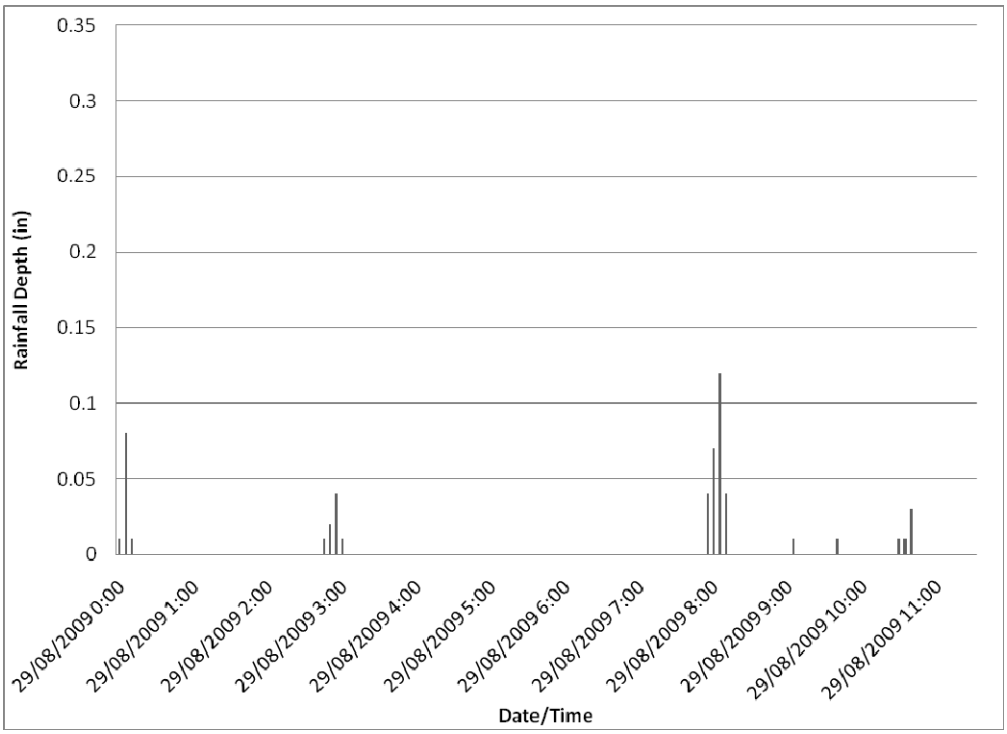
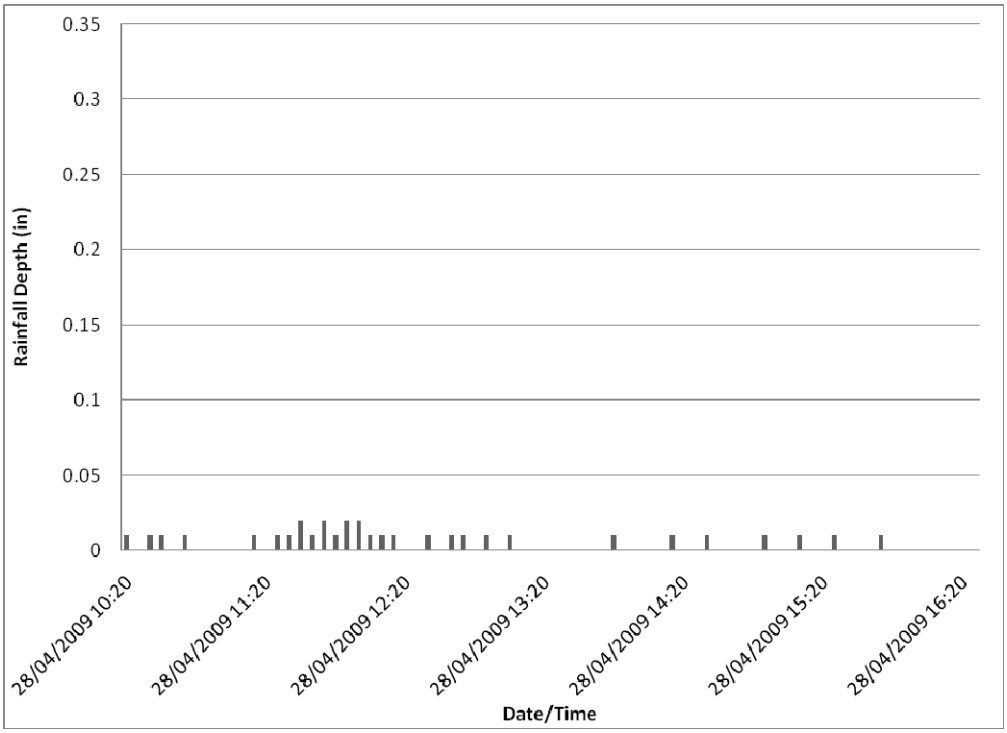


Figure 2-5: Hyetograph: 1-week Event (28/04/2009)



2.3.3 2009 Reference Event Baseline Overflow Results

The XP-SWMM model was simulated for each of the four equivalent 2009 rainfall events. Overflow results for all CSO outfalls and SPPs are included in Appendix A, Table A-2 and Table A-3 respectively. Table 2-8 and Figure 2-6 summarize the total overflow volume results by sewer district for the four selected events, while Table 2-9 summarizes the overflow distribution in percentage by event for each sewer district. By comparing the distributions, the collective overflows from the Scajaquada District are relatively consistent depending on the event, while the overflow from the North District are more significant during larger events, and the overflow from the South-Central District are more significant during smaller events. Part of this is attributed to the rainfall distribution and characteristics, but also due to the number and hydraulic setup and capacity of each district's SPPs as well of the number of CSO outfalls.

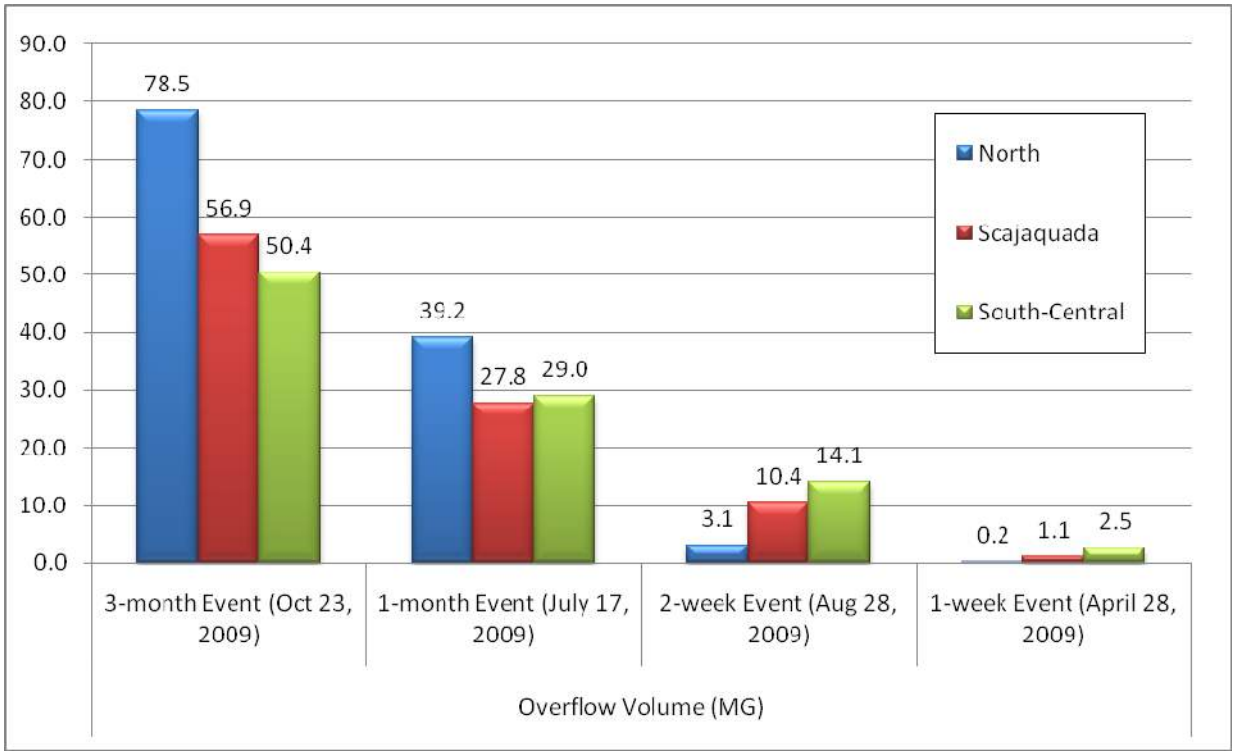
Table 2-8: Volumetric Distribution of Overflow Volumes by Sewer District and Event

Sewer District	Overflow Volume – Selected 2009 Events (MG)			
	3-month Event (Oct 23, 2009)	1-month Event (July 17, 2009)	2-week Event (Aug 28, 2009)	1-week Event (April 28, 2009)
North	78.5	39.2	3.1	0.2
Scajaquada	56.9	27.8	10.4	1.1
South-Central	50.4	29.0	14.1	2.5
SYSTEM TOTAL:	185.8	95.9	27.6	3.8

Table 2-9: Percentage Distribution of Overflow Volumes by Sewer District & Event

Sewer District	% of Total Event Overflow			
	3-month Event (Oct 23, 2009)	1-month Event (July 17, 2009)	2-week Event (Aug 28, 2009)	1-week Event (April 28, 2009)
North	42%	41%	11%	5%
Scajaquada	31%	29%	38%	28%
South-Central	27%	30%	51%	67%

Figure 2-6: Volumetric Distribution of Overflow Volumes by Sewer District and Event



As indicated in the previous section, the South-Central District accounts for the greatest majority of the overflow volume over the 9-month control period during the typical year. This indicates that the CSO outfalls from this district are active more often over a greater variety of events, thus collectively contributing to greater overflow volumes.

3. IDENTIFICATION OF RTC OPPORTUNITIES AND CONSTRAINTS

3.1 METHODOLOGY AND ASSESSMENT CRITERIA

3.1.1 Methodology

A review of the key network components along with the results of the overall simulation of baseline conditions was conducted in order to identify:

- Opportunities for additional flow capture;
- System constraints and limitations;
- Potential control sites

The simulation of one of the selected reference rainfall events (equivalent typical 2-week event from 2009 rainfall chronology), is analyzed and presented to help identify and illustrate system opportunities and constraints. Data is compiled and comparisons are made between: sewer flow capacities, peak flows, the duration of peak flows, hydraulic grade line (HGL), times to travel from different parts of the network, and the duration of peak conditions. Preliminary estimates of residual hydraulic capacity for flow conveyance and in-line storage in the main collection and interception trunks are determined and assessed. Capacities along the main flow paths are evaluated to help identify hydraulic bottlenecks and opportunities. The results of this review were then used to define the RTC approach that is presented and evaluated in Sections 3 and 4.

3.1.2 Goals and Criteria

The methodology that is applied for the selection of the control sites is based on finding opportunities in the system to achieve the goals described below. These goals relate to better management of flow in wet weather flow conditions and maximized uses of available capacities in all situations.

1. *Increasing regulated inflows to the interceptors (STI, SI, and NI)*

   For most rainfall events and for much of their duration, peak flow conditions in the STI, SI and at the WWTP are below the available capacity. Even in cases where flows approach or exceed the interceptor or WWTP capacity, they will do so for only a short period of time. The remainder of the time, residual capacity is available. This is due to the limitations of static regulation where flow controls are set primarily to prevent excess flow in the interception system for significant and critical events. For most, and less significant rainfall events, peak flows are lower because:

   - Flows from non-regulated inflows and direct connections to the interceptors are smaller than they would be under maximum peak flow conditions;
   - The time to travel within the network means that peak flows from different areas do not always coincide; thus allowing for windows of opportunity for adding more flow to the system while overflow is occurring;
   - The trunk collection system provides an attenuation of peak flows;
   - Events with durations shorter than the time to travel in the interceptors will not generate peak flow conditions at the downstream end since one or many of the major inflows into the interceptors will not arrive at the same time as the others.

   To take advantage of this residual capacity in the system and maximize wet weather flow capture, the approach first identifies the major overflow sites responsible for the majority of the overflow volumes. These overflow sites represent the sites with the greatest potential for additional flow interception. For a typical network, it is not unusual to find that 20% of the regulators and weirs can generate up to 80% of the overflow volume. These locations are thus the prime candidates for real time control sites.

2. Making use of in-line storage capacities in the main trunk sewer system

Potential for in-line storage capacity within an existing system is typically evaluated for interception and collection trunks, considering:

- Locations where the upstream profile has a relatively flat slope thereby maximizing the length of pipe where storage can take place;
- Pipes with diameters of at least 3 ft;
- As a rule of thumb, a potential in-line storage site should have a storage capacity of at least 0.5 MG or more to be cost effective when compared to off-line storage.

The initial screening assessments of in-line storage are made considering:

- That, in most cases, the maximum water level should be at crown level to minimize the risk of flooding. In cases where the pipe is deep, the evaluation criteria is that the level should be at least 15 ft below the ground elevation or that the maximum level is less than 10 ft above the crown of the conduit. Critical elevations are verified prior to confirming the maximum surcharge elevation that is to be applied;
- A first cut screening estimate of the total volume available along a sewer line, in order to identify potential candidates, considering a given maximum water elevation for in-line storage.

The above assessment leads to the identification of the most promising locations for providing in-line storage. Further investigations of the impact that the proposed surcharge elevations may have on tributary sewer connections are then made prior to confirming the locations as valid in-line storage candidates. The main criteria for the selection of in-line storage sites that are to be part of the various approaches are: that there should be no increased risk of flooding, and, the total amount of effective storage volume that is available. In order to be cost effective, this volume has to be significant enough to have a beneficial impact on overflow volumes.

3. Making use of existing underutilized off-line storage

The potential for underutilized offline storage opportunities within an existing system is evaluated on a case by case basis considering:

- Current operation (if any) and possible opportunities and constraints related to increasing flow conveyance;
- Requirements and challenges related to retention and dewatering;
- Available residual capacity.

3.2 WET WEATHER SYSTEM ANALYSIS

Based on model observations and the baseline results that were summarized in Section 2.3.3, the following sub-section explores key findings on the system's constraints and discusses potential RTC opportunities. Since the sewer districts are relatively independent from one another, each is analyzed and presented separately.

3.2.1 North District Analysis

The majority of the North Sewer District is served by a set of large inter-linked trunk sewers (Hertel Avenue Dual Trunks), which receive mostly unregulated flows from local sewers. The Hertel Avenue Dual Trunks connect with the NI at SPP 001, while the remaining drainage areas in the district drain directly to the NI downstream of this junction. Flows that are not intercepted by the NI at SPP 001 overflow to the Niagara River at CSO 055 (Cornelius Creek), which accounts for 95% of the district's typical discharge

volumes over 9 months (25% system-wide). Since the remaining five CSO sites within the North District discharge considerably less volume than CSO 055, they have not been further considered for the current analysis.

Increasing Regulated Inflows

As the Hertel Dual Trunks are able to convey considerable flows to SPP 001, and since the capacity of the NI is far less than that of the incoming trunks, SPP 001 becomes a significant hydraulic bottleneck in the system. With a weir crest elevation of 6.8 ft (slightly below the crown elevation of the NI), overflow does not occur during more frequent events. However, during less frequent events, the NI's inability to convey upstream flows and the backflow effects from a high HGL in the NI are responsible for the significant overflow volumes at CSO 055. Due to the limited interception capacity at SPP 001, this is not an ideal site for increasing regulated inflows since overflows do not occur while there is available downstream capacity.

In-line Storage

Based on a review of the characteristics of the Hertel Avenue Dual Trunks, there is potential for implementing in-line storage within certain reaches meeting the previously stated minimum criteria. Since both the upper and lower branches are linked at certain points, the selected locations begin and end at adjacent manholes.

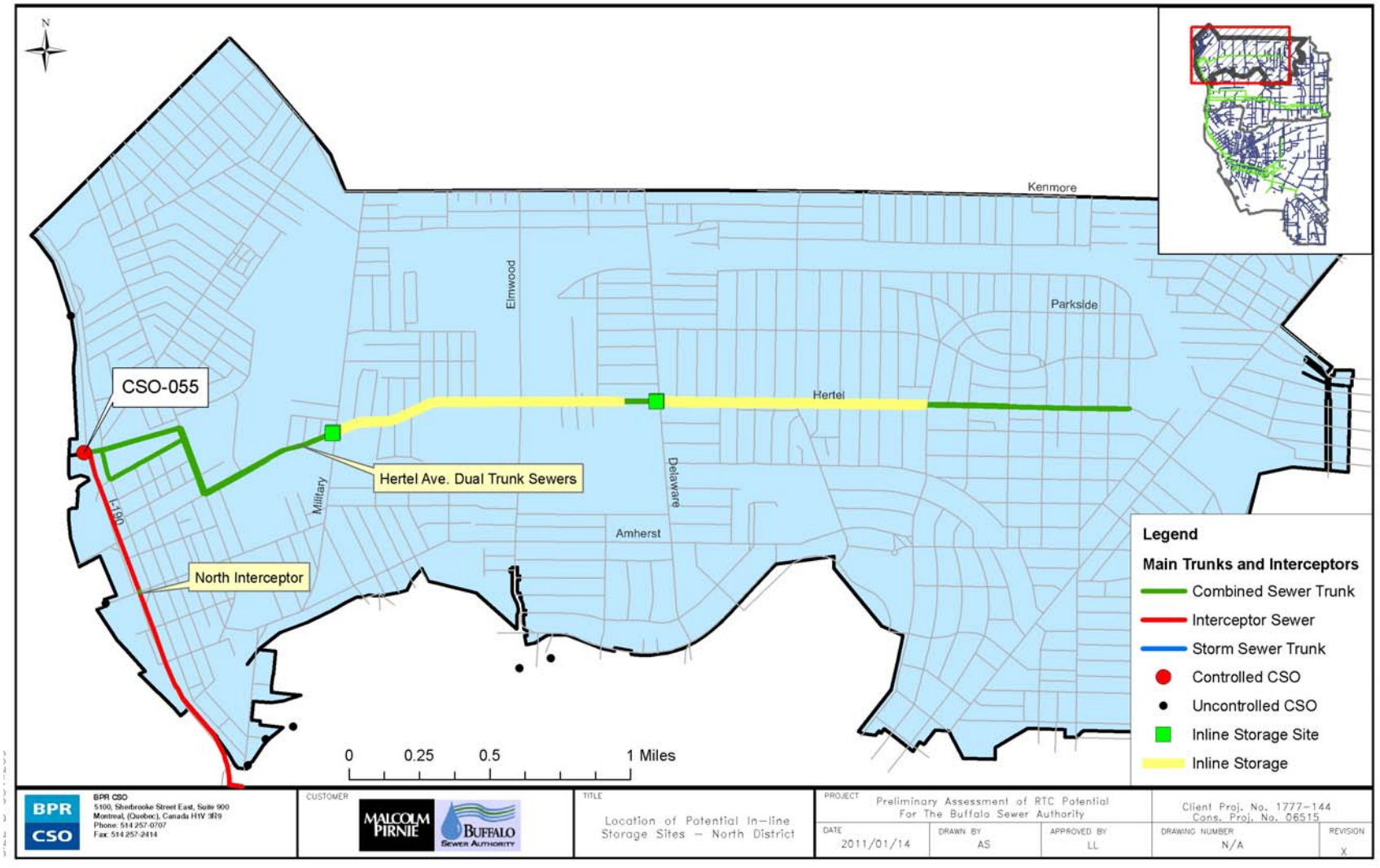
The first cut screening estimate of the total volume storage along the Hertel Trunks is summarized in Table 3-1, while Figure 3-1 shows the location and extent of each potential storage reach, and Figure C-1 to Figure C-4 in Appendix C show their profiles.

Table 3-1: Summary of Potential In-line Storage Sites - North District

Reach ID	Potential In-line Downstream Control Site				Extent of Upstream In-line Storage		Calculated Storage Volume (MG)
	Model Node	Location	Crown Elevation Considered	Conduit Dimensions (D/S)	Model Node	Location	
Military (Upper Branch)	395	Military Rd	580.45 ft	8.5 ft x 11.3 ft (rectangular)	495	W of Delaware Ave	1.9
Military (Lower Branch)	544	Military Rd	580.45 ft	8 ft x 9 ft (rectangular)	626	W of Delaware Ave	1.1
Delaware (Upper Branch)	455	Delaware Ave	591.09 ft	8.5 ft x 10.5 ft (rectangular)	676	Parkside Ave	1.3
Delaware (Lower Branch)	1042	Delaware Ave	589.22 ft	7.5 ft (Circular)	653	Parkside Ave	0.7
						TOTAL:	**5.0**

It should be noted that the calculated storage volumes represent a conservative value of CSO reduction at the impacted outfall (in this case, CSO 055) considering a maximum water elevation at the downstream crown level of each reach. Therefore, considering all four reaches, the in-line storage capacity is conservatively in the order of 5 MG.

Figure 3-1: Location of Potential In-line Storage Sites - North District



3.2.2 Scajaquada District Analysis

The Scajaquada Sewer District is served by the STI and the Bird Avenue Trunk, both of which drain into the NI. Under wet weather flow conditions, the district's main SPPs are able to intercept approximately six times the DWF into the STI and the Bird Trunk, while the overflow portion of certain SPPs is conveyed to either the Scajaquada or Delevan drains, which discharge at CSOs 053 and 006, respectively. Since the hydraulic capacity of most SPPs is such that the maximum interception rates have been established to protect the interceptor system during extreme events, overflows may occur unnecessarily for smaller and more frequent rainfall events before the capacity of the interceptor has been reached.

One particularity of this sewer district is that the intercepted flows and the overflows can take different paths depending on the rainfall event characteristics and dual-regulation (i.e. a portion of intercepted flows can overflow further downstream, and portions of overflow discharges can be redirected to different outfalls). This is primarily due to the evolution of certain trunk sewers in this district which were originally constructed to convey different types of flows, and due to inherent safety redundancies in the system that allow for flow relief during extreme events. For example flows that have already been intercepted by either the STI or Bird trunks can overflow at CSOs 061 and 004 respectively, under high HGL conditions caused by increased intercepted flows and/or hydraulic bottlenecks in the NI during less frequent events. A more convoluted example is SPP 332, which is at the junction of the STI and the Bird Trunk: flows that are not intercepted into the STI are conveyed to the Bird Trunk and will be intercepted by the NI, or overflow into the Delavan Drain at SPP 180, or overflow at CSO 004.

During dry weather conditions, base flow from Scajaquada Creek is conveyed through the Scajaquada Drain and out through CSO 053 to the open creek with no overflow from the tributary SPPs. During wet weather, however, once the capacity at SPP 170A/CSO 053 is reached, flows are diverted to the Delevan Drain which overflows to the Black Rock Canal at CSO 006. These two CSOs collectively account for 88% of the district's typical annual discharge volumes (26% system-wide). It should be noted that while these CSO outfalls are very significant, a large proportion of their discharge volume can be attributed to the creek flow during wet weather conditions, which continues to contribute to the volume discharge at CSOs 053 and 006 well after the end of the rainfall event due to slower response from the upstream watershed. Furthermore, the SPPs that overflow to these drains are only active during a short period. Consequently, from an RTC perspective, it is more practical to prioritize the control and reduction of overflows at the SPP level rather than attempting to mitigate the large volumes discharging at these two CSO outfalls.

Increasing Regulated Inflows

The baseline overflow analysis shows that a small number of SPPs and CSO outfalls are responsible for the greatest discharge volumes due to low threshold interception rates. Consequently, approximately 10 major SPPs were initially considered for further analysis to determine if interception rates could be increased in an effort to reduce overflow.

Based on the available capacity in the STI, the existing hydraulic setup of the major SPPs, and their limited threshold interception rates, four particular SPPs displayed the greatest potential for increasing interception rates to the STI to significantly reduce or eliminate overflows during most events. Using the 3-month event baseline simulation results, it was determined that since the STI is capable of conveying up to 365 cfs, the interception rates at the four selected sites could be proportionally increased to a conservative rate that still does not exceed this capacity during the more frequent events (i.e. 1-week and 2-week events). Consequently, the STI can be more fully utilized before overflow occurs at these SPPs.

It should be noted, however, that although the STI relief overflow at CSO 061 is activated when the flow is above 250 cfs (and/or HGL is above weir crest elevation of 11.2 ft above the downstream crown), the application of RTC for increased flow capture on the four selected SPPs would most likely still result in an

overall CSO reduction for the district during the most frequent events. Figure 3-2 shows the location of the four potential RTC control sites at existing SPPs.

In-line Storage

Based on an assessment of the district's trunk sewer characteristics, there is potential for implementing in-line storage within several reaches that meet the previously stated minimum criteria. Several of the reaches identified in the current analysis had also been identified in the 2004 LTCP report.

The first cut screening estimate of the total volume storage along the identified reaches is summarized in Table 3-2, while Figure 3-2 shows the location and extent of each potential storage reach. The profiles for each in-line storage branch are presented in Figure C-5 to Figure C-10 in Appendix C.

Table 3-2: Summary of Potential In-line Storage Sites - Scajaquada District

Reach ID	Downstream Control Site				Extent of Upstream Storage		Calculated In-line Storage Volume (MG)
	Model Node	Location	Crown Elevation (ft)	Conduit Dimensions	Model Node	Location	
Bird	5723	Bird & Dewitt	595.02	8 ft (circular)	10381	Delaware & Saybrook	1.6
East Ferry (SPP 336B)	4312	Kensington Expy & East Ferry	625.06	7 ft (circular)	4146	East Ferry & Cornwall	1.2
Colorado (SPP 337)	2973	Scajaquada & Colorado	632.09	9 ft x 5 ft (rectangular)	3018	East Delevan & Northumberland	0.2
Bailey (SPP 338)	3595	Bailey & East Delevan	636.64	6.75 ft (circular)	3640	Bailey & Oakmont	0.6
Texas (SPP 339)	2793	Texas & Lang	635.38	13.5 ft x 6 ft (rectangular)	2,730	Suffolk & Langfield	1.1
Hagen (SPP 340)	2658	Hazelwood & East Delevan	640.14	8.5 ft (circular)	2750	Edison & Kensington	1.7
	2632	Hagen & Kerns	630.54	8.5 ft (circular)	2658	Hazelwood & East Delevan	
						Total:	**6.3**

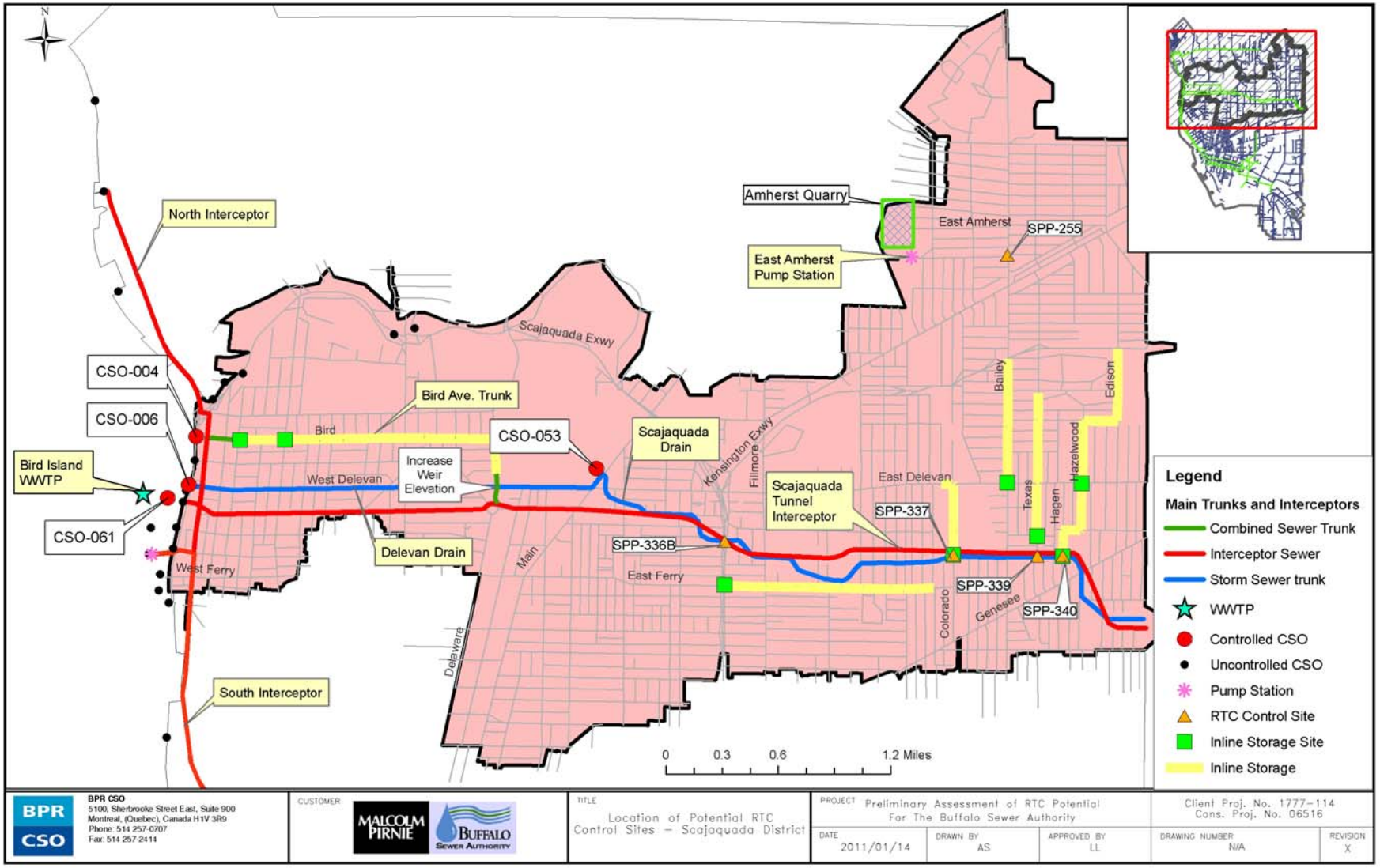
It should be noted that the calculated storage volumes represent the available capacities in the identified reaches considering a maximum water elevation at the downstream crown level of each reach. Therefore, considering all selected reaches, the in-line storage capacity is conservatively in the order of 6.3 MG.

Off-line Storage

During preliminary discussions with the BSA, the Amherst Quarry was identified as a potential off-line storage site for CSOs. As it is understood, the Quarry currently acts as a stormwater retention and flocculation treatment facility. Dewatering by the East Amherst Pump Station is initiated manually by an operator after 1-2 days of retention and is conveyed to the Bailey Trunk. The estimated capacity of the Quarry provided by the BSA is approximately 18 MG at the level of the pump house. According to the simulation results from the 3-month event, the current stormwater volume conveyed to the Quarry is approximately 5.7 MG. Therefore, it has been assumed that a conservative volume of 10 MG would be available for CSO storage.

During more frequent events, it was determined that combined sewer flows tributary to the Bailey Trunk from the area north of East Amherst Street (above the peak DWF of 10 cfs) could be redirected via SPP 255 to the Quarry and stored until a predetermined time after the rainfall event. Dewatering would occur using either existing or upgraded pumping facilities. The Location of the Quarry, the pump station, and the potential regulating site (SPP 255) are presented on Figure 3-2.

Figure 3-2: Location of Potential RTC Sites (Interception, In-line, Off-line) - Scajaquada District



3.2.3 South-Central District Analysis

The South-Central Sewer District is served by the South Interceptor (SI) and the Swan Trunk. Somewhat similar to the Scajaquada district but more complex, regulated flows in the South-Central can take several different paths between interception and overflow points.

Although the Swan Trunk acts almost like an interceptor, it is considered a combined trunk sewer as it has several overflow relief points. Prior to the construction of the SI in the 1930s, the Swan Trunk was the primary interceptor for the sewer district and therefore receives regulating inflow at several SPPs, many of which also contribute significant volumes to some of the top CSO outfalls. At its terminus, flows conveyed by the Swan Trunk are either intercepted by the SI at SPP 024 or discharged to the Black Rock Canal via CSO 011 (Albany). The capacity of the trunk sewer at this point is approximately 115 cfs, with overflow beginning to occur at 90 cfs. A quick capacity assessment reveals that for most wet weather events, the Swan Trunk has relatively little residual capacity along most of its length, this despite several overflow relief points and a direct transfer sewer connection to the SI (near West Swan Street at the Buffalo Skyway).

The SI extends further east than the Swan Trunk and intercepts flows from several regulated inflow points, as well as pumped tributary areas. The capacity of the interceptor at its terminus is over 450 cfs. A quick capacity assessment reveals that for events up to and including the 2-week event, the SI has residual capacity through most of its length, while for larger events, it has little to no residual capacity and is running full or surcharged during most of its length.

The South-Central District has considerably more CSO outfalls than the other two sewer districts, which collectively account for 45% of the system-wide discharge volumes over a typical 9-month period. Two of the district's CSO outfalls, 026 and 017, are ranked fourth and fifth system-wide respectively.

Increasing Regulated Inflows

Based on the baseline simulation results, approximately one fifth of the CSO outfalls account for 80% of the overflow volume, and similarly, a small number of SPPs tributary to these main CSO outfalls are responsible for the greatest discharge volumes due to low threshold interception rates. Consequently, approximately 10 major SPPs were initially targeted for further analysis to determine if interception rates to the SI and the Swan Trunk could be increased in an effort to reduce overflow.

Six SPPs showed the greatest potential for increasing interception rates to the SI and/or the Swan Trunk based on available residual capacities; they include: SPPs 317, 217, 281 (upstream group), 296, 23, and 24 (downstream group). The first three upstream SPPs are tributary to the Swan Trunk (and indirectly to the SI), while the other three downstream SPPs, which are all adjacent to one another, are tributary directly to the SI. As mentioned above, while the SI has some residual capacity during more frequent events, the Swan Trunk has little.

Since the SI is capable of conveying up to 450 cfs, the interception rates at the three downstream SPP sites could be increased up to a conservative rate that still does not exceed this capacity during frequent events. With the upstream sites, however, the capacity limitations of the Swan Trunk are such that the interception rates cannot be increased without creating additional downstream capacity. This would need to be achieved by regulating the transfer connections between the Swan Trunk and the SI. With a significant time lag between the three upstream SPPs and the downstream end of the SI, there is potential to increase interception rates at these without adversely impacting the downstream capacity. Figure 3-3 shows the location of the potential RTC control sites at existing SPPs.

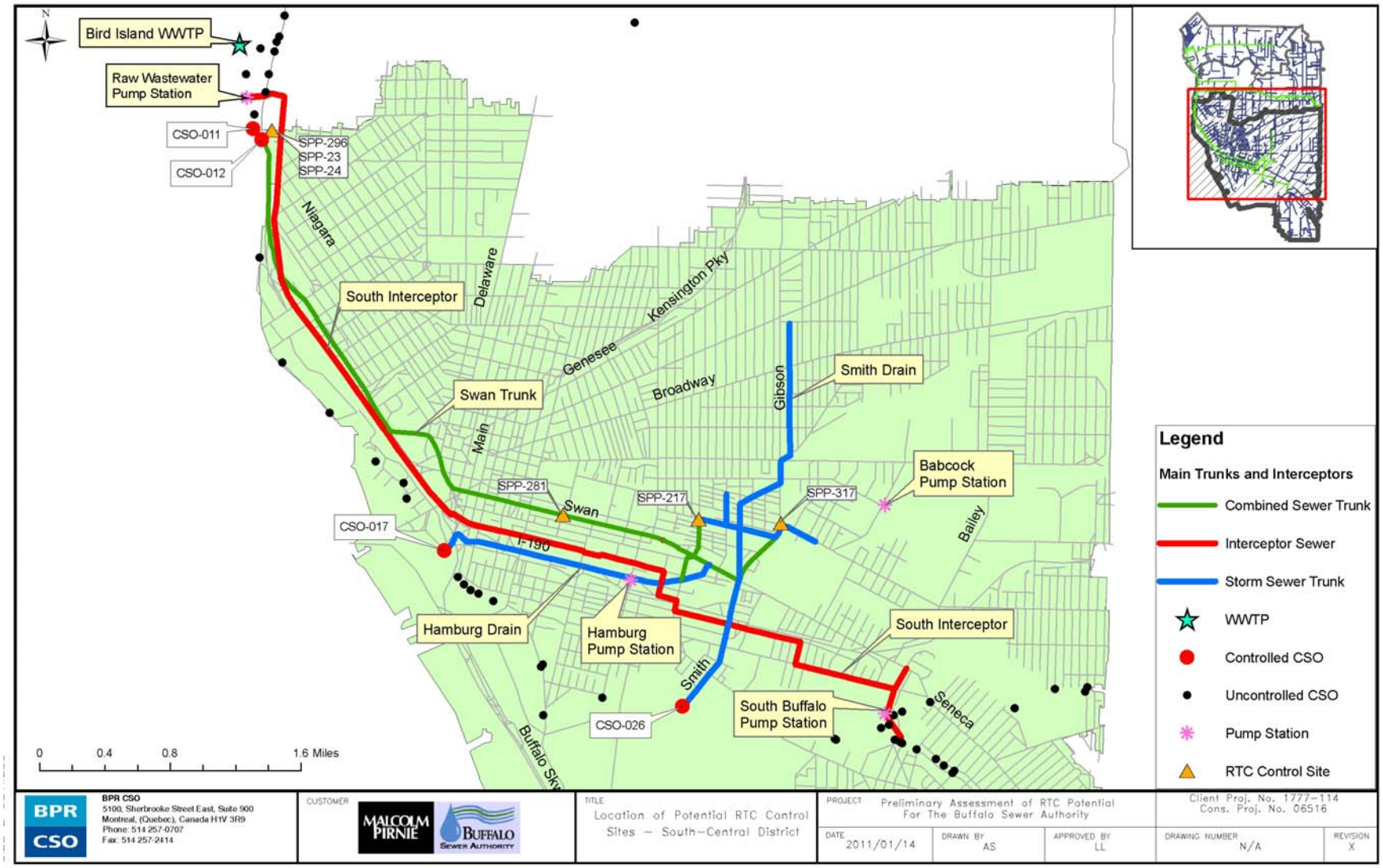
In-line Storage

Though an analysis of the trunk sewers in this district showed some in-line storage potential within certain reaches, the available volume was often near the minimum criteria indicated in Section 3.1.2. Consequently, no in-line storage sites were considered for RTC.

Off-line Storage

During preliminary discussions with the BSA, the Hamburg Drain was identified as a potential off-line storage site for CSOs. To be considered, the outfalls of the Hamburg Drain would need to be sealed to act as an end-of-pipe facility requiring dewatering back to the SI following a rainfall event. Though this presents an attractive opportunity for CSO capture which would virtually eliminating almost all CSO occurrences at some of the top CSOs system-wide during most wet weather events, this option was not considered any further at this point as there is an on-going study by the BSA and its consultant concerning the use of the Hamburg Drain.

Figure 3-3: Location of Potential RTC Control Sites - South-Central District



3.3 INITIAL SUMMARY OF PROPOSED RTC STRATEGIES

Based on the analysis of RTC opportunities and system constraints, Table 3-3 summarizes the proposed RTC strategies for each district and includes descriptions for each potential site. At this point in the study, all sites are presented and have not been analyzed in terms of performance or cost, which are covered in the following two sections.

Table 3-3: Initial Summary of RTC Strategy

Sewer District	Site ID	Location	Model Link/Node	CSO Outfall Impacted by RTC	Type of RTC	Generalized Control Description
NORTH	Hertel Dual Trunk @ Military	Military to W of Delaware	544 & 395	CSO 055 (Cornelius Creek)	In-line Storage	Retain flows based on NI capacity
	Hertel Dual Trunk @ Delaware	Delaware to Parkside	1042 & 455	CSO 055 (Cornelius Creek)	In-line Storage	Retain flows based on Hertel Trunk and downstream storage capacity
SCAJAQUADA	SPP 336B	Kensington Expy, north of East Ferry	SPP-336B	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	RTC Interception	Increase threshold interception capacity based on the STI capacity
	SPP 337	Colorado and Scajaquada	SPP-337	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	RTC Interception	
	SPP 339	Texas and Kerns	SPP-339	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	RTC Interception	
	SSP 340	Hagen and Kerns	SPP-340	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	RTC Interception	
	Bird Trunk	Bird & Dewitt to Delaware & Saybrook	10322 & 10329	CSO 004 (Bird)	In-line Storage	Retain flows based on activation of overflow at downstream SPP
	East Ferry	Kensington Expy & East Ferry to East Ferry & Cornwall	4313	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	In-line Storage	
	Colorado	Scajaquada & Colorado to East Delevan & Northumberland	2973	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	In-line Storage	
	Bailey	Bailey & East Delevan to Bailey & Oakmont	3595	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	In-line Storage	
	Texas	Texas & Lang to Suffolk & Langfield	2793	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	In-line Storage	
	Hazelwood (Hagen)	Hazelwood & East Delevan to Edison & Kensington	2632	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	In-line Storage	
	Hagen	Hagen & Kerns to Hazelwood & East Delevan	2658	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	In-line Storage	
	Bailey/Amherst	Bailey & East Amherst	SPP-255	CSO 053 (Scajaquada Drain) CSO 006 (Delevan Drain) [CSO 061 (STI)]*	Off-line Storage	Divert flows upstream of SPP 255 towards the Amherst Quarry based on excedance of peak DWF rate
SOUTH-CENTRAL	SPP 024	I-190 & Albany	SPP-24	CSO 011 (Albany)	RTC Interception	Increase threshold interception capacity based on the SI capacity
	SPP 023 and SPP 296	I-190 & Albany	SPP-296 & 6048W	CSO 012 (Albany)	RTC Interception	
	SPP 281	Pine & Swan	SPP-281	CSO 017 (Hamburg)	RTC Interception	Increase threshold interception capacity based on the Swan Trunk capacity. (Requirements for flow transfer between Swan and SI)
	SPP 217	Emslie & Eagle	SPP-217 & SENEM	CSO 026 (Smith)	RTC Interception	
	SSP 317	Fillmore & Clinton	SPP-317	CSO 026 (Smith)	RTC Interception	

****Note*: *CSO site indirectly impacted by regulation***

4. EVALUATION OF RTC PERFORMANCE RESULTS

This section provides the RTC performance results in terms of CSO reductions for the four selected reference events and extrapolated results for the 9-month control period during the 1986 typical year.

4.1 METHODOLOGY

4.1.1 Results for Reference Events

The baseline simulation results of the four selected events and the outcomes of the RTC opportunities and constraints analysis provide the necessary data and information to generate conservative performance results through specific hydraulic evaluations. The two-part approach can be summarized as follows:

1. Spreadsheet approach: Compilation of flows and volumes at key locations and potential RTC control sites using hydrographs and time series. Verifications of hydraulic opportunities and feasibility for increasing intercepted flows and/or retaining them during each of the four selected reference events.

2. Validation/test simulations with XP-SWMM: Test and confirm hydraulic conditions of RTC regulation and performance of overflow sites for each of the four selected events using the base control functionality of XP-SWMM allowing for reactive control and variation of weir and orifice heights based on adjacent water elevations.

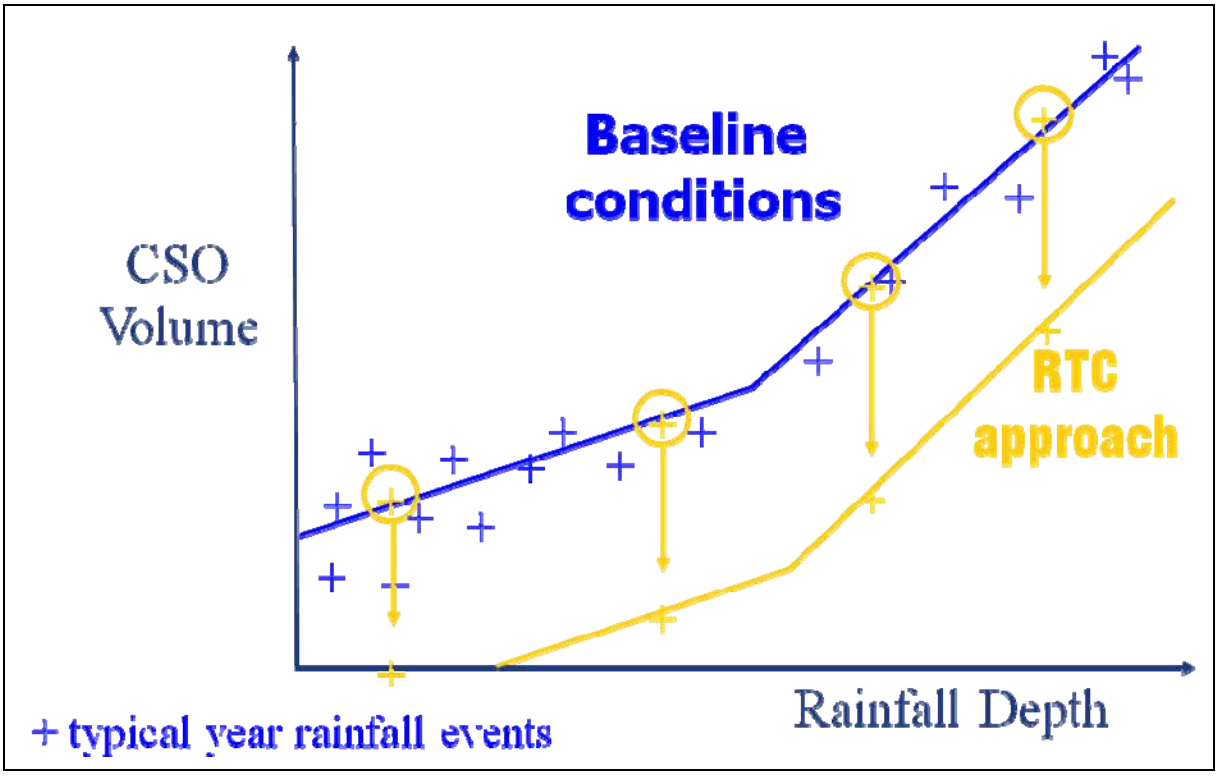
With the intention of providing a *conservative appreciation of potential RTC performance*, Section 4.2 presents the results based on the spreadsheet approach. Although the test simulations in XP-SWMM yield generally superior results, they have been added in Section 4.3 for comparison purposes since they do not result from a full detailed modeling exercise of RTC conditions, but are intended to provide a validation of key assumptions and deductions made about the system's hydraulic conditions.

4.1.2 Extrapolation Results for 1986 Typical Year

The performance results from the four selected reference events are used to extrapolate CSO reduction results over all events within the 9-month control period from the 1986 typical year.

Firstly, a regression fit equation between baseline CSO volumes and rainfall depths is determined with simulated results from the four selected events. The baseline reference overflow volumes are then computed by applying this regression fit equation to the depths for all events from the 9-month control period for the 1986 typical year. This results in a total extrapolated overflow volume of 2,622 MG. Although this value does not correspond with the simulated value of 2,863 MG, it provides an acceptable basis of comparison for the RTC performance results. This discrepancy can be most likely attributed to the proportionally high CSO discharge volume generated by the typical year's largest event (3.63 inches) for the South-Central District, which accounts for close to 50% of the seasonal overflow. Secondly, the RTC performance evaluation for each scenario is established by applying a second regression curve on the same events of the reference year. The computed CSO volume with the corresponding RTC scenario is used to establish the CSO volume reduction and to demonstrate RTC benefit compared to the baseline reference. Figure 4-1 presents a schematic example of a regression fit. The regression method is applied to each of the three districts separately and results were compiled for the system-wide CSO volume reduction.

Figure 4-1: Example of CSO Volume to Rainfall Depth Regression Fit



4.2 PRESENTATION AND INTERPRETATION OF RTC RESULTS

The following section summarizes the RTC performance results from the spreadsheet approach in terms of CSO volume reductions for the four selected rainfall reference events, and the extrapolated reductions for the 1986 9-month control period using the regression curve fit method for each district.

4.2.1 North District

The performance results for the two sets of in-line storage branches are presented in Table 4-1, both separately and cumulatively. It should be noted that since the in-line storage sites only impact CSO 055 (Cornelius Creek), all other CSO outfalls in the North District will continue to overflow as under the baseline conditions; though their collective district overflow volume accounts for only 5% of the typical seasonal overflow volume.

Since CSO 055 does not overflow during the 1-week event, there is no reduction in overflow for this event under RTC. As previously indicated, the remaining outfalls still contribute to the district overflow balance, though not significantly (0.2 MG). For the two-week event, the available in-line storage volume of the downstream branch (Military Rd) is sufficient to virtually eliminate overflow at CSO 055 and in-line storage in the upstream branch (Delaware) is not activated. There is potential for eliminating, on average, 18 events over the 9-month control period at CSO 055.

For the 1-month and 3-month events, the capacity of the in-line storage branches provides similar volumetric overflow reductions. For the extrapolated CSO results for the typical year, a conservative view of the CSO volume reduction considering both in-line storage sites is approximately 11%.

Table 4-1: RTC Performance Results - North District

Rainfall Frequency	Baseline			In-line Storage at Military		In-line Storage at Delaware		All RTC Sites Considered	
	CSO Volume from Uncontrolled Sites (MG)	CSO Volume from Controlled Sites (MG)	Total District CSO Volume (MG)	CSO Volume Reduction (MG)	% Reduction	CSO Volume Reduction (MG)	% Reduction	New CSO Volume (MG)	% Reduction
1-week	0.2	0	0.2	0	0%	0	0%	0.2	0%
2-week	0.4	2.7	3.1	2.7	87.5%	0	0.0%	0.4	87.5%
1-month	1.0	38.1	39.2	2.9	7.5%	2.0	5.1%	34.2	12.6%
3-month	2.2	76.3	78.5	2.9	3.7%	2.0	2.6%	73.6	6.3%
Extrapolated 9-month District CSO Volume for 1986 Typical Year	-	-	747.8	56.6	7.6%	22.0	2.9%	669.1	10.5%

4.2.2 Scajaquada District

The performance results for the RTC control sites for interception increase, the in-line storage branches, and the off-line storage at the Amherst Quarry are presented in Table 4-2. It should be noted that since the proposed RTC sites only impact CSOs 053, 006, 061, and 004, all other CSO outfalls in the Scajaquada District will continue to overflow, although these other outfalls only account for 2% of the typical seasonal overflow volume. More importantly, there are several static SPPs tributary to the four impacted CSOs that would continue to contribute overflow even during frequent events; though their collective overflow volume is generally less than the SPPs selected as RTC sites.

For the 1-week and 2-week events, the collective impact of both the use of increased interception and in-line storage through RTC results in appreciable CSO reductions for the district (59% and 51% respectively), which can be mainly attributed to CSOs 053 and 061 .

The use of the Quarry for off-line storage does not have a significant impact for the 1-week and 2-week events since the flow from the area tributary to SPP 255 can be retained by the application of the in-line storage on the Bailey Trunk. However, during the 1-month and 3-month events, the flow diverted and stored in the Quarry has a more significant benefit in reducing overflow at downstream outfalls (e.g. CSO 053). This implies that the use of the Quarry should perhaps be limited to dynamic management that favors diversion only during less frequent events to avoid the retention and pumping of flows that could otherwise be captured by downstream control sites.

For the 1-month event, the selected RTC sites continue to contribute to CSO reductions through the maximization of interception since there is residual capacity in the STI. However, for the 3-month event, the limiting capacity of the STI prevents increased interception and therefore results in unchanged overflow results. The use of in-line storage remains beneficial during both the 1-month and 3-month events in reducing CSO volumes since there is residual capacity in all seven branches.

For the extrapolated CSO results for the typical year, a conservative view of the CSO volume reduction considering all RTC sites is approximately 30%.

Table 4-2: RTC Performance Results - Scajaquada District

Rainfall Frequency	Baseline			RTC Interception at SPPs: 336B, 337, 339, and 340		In-line Storage at 7 sites		Off-line Storage at Amherst Quarry		All RTC Sites Considered	
	CSO Volume from Uncontrolled Sites (MG)	CSO Volume from Controlled Sites (MG)	Total District CSO Volume (MG)	CSO Volume Reduction (MG)	% Reduction	CSO Volume Reduction (MG)	% Reduction	CSO Volume Reduction (MG)	% Reduction	New CSO Volume (MG)	% Reduction
1-week	0.1	1.0	1.1	0.6	59.3%	0.0	0.0%	0.0	0.0%	0.4	59.3%
2-week	0.3	10.2	10.4	3.0	28.3%	2.4	23.3%	0.0	0.0%	5.0	51.6%
1-month	0.5	27.3	27.8	5.9	21.4%	4.7	16.9%	2.2	7.9%	15.0	46.1%
3-month	1.7	55.2	56.9	0.0	0.0%	4.7	8.2%	4.1	7.2%	48.1	15.5%
Extrapolated 9-month District CSO Volume for 1986 Typical Year	-	-	787	94.7	12.0%	86.2	11.0%	49.4	6.3%	556.8	29.3%

Table 4-3 includes a breakdown of the in-line storage potential by individual branch and their associated overflow reductions estimated proportionally from the extrapolated typical year overflow results of the Scajaquada district.

Table 4-3: Summary of 1986 Extrapolated Results for In-line Storage Sites - Scajaquada District

In-line Storage Branch	In-line Storage Volume (MG)	Overflow Reductions for Extrapolated 1986 Typical Year (MG)
Bird	1.6	21.8
East Ferry	1.2	16.0
Colorado	0.2	2.3
Bailey	0.6	8.0
Texas	1.1	14.6
Hazelwood (Hagen)	0.7	10.1
Hagen	1.0	13.5
TOTAL	**6.3**	**86.2**

4.2.3 South-Central District

The performance results for the two sets of RTC interception sites are presented in Table 4-4. It should be noted that since the proposed RTC sites impact CSOs 011, 012, 017, and 026, all other CSO outfalls in the South-Central District will continue to overflow. Unlike the other districts, the four impacted CSOs account for 57% of the district overflows during the typical seasonal overflow volume. Furthermore, there are several static SPPs tributary to the impacted CSOs that would continue to contribute overflow even during frequent events; though their collective overflow volume is generally less than the SPPs selected as RTC sites. The first set of RTC interception sites (SPPs 296, 23, and 24) directly affects CSOs 011 and 012 (Albany). The RTC interception sites at SPPs 217 and 317 directly affect CSO 026 (Smith), while the site at SPP 281 affects CSO 017 (Hamburg).

Since the 1-week event does not generate significant CSO volumes for the four impacted CSOs, the RTC interception sites offer only modest reductions. For the 2-week and 1-month events, both sets of RTC sites show appreciable CSO reductions, with greater reductions attributed to CSOs 012 and 011. Despite the limiting capacity of both the SI and the Swan Trunk during the 3-month event, there are still reductions in CSO volumes, which are most likely due to short periods of available capacity before and after the peak flows occur in the interceptors.

For the extrapolated CSO results for the typical year, a conservative view of the CSO volume reduction considering all RTC sites is approximately 20%.

Table 4-4: RTC Performance Results - South-Central District

Rainfall Frequency	Baseline			RTC Interception at CSOs 011 & 012		RTC at SPPs 281, 217, & 317		All RTC Sites Considered	
	CSO Volume from Uncontrolled Sites (MG)	CSO Volume from Controlled Sites (MG)	Total District CSO Volume (MG)	CSO Volume Reduction (MG)	% Reduction	CSO Volume Reduction (MG)	% Reduction	New CSO Volume (MG)	% Reduction
1-week	1.5	1.0	2.5	0.2	7%	0	0%	2.4	7%
2-week	4.0	10.1	14.1	3.4	23.8%	1.5	10.8%	9.2	34.6%
1-month	7.0	22.0	29.0	8.9	30.7%	3.7	12.9%	16.4	43.6%
3-month	6.9	43.4	50.4	3.9	7.8%	3.4	6.7%	43.1	14.5%
Extrapolated 9-month District CSO Volume for 1986 Typical Year	-	-	1,087.5	148.5	13.7%	63.3	5.8%	875.7	19.5%

4.3 CONSIDERATION OF TEST SIMULATIONS

As previously indicated, the purpose of the test simulation runs in XP-SWMM was to validate and confirm the results compiled and for each rainfall event that were determined using the spreadsheet approach. The results of the simulation tests were extrapolated to generate seasonal CSO discharges for the typical year (9-month control period). Comparative results for each district and system-wide are presented in Table 4-5.

Table 4-5: Comparison of RTC Performance Results (District and System-Wide)

Sewer District	Baseline	RTC Results			Simulated RTC Validation Results		
	CSO Volume (MG)	CSO Volume (MG)	CSO Reduction		CSO Volume (MG)	CSO Reduction	
			Volumetric (MG)	Percent (%)		Volumetric (MG)	Percent (%)
North	748	669	79	11%	580	168	22%
Scajaquada	787	557	230	29%	558	229	29%
South-Central	1088	876	212	19%	854	233	21%
System Total	2622	2102	521	20%	1995	628	24%

The test simulations show the most pronounced improvement for the North Sewer District. This can be partially attributed to a more dynamic use of both in-line storage branches during less frequent events (1-month and 3-months) enabling the storage volume to be utilized more efficiently if an event has two or more peaks. Furthermore, the retention of flows within certain in-line storage branches in the Scajaquada District (primarily the Bird Trunk) increases the capacity of the NI, thus helping to the reduce the backflow effect that contributes to overflows at CSO 055. This allows more interception of flows from the Hertel Trunks and contributes to further CSO reductions at CSO 055.

In the Scajaquada district the simulation tests confirm the results of the spreadsheet approach, yielding very similar reduction results. During the less frequent events, the RTC interception sites reach their threshold capacity according to the available capacity of the STI. With several of the selected in-line storage sites being directly upstream of the four RTC interception sites, the test simulations demonstrate that retained flows allow for a more balanced interception rate, thus helping to reduce CSO volumes at CSO 053 (Scajaquada Drain) and CSO 006 (Delevan Drain). Other than helping to increase the capacity of the NI, in-line storage in the Bird Trunk is also beneficial for reducing discharge volumes at CSO 004 (Bird). The simulation tests also validate the notion that the Amherst Quarry is best utilized during the larger and less frequent events. The control strategy in that area should first favor the maximization of interception capacity to the STI and then the utilization of the in-line storage capacity along the Bailey Trunk before diverting excess flow to the Quarry through SPP 255.

Furthermore, the simulation tests show that although the increased interception rates to the STI cause an increase in overflows at CSO 061 (STI relief point) during the less frequent events, the net overflow volumes reductions for the district (attributed primarily to CSOs 053 and 006) are positive and compensate for this increase. Additional consideration for a more dynamic management of the STI's capacity and fine tuning of the RTC approach would provide opportunities for a more balanced approach between maximizing interception and reducing overflows.

For the South-Central district, under the current system settings, overflows at CSOs 011 and 012 (Albany) occur before the SI reaches its peak. This is mainly attributed to the fact that the regulation threshold at SPPs 296, 023, and 024 are set too conservatively. However, since these SPPs are located at the downstream end of the SI, there is potential to use RTC and increase their threshold interception rates so that overflow does not occur unnecessarily. The simulation tests confirm that this RTC strategy allows for significant CSO reductions in the district.

Since the other potential RTC interception sites in the South-Central district (SPPs 281, 217, and 317) are located further upstream, their hydraulic benefits are somewhat different. The goal of maximizing interception at SPPs 217 and 317 to the Swan Trunk is to reduce overflows at CSO 026 (Smith). Yet due to the limited capacity of the Swan Trunk during certain events, any additional intercepted flows could potentially increase overflows at CSO 017 (Hamburg Drain) by way of a key relief point along the Swan Trunk at SPP 067. However, the modeling and simulation tests demonstrate that although the CSO discharge to the Hamburg Drain does increase, the net CSO reductions at the other impacted CSOs compensate for the increase due to the strategic use of transfer points between the Swan and the SI. With the on-going study on the use of the Hamburg Drain as a storage and or screening facility, the ability to dynamically re-direct overflows to the drain for certain events using RTC could be both beneficial for reducing CSO volumes at other outfalls and potentially cost-effective.

Overall, the simulation tests were beneficial in assessing the hydraulic behavior of the model and providing comparative CSO performance results, albeit with control rules that did not extend further than adjacent monitoring points. The results of the spreadsheet approach remain generally conservative and offer a basis for more detailed RTC assessments.

Though the RTC analysis for each district was developed and presented distinctly using the spreadsheet approach, the simulation tests and the interpretation of the results demonstrate the potential of global and coordinated control, both within the districts and between districts, can be valuable in improving CSO reductions. Examples include:

- Control of the NI's HGL and capacity to limit backflow and reduce CSOs in the North District
- Coordinated activation of in-line and off-line storage at upstream locations in the network to yield CSO reductions at sites further downstream; i.e. coordinated and dynamic flow management between the North and Scajaquada districts and the use of off-line storage at the Amherst Quarry during less frequent events.
- Potential for coordinated management of inflows and flow balancing between the SI, the Swan Trunk, and the Hamburg Drain.

Considering the aforementioned opportunities and the potential for more balanced coordinated management between potential RTC regulation and storage sites, there is merit in considering the future operation of potential RTC sites with a global and predictive approach for not only reducing CSO discharge volumes, but also improving system operation. Past experience in the City of Montreal RTC project demonstrates that the GOP RTC system offers an additional performance of more than a 10% reduction of annual CSO volume without the need to construct additional off-line storage facilities.

5. OVERVIEW OF RTC SYSTEM CONFIGURATIONS

This section provides an overview of a generic real time control system to illustrate the system configurations and requirements with regards to different levels of complexity. It is recognized that not all components are required for a functional RTC system, therefore they are mainly listed for reference and for future re-evaluation with regards to the expected performance results and efficiencies once the LTCP alternatives and their integrations with RTC have been determined and evaluated.

5.1 DEFINITION OF REAL TIME CONTROL

In order to maximize operations and the management of flows in collection systems, RTC includes practices and tools for actively managing wastewater networks and facilities in a safe manner. RTC is a dynamic management of the sewer network, and unlike static management, takes into consideration the distribution of flow in time and space throughout the network. RTC allows flow regulators and interceptor sewers to operate more efficiently and, in turn maximizes the utilization of existing conveyance, treatment and storage capacities while adapting to real-time conditions that may or may not be foreseeable (i.e. scheduled maintenance of a pump station or sudden sensor/equipment breakdown).

At the design stage, the objective of implementing an RTC system is to minimize the extent of new capital works required to meet the same performance objectives. For the operation of an existing system, opportunities arise through the addition of an improved control strategy that can make better use of available capacity. The added performance of the RTC approach depends on the sewer network's layout and on the environmental objectives pursued.

A generally accepted definition of RTC, originally defined by Wolfgang Schilling in his IWA report on the state of the art of RTC, is that "a wastewater collection system is said to utilize RTC if it involves the use of monitored process data to operate regulators to achieve better system performance." In 2006, the EPA published a document entitled *Real Time Control of Urban Drainage Networks*. As part of the report, the EPA provides the following definition of RTC:

RTC can be broadly defined as: a system that dynamically adjusts the operation of facilities in response to online measurements in the field to maintain and meet the operational objectives, both during dry and wet weather conditions.

Flows and levels in sewer systems are typically manipulated by static facilities (e.g., weirs) that are not adjusted in real time. RTC adds a dynamic component, where some of the facilities are actively adjusted in real time based on system conditions.

The term "Real Time Control of Sewer Systems" has often been used to describe control systems that include system-wide ("global") control rules and may include such sophisticated components as linear optimization algorithms. When municipalities consider RTC, they should consider a range of possible solutions, starting from simple and straightforward and potentially culminating in a "global predictive optimal" configuration.

We can characterize RTC according to progressive complexity of implementation and performance:

- Local Reactive Control: A system is operated on a local reactive control level when it involves closed-loop control of individual regulators, gates or pumps. The actuators are not remotely operated from a control room and process measurements are taken directly at the actuator site. Local reactive control is the simplest form of automatic control, where a flow regulating device is activated according to flow or water level measurements, either upstream or downstream.

- Extended Reactive Control: Extended RTC is similar to local reactive control except that process measurements are received from a remote site or a number of remote sites. The

Extended RTC can be built upon as supervisory control and data acquisition (SCADA) system that exchanges data with numerous local stations. SCADA can also send set points to a local controller, either automatically or manually (performed by the operators).

- Global Optimal Predictive Control: When system objectives require greater operational efficiency from inter-dependent flow control facilities, or if their actuators have to be jointly operated, global control becomes necessary. In this case, data is centralized and accessible to coordinate the action of all actuators in the field. An optimization process is used and can be on many different kinds of algorithms, e.g. rule-based, expert systems, neural network systems, genetic algorithms, or various forms of linear and non-linear optimization algorithms. It minimizes an objective function (CSO volume, CSO occurrences, energy cost, actuator movements, etc.) while respecting a set of constraints (e.g. maximum water levels in sewers, maximum flow capacity, maximum retention volume, wastewater treatment plant/pump station flow capacity). Main approaches to the optimized control of many facilities involve the use of mathematical models to compute hydraulic conditions and determine the control actions. Prediction refers to the estimation of flows at future time intervals, assisted by rainfall predictions.

It is important to understand that the control strategies are not necessarily independent of each other. The lower levels remain present in more complex configurations. Therefore, when something fails in the hierarchy of systems, the system should be designed to fall back progressively to a lesser degree of control, and thus of efficiency. It is also important to note that a sewer system does not need to be controlled at any given time by one single strategy. For example, one facility can be under local automatic control while the overall system is being managed under a global optimal predictive scheme.

Also, control systems can be categorized with respect to the person that makes the control decision:

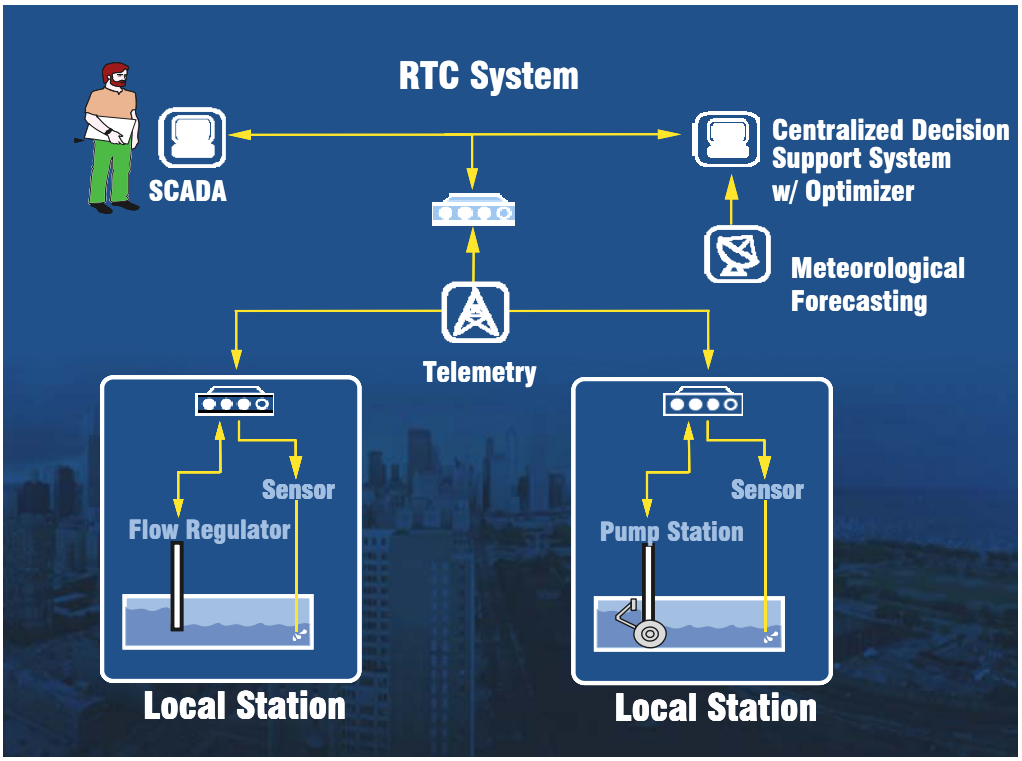
- Control can be manual (if the operator on site makes the decision);
- Supervisory (if the operator in the central control room makes the decision on control at a remote site);
- Automatic (if the control logic and rules and programmed and made without the direct input of the operator).

In all of those possible control systems, the use of control algorithms will be balanced against the role and responsibility of the operator. For example, several control algorithms can be present for the management of one facility, but the control system still requires the intervention of an operator to make a decision.

5.2 COMPONENTS OF A RTC SYSTEM

A typical layout for components that might be included in a RTC system is conceptually depicted using its functionality and subsystems. This presentation is kept as general as possible and the description is based on generic architecture requirements. Figure 5-1 demonstrates a typical RTC system architecture.

Figure 5-1: A Generic Centralized RTC System Architecture with Rainfall Prediction



A RTC system may contain one (if local RTC) or all of the below subsystems (if GOP RTC):

1. Monitoring Station Subsystem

   The monitoring station systems include different types of monitoring stations: pump, flow and water level, and rain gauge. The information provided is used to estimate the sewer network's capacity to the supervisory and decision-making subsystems. These capacities are used to determine the weather control status and flow rate constraints. Information captured in the field is communicated from the remote stations to the computers that will process, store and archive it.

2. Local Control Station Subsystem

   The local control stations are responsible for controlling the FINAL DRAFT elements on the network: gates, regulators, pumps, and for the collecting and transmitting of data to the supervisory subsystem at the central station. They are also responsible for local tasks related to the implementation of a GOP RTC system, including the management of the control site under normal and degraded situations. More specifically, the local control stations have the responsibility to:

   - Determine the operating mode that must be activated according to the level of degradation of the system;
   - Discover the gate positioning or the on/off status of the pumps according to the process and operating mode applied;
   - Protect field crewmembers, sewer network civil works and instrumentation, citizens against flooding, and the environment during degraded or emergency situations. In the worst case

scenario, the local stations react in such a way that system performances should not be worse than the ones achieved before the implementation of the RTC system.

3. Telemetry Subsystem

Generally speaking, the objective of a telemetry subsystem is to ensure the transmission of information between a central station and remote sites for monitoring and remote control purposes. The telemetry system has to ensure communications between the central station and the remote-controlled and monitored RTC sites.

The telemetry subsystem becomes necessary in order to report the conditions of the sewer network from strategically located RTC remote sites to a central station where the decision-making subsystem is implemented, and then the computed set points are sent back to the control sites.

4. Supervisory Subsystem (SCADA)

From all of the RTC subsystems, the supervisory subsystem, with its human machine interface (HMI), is the most visible component. Its role is to show a schematic view of all local stations with their equipment and instrumentation online. Operators use the tool from the central control room to monitor the activities of a station and to react remotely.

During a rainfall event, animation on the graphical display shows the modulation of the gates, equipment status, water levels, flow rates, volumes, gate openings, set points, local operating modes, and alarms. The operators can modify, using the interfaces, the local control modes, the weather control status, the validation status, and perform manual flow control or manual gate positioning.

5. Meteorological Forecasting Subsystem

The meteorological forecasting subsystem is used in the GOP RTC system as a tool to provide reliable rainfall intensities over a prediction horizon. Therefore, it acts partly as virtual rain gauges installed on each squared pixel of the service area and partly as a prediction tool to forecast future rainfall intensities. The predicted rainfall estimates are used as inputs to simulate the hydrologic behavior of the sewer network over a given control horizon.

6. Decision Support System (DSS) with Optimizer Subsystem

The optimizer subsystem can be an integral part of a centralized decision support system. It is used to compute the optimal flow set points that must be reached and maintained according to the system-wide RTC scheme. The subsystem also determines the weather control status and modifies control parameters associated with the control objectives and operating constraints.

5.3 DECISION SUPPORT FOR OPERATIONS

The use of monitoring and data management processes that constitute a simpler type of DSS aims to help the operator make better decisions in a timely manner with relevant, concise and better quality of information. This can include rainfall information and/or metrological forecasting. A picture of current and past rainfall intensities over the sewershed would allow the operator to better assess the spatial distribution of rainfall. Strategically located flow and level monitoring in the collection system provide the operators with hydraulic conditions and system status. For example, schematic views with inline storage pipe profiles showing filling of the pipes, pumped flows with color coding describing capacity used and available can be programmed into a DSS.

When hydrologic and hydraulic models and weather forecasted are integrated into a DSS, they can generate even more valuable information about current and forecasting hydraulic conditions anywhere in

the network. With models and the optimization process, operators could test different operating scenarios or be provided with scenarios that can help them decide whether or not to apply them.

A DSS integrates the information that resides in different parts, ensures data validity, and fast computations. The key to helping operators make better decisions is to provide them with information that will facilitate their decision-making process. DSS can be further seen as a broader application for flow management of wastewater networks and facilities and therefore RTC becomes a component of an overall DSS.

The RTC approach proposes the use of control algorithms at different levels. As such, the goal would be to support operators in some decision-making processes with automated control decisions and to allow the operation to be more efficient, and at the same time, more standardized.

A DSS integrating a system-wide (global) automatic controller (optimization process) helps process a large quantity of data in order to determine the "best" global control strategy. The DSS is able to take into account the hydraulic inter-dependency between flow control facilities and the spatial and temporal distribution of the rainfall. The actuators and pumps are jointly operated and coordinated with global control. A DSS can rely on various kinds of algorithms, such as model-based, rule-based, expert systems, neural network systems, genetic algorithms, or a variety of forms of linear and non-linear optimization algorithms. The latter usually refers to optimization techniques, which offer an "optimal" solution. It minimizes an objective function (e.g. CSO volume, energy cost, actuator movements, etc.) while respecting a set of constraints (e.g. maximum water levels in sewers, maximum flow capacity, maximum retention volume, and wastewater treatment plant/pump station flow capacity). The centralized automatic controller must also typically rely on a relational database providing multiple functions to handle real-time data transfers, data storage and retrieval, data organization, data validation and calculations, and extensive graphing/reporting capabilities for various purposes (system operational performance, maintenance schedule, episodic and periodic reporting about rainfalls, discharge conditions, and mass balance of flow through the treatment facilities).

There is a need for tools to perform analysis during and/or after an event for the continuous improvement of the operation and adapted management of a LTCP. Such a centralized DSS provides improved data management from SCADA, allows for the consultation of results in real time on a geo-referenced map and the generation of reports and graphs of actual and historical conditions for each site. Dashboard display options are also possible to consult some types of information.

The implementation of a global and centralized control strategy could be automatic or be proposed and enacted manually by an operator. In the first configuration, the operator should always have the capability to view the control actions, present and future, and to override the control system, in part or entirely.

5.4 RTC FEATURES

5.4.1 Reliability

The concept of reliability can be largely associated to the system's performance and specifically to the difference between the measured and expected performances. The selection of equipment, such as sensors, actuators, radios, gates, and pumps, is a good starting point, but any electronic or mechanical device is prone to failure, especially when submitted to a harsh sewer environment. Therefore, we must recognize equipment failures as a given and devise strategies to improve the reliability of the system, where necessary.

Many strategies to increase system reliability are inter-related. Some of those strategies are described below:

1. Gate Redundancy at Strategic Locations

A new sluice gate installation, either for conveyance or retention, will normally have at least two valves in order to provide redundancy in case of device failure. When that happens, the position of the faulty valve will be taken into consideration for the computation of the set point for the other valve.

2. Sensor redundancy at strategic locations

   Water level metering redundancy is used at strategic locations. Water level sensors provide valuable, sometimes critical, information for the detection of high water levels, as well as for the computation of flow rates. Coupling flow monitoring with water level monitoring in parallel (using two or three different hydraulic formulas to compute flow) can produce redundancy. Depending on the accuracy of such formulas, a hierarchy or comparison can be established to use only the validated data and/or inter-validated data.

3. Data validation

   The data validation process can use a local statistical analysis to detect data oscillations and deviations out of the realistic range. Data validation algorithms will discard the value of a faulty transmitter or will alert the operator if discrepancies between the two transmitters are too high and too frequent.

5.4.2 Safety

Fail-safe design does not differ from good engineering practices applied to pump stations or other flow regulating structures, but increases the reliability of a given function provided by equipment.

Depending on the design of the site, fail-safe design may take the form of:

- An overflow weir designed to carry the entire flow whenever the sluice gate or any other downstream flow regulating structure would obstruct the normal flow;
- An emergency actuated isolation sluice gate to cut off flow from entering a sewer prone to flooding;
- A hydraulic or pneumatic reservoir, or a UPS or electric generator, to activate a gate actuator to a safe position during a power failure;
- Software and hard-wired equipment interlocks (level switches).

5.4.3 Operational Flexibility

In a centralized control system, the operator can take control of the system at all times, whether to override the entire control system or to impose a gate opening or a flow objective at a specific local station. The central station operator interacts with the control system through the HMI and can control each site manually. The manual mode provides control flexibility and an additional level of security to the system. In general, the manual mode is used to divert flows to different collectors and interceptors for maintenance or repair purposes.

The field operator also takes control of the local station when visiting the site. The field operator can locally impose a control set point, which is reported back to the central and taken into consideration for control events. (Field-imposed set points cannot be overridden by the central station. The control station takes this as a constraint, no longer as a variable.)

5.5 OWNER AND OPERATOR ACCEPTANCE

It is recognized that not all constraints to the successful implementation of an RTC system are physical or hydraulic in nature. Given that RTC operation of wastewater collection systems is a relatively new field, it

is understandable that system owners and operators would be apprehensive and cautious in embracing the implementation of a sophisticated RTC system. Common misconceptions include:

- Additional operational complexity;
- Added equipment maintenance and labor resources will be required;
- Control of the operation of the system will be lost;
- RTC results in added potential for operational risks.

It should be noted that the degree of sophistication of a system can vary depending on the performance objectives and based on the comfort level of system operators and owners. With the prevalence of the use of SCADA systems in the operation of current wastewater collection systems, operators are experienced with automated system control of their facilities and are seeing the implementation of broader system-wide control in real-time as the next logical step. With this, experience issues of system complexity are becoming less of a concern given the skill level that system operators and equipment maintenance staff now possess. This is especially true in the case of the City of Ottawa, where highly skilled personnel are on staff.

In terms of the level of sophistication of a given RTC system, various approaches are possible in the implementation of such systems and range from:

- A phased approach with implementation of a more limited number of RTC sites than proposed under the full and preferred scenarios;
- A phased approach with the gradual upgrading of the capabilities of a system (i.e., from a fixed (static) operation to a local reactive control to extended control and ultimately a global predictive mode of operation);
- An implementation of a system that is fully capable of all modes of operation, but that can be operated in degraded modes of operation depending on the preference of system operators.

Proper reliability of equipment and instrument is crucial for the system independently of the level of control. An automated approach for the regulation of flow adds to the amount of equipment to maintain. It should be noted that verification and maintenance can be partially realized through automation.

With respect to operational control of the system, a key feature of successful RTC systems is to provide system operators with the ability to adjust operating parameters as further experience and performance data becomes available. In addition, the system must also provide the ability for operators to manually override the system when needed for maintenance or emergency conditions. This, as well as proper system design, is what will ensure that the RTC system provides a safe, robust, reliable, and flexible operation. The recognition and mitigation of operational risks is an integral part of the proper design of such systems.

6. CONCEPTUAL LEVEL COST ESTIMATES AND COST-BENEFIT ANALYSIS

6.1 DEVELOPMENT OF CONCEPTUAL COST ESTIMATES

The development of RTC opportunities for increasing flow interception and providing in-line storage is detailed in Section 3. The conceptual cost estimates for these options are based on typical installations done in the context of similar projects in Louisville, KY, Wilmington, DE, Ottawa, ON, Hamilton, ON, Montreal, QC, and Quebec City, QC.

The conceptual RTC cost estimates represent an "opinion of probable cost" and have been prepared to help guide the study's evaluation and implementation from the most current information available. The actual total cost estimate of the RTC project will depend on the FINAL DRAFT project scope as well as actual labor and material costs, competitive market conditions, implementation schedule, and other factors. The costs provided herein are conceptual in nature and are intended to provide a means of comparison for the RTC options as part of a feasibility study as well as for capital budgeting purposes. A further refinement of costs will be required at the pre-design stage of any RTC implementation plan.

The conceptual cost estimates include contingency amounts and non-construction related engineering and management fees that are based on a percentage of construction cost calculations derived from historical cost data for wastewater related and similar RTC projects tracked over a number of years. The following definitions are thus considered:

Construction: The estimated construction cost of the proposed works. This has been estimated for each work site based on the best available information.

Construction Contingency: The construction contingency as a percentage of the construction costs. For large capital construction projects (over $2M), the contingency is typically 5%. An allowance for the conceptual nature of this cost estimate is covered in an overall project contingency to accommodate uncertainties in scope (for both engineering and construction).

Property and ROW Acquisition: It is defined as the cost to obtain required land and or easements to enable construction to proceed. Typically this amounts to $80,000/acre. Since most sites are situated beneath municipal roads, it has been assumed that no land acquisition would be required for this project.

Engineering Services: An allowance that is a percentage of the construction costs for the preliminary and detailed design, construction services, and commissioning. Given the complex nature of this assignment and the uncertainty of the scope, a higher allowance is recommended (24% based on 5% preliminary design, 7% detailed design, 5% construction services and 7% for specialized calibration and programming services). It should be noted that specialized calibration and programming services are not directly proportional to the construction costs, but have been included in the allowance for ease of computation at this stage. A minimum cost for these services will need to be developed on a site-by-site basis during the design stage.

Utilities Impacts/Relocations: The need to relocate and/or replace other existing infrastructures to accommodate construction, as a percentage of the construction costs. Given the relatively small footprint requirements in congested areas, we suggest 5% on construction costs allotted to this allowance.

Project Management and Administration (BSA): An allowance for internal BSA management and administration as a percentage of construction, engineer and utilities costs. This allowance is typically set at 5%.

Inspection (BSA): An allowance for BSA inspection services as a percentage of construction, engineer and utilities costs. This allowance is estimated to be 7% given the number of control sites involved and the need for multiple inspection staff.

Project Contingency: It is a percentage of all other project costs, which recognizes the conceptual nature of the project definition and the limited information available. An allowance of 25% is applied.

Table D-1 in Appendix D summarizes the contingencies and non-construction related fees and calculates the **Total Project Cost Factor of 1.708** to be applied on construction costs for each site.

6.2 CONSTRUCTION COST ESTIMATES FOR CONCEPTUAL DESIGN

6.2.1 Potential RTC Interception Sites

An automated control site for increasing interception at an existing SPP location includes:

- Above ground control building services for operating equipment, complete with electrical and mechanical services (heating, ventilation, dehumidification, lighting, and power distribution);
- Civil works at the regulator location;
- A new isolation sluice gate that comes with an electric actuator;
- A new modulating sluice gate that comes with an electric actuator (downstream of isolation gate);
- One level transmitter in the sewer;
- Two level transmitters upstream of the modulating and isolation gate;
- One level transmitter downstream of the modulating gate;
- One level transmitters in the interceptor;
- Two float switches in the interceptor (for safety interlocks, one set and one reset);
- Power back-up system (UPS or generator);
- PLC and telemetry.

To provide maximum reliability, the actuator of the isolation gate at each control site will use a different power source than the actuator of the modulating gate. This is to provide a better level of redundancy in closing off the flow to the interception system. For the on-site RTU and PLC a UPS will be provided within the electrical distribution panel at each of the control sites as a back-up for control equipment. The most versatile option for the gates is to use a diesel powered electric generator where possible as a back-up for the gate actuators. However, an adequately sized UPS is considered acceptable for those sites where constraints do not allow for the installation of a generator.

The main advantage of the electric generator is that it can be sized (at a marginal cost increase), to feed the entire site and maintain full functionality for prolonged power failures. With the installation of a UPS back-up system, the same functionality as the hydraulic actuator can be provided at significantly less cost and would be much easier to integrate into the existing regulator sites than an on-site generator.

Applying the same philosophy for redundancy in the level transmitters, it is assumed that they will be different technologies. For the conceptual estimate, the most common and reliable technologies proposed are ultrasonic and radar (we recommend non-contact technologies). During the preliminary design phase, FINAL DRAFT decisions will be made on the preferred technologies to be used in regards to feasibility, robustness, accuracy, and client preferences.

Table D-2 in Appendix D summarizes the construction costs for each RTC interception site.

6.2.2 Potential In-line Storage Sites

An automated control site for an in-line storage facility within an existing trunk sewer includes:

- An above ground control building services for operating equipment, complete with electrical and mechanical services (heating, ventilation, dehumidification, lighting, and power distribution);
- Civil works at the in-line storage site location;
- Inflatable dam or sluice gate;
- Inflatable dam operating equipment (air blowers, vacuum pump, and pressure transmitters);
- One level transmitter at the control SPP or CSO (could be outside of the site location);
- One float switch upstream of dam or sluice gate;
- One level transmitter upstream of dam or sluice gate;
- One level transmitter downstream of dam;
- Power back-up system (UPS or generator);
- PLC and telemetry.

One major constraint with inflatable dams is that they cannot be installed in brick sewers, as the pull-out load of the anchors is too high for bricks. There are two alternatives: installing sluice gates at this location or replacing a 30 ft section of the brick sewer with a concrete sewer. The cost of sluice gate implementation is about the same as a dam implementation.

During preliminary engineering, all in-line storage sites will be studied and surveyed in order to establish requirements, constraints and feasibility. The survey includes the inspection of structures, pipes and sewers to be modified, including manholes, pipes and sewers in proximity. It includes also pull-out tests and pipe wall thickness verification for the inflatable dam anchors. The best retention device, inflatable dams or sluice gates, will then be selected. For safety reasons, sluice gates should always be redundant. The installation of a bending weir over gates can also be taken into consideration for safety issues.

No sewer pipe works are planned except in the vicinity of the dams. It is assumed that the existing sewers are in good condition and therefore adequate for low surcharge. Repairs to damaged or weakened sewers have not been taken into consideration and the preliminary engineering includes the inspection of sewers where dams or gates are to be installed.

Table D-3 in Appendix D summarizes the total construction costs for each in-line storage site.

6.2.3 Potential Off-line Storage Sites

An automated control site for an off-line storage facility (Amherst Quarry) includes:

- An above ground control building services for operating equipment, complete with electrical and mechanical services (heating, ventilation, dehumidification, lighting, and power distribution);
- Civil works at the control site location;
- A new isolation sluice gate that comes with an electric actuator;
- A new modulating sluice gate that comes with an electric actuator (downstream of isolation gate);
- One level transmitter in the sewer;
- Two level transmitters upstream of the modulating and isolation gates;
- One level transmitter downstream of the modulating gate;
- One level transmitter in the downstream sewer;
- Two float switches in the interceptor (for safety interlocks, one set and one reset);
- Power back-up system (UPS or generator);
- PLC and telemetry.

The chamber configuration is similar to increasing the number of interception site chambers. Thus, the cost is estimated to be the same at approximately $3.42M.

Table D-4 in Appendix D summarizes the construction costs for the Amherst Quarry site for off-line storage.

6.2.4 Operation and Maintenance Costs

The "Opinion of Probable Cost" for annual maintenance for the physical upgrades of the BSA's RTC system have been estimated based on comparable RTC system experiences and were further validated by comparing these experiences to best management practices (BMPs) for staffing wet weather control facilities.

The operating and maintenance costs presented in Table 6-1 are based on a period of 40 years. They include replacement costs of individual equipment, depending on their lifecycle duration. The equipment taken into consideration includes:

- Mechanical regulators:
  - Gates: replacement and O&M

- I&C – regulators:
  - Level meters: replacement and O&M;
  - Float: replacement and O&M

- Electrical regulators:
  - Backup power system: replacement and O&M
  - On/Off actuators: replacement and O&M
  - Modulation actuators: replacement and O&M.

For operating and maintenance costs, it is estimated that the annual cost is approximately $500,000 per year.

Table 6-1: Summary of Operation and Maintenance

Description	Quantity	$/unit	Cost	Replacement Period (year)	$/year
Mechanical - Regulators:					
Gates Replacement	34	$15,000	$510,000	25	$20,400
Gates O&M	34	$1,020	$34,680	1	$34,680
I&C - Regulators:					
Level Meters Replacement	85	$2,000	$170,000	10	$17,000
Level Meters O&M	85	$2,040	$173,400	1	$173,400
Float Replacement	46	$350	$16,100	10	$1,610
Float O&M	23	$2,040	$46,920	1	$46,920
Electrical - Regulators:					
Backup Power System Replacement	23	$5,000	$115,000	30	$3,833
Backup Power System O&M	23	$680	$15,640	1	$15,640
On-Off Actuators Replacement	11	$10,000	$110,000	20	$5,500
On-Off Actuators O&M	11	$2,040	$22,440	1	$22,440
Modulation Actuators Replacement	23	$12,000	$276,000	15	$18,400
Modulation Actuators O&M	23	$2,040	$46,920	1	$46,920
RPU/Communications Equipment:					
Communication System Replacement	25	$30,000	$750,000	15	$50,000
Communication System O&M	25	$1,500	$37,500	1	$37,500
				Total (per year)	**$494,243**

Note: Labor (hourly rate): $85 assumed for O&M calculation

It is also important to take into account that specific maintenance tasks will have to be executed in confined spaces. As a result, more labor (two or three persons) is required for periods of time longer than normally required for work in open spaces, for specific tasks such as cleaning level sensors.

Table D-5 in Appendix D lists an example of the maintenance tasks that should be executed yearly at all the regulation sites, preferably early in the Spring, to get the RTC system ready before the main control period of wet weather begins. They constitute the main activities of a preventive maintenance program.

Site visits following the acknowledgement of an alarm to investigate problems should be rare once the system is commissioned and fully operational. Based on the system that has been in operation in Quebec City for nearly 10 years, one or two annual visits per site can be anticipated to address problems related to monitoring errors, telemetry, control processes and gate modulation.

6.2.5 Cost Summary

Table 6-2 includes the estimated costs of RTC opportunity sites for each sewer district, as well as O&M costs.

Table 6-2: Total Estimated Costs for all RTC Sites

Summary of Estimated Construction Costs				
Sewer District	**RTC Site**	**Type**	**Site Location**	**Cost ($M)**
North	Hertel (Military)	In-line storage	Hertel Ave & Military Rd	5.04
	Hertel (Delaware)	In-line storage	Hertel Ave & Delaware Ave	5.02
Scajaquada	SPPs 336B, 337, 339 & 340	RTC Interception	SPP 336B: Kensington Expy, north of East Ferry SPP 337: Colorado & Scajaquada SPP 339: Texas & Kerns SPP 340: Hagen & Kerns	13.66
	Bird	In-line storage	Bird/Dewitt & Herkimer	4.30
	East Ferry	In-line storage	Kensington Expy & East Ferry	2.42
	Colorado	In-line storage	Colorado & Scajaquada	2.40
	Bailey	In-line storage	Bailey & East Delevan	2.40
	Texas	In-line storage	Texas & Lang	2.57
	Hazelwood (Hagen)	In-line storage	Hazelwood & East Delevan	2.42
	Hagen	In-line storage	Hagen & Kerns	2.43
	Amherst Quarry	Off-line storage	Bailey & Amherst	3.42
South-Central	SPPs 295, 23, 24	RTC Interception	I-190 & Albany	10.25
	SPPs 217, 317 & 281 (3 locations)	RTC Interception	SSP 217, 317 & 281 (3 locations)	10.25
			TOTAL Construction Costs:	**66.58**
Operation and maintenance Costs Estimates Summary ($M/yr)				**0.50**

6.3 COST-BENEFIT ANALYSIS

6.3.1 Cost Performance Indicators for RTC Sites

Based on individual RTC site costs and annual volume reductions of CSOs for the 1986 reference year, cost performance indicators (CPI) are calculated by dividing the individual cost of each RTC site by the corresponding CSO volume reduction. These indicators are presented in $/1000 gallons for each sewer district in Table 6-3. The increased interception opportunity sites are grouped when they share the residual capacity of one local interceptor. Therefore, the following SPP sites are considered as joint solutions:

- Sites SPP 336B, SPP 337, SPP 339 and SPP 340 in the Scajaquada District;

- SPPs 023, 024 and 296 (CSOs 011 and 012) in the South-Central District;
- Sites SPP 217, 281 and 317 in the South-Central District.

Table 6-3: Summary of Cost Performance Indicators for RTC Sites

Sewer District	RTC Site	Type	Total Reduction Volume (MG)	Cost ($M)	Cost Performance Indicator ($/1000 gal)
North District	Hertel (Military)	In-line storage	56.6	5.04	88.91
	Hertel (Delaware)	In-line storage	22.0	5.02	228.26
Scajaquada District	SPPs 336B, 337, 339 & 340	RTC Interception	94.7	13.66	144.31
	Bird	In-line storage	21.8	4.30	197.52
	East Ferry	In-line storage	16.0	2.42	151.34
	Colorado	In-line storage	2.3	2.40	1068.77
	Bailey	In-line storage	8.0	2.40	299.19
	Texas	In-line storage	14.6	2.57	176.08
	Hazelwood (Hagen)	In-line storage	10.1	2.42	240.51
	Hagen	In-line storage	13.5	2.43	179.76
	Amherst Quarry	Off-line storage	49.4	3.42	69.08
South-Central District	SPPs 295, 23, 24	RTC Interception	148.5	10.25	69.01
	SPPs 217, 317 & 281 (3 locations)	RTC Interception	63.3	10.25	161.96

6.3.2 Cost-Benefit Analysis for RTC Sites

The RTC opportunity sites are sorted on the basis of the calculated CPI and presented in Table D-6 in Appendix D.

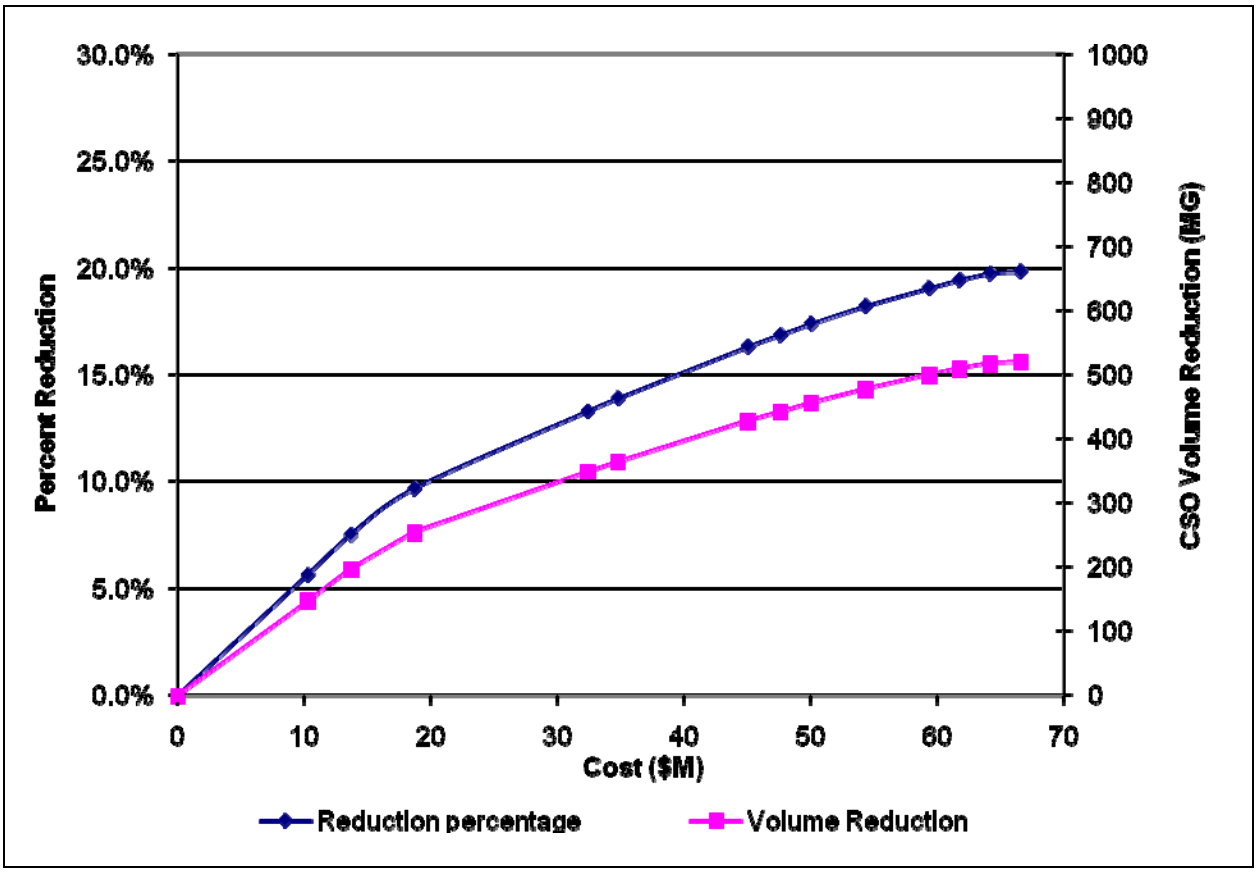
Cumulative costs and volumes are calculated for each RTC site (sorted by CPI) and presented in Table 6-4. Reduced CSO volumes for the 1986 reference year are presented in MG as well in percentage figures.

Table 6-4: Cumulative Costs of RTC vs. Cumulative CSO Volume Reductions

Sewer District	Site	Type	Cost Performance Indicator ($/1000 gal)	Cumulative Cost ($M)	Cumulative CSO Volume Reduction	
					(MG)	(%)
South-Central	SPPs 296, 23, 24	RTC Interception	69.01	10.25	148.5	5.66%
Scajaquada	Amherst Quarry	Off-line storage	69.08	13.66	198.0	7.55%
North	Hertel (Military)	In-line storage	88.91	18.70	254.6	9.71%
Scajaquada	SPP 336B, 337, 339 & 340 (4 locations)	RTC Interception	144.31	32.36	349.3	13.32%
Scajaquada	East Ferry	In-line storage	151.34	34.78	365.3	13.93%
South-Central	SPPs 217, 317 & 281 (3 locations)	RTC Interception	161.96	45.03	428.5	16.34%
Scajaquada	Texas	In-line storage	176.08	47.60	443.1	16.90%
Scajaquada	Hagen	In-line storage	179.76	50.03	456.7	17.41%
Scajaquada	Bird	In-line storage	197.52	54.33	478.4	18.24%
North	Hertel (Delaware)	In-line storage	228.26	59.35	500.4	19.08%
Scajaquada	Hazelwood (Hagen)	In-line storage	240.51	61.77	510.5	19.47%
Scajaquada	Bailey	In-line storage	299.19	64.18	518.5	19.77%
Scajaquada	Colorado	In-line storage	1068.77	66.58	520.8	19.86%

Cumulative costs for RTC opportunity sites are plotted against cumulative reduced CSO volumes for the 1986 reference year (percentage and actual volumes in MG). Figure 6-1 presents the cost-benefit comparison based on the knee-of-the-curve analysis.

Figure 6-1: Cost-Benefit Curves – Cost of RTC versus CSO Reductions



The above curves demonstrate that some CSO opportunity sites offer better CSO volume reduction performance than others. The FINAL DRAFT choice for the LTCP strategy and alternatives should take into account this cost/benefit analysis by eliminating sites with lesser performance results. For example, the in-line storage opportunity in the Colorado Trunk Sewer (SPP 337) is estimated at $2.4M (3.6% of all sites cost), yet offers only 2.3 MG in annual CSO volume reductions (less than 0.1% of the total reduced volume at all sites). Therefore this particular site could be discarded from the preferred alternatives.

7. CONCLUSIONS AND NEXT STEPS

The results of this feasibility study show that the integration of RTC for the City of Buffalo's combined sewer network is both beneficial in reducing overflow volumes and cost effective when compared to other mitigation solutions. The following section summarizes the study's findings, implementation costs, and recommendations for next steps.

7.1 RTC FEASIBILITY STUDY FINDINGS

The analysis conducted as part of this feasibility study demonstrates that the implementation of RTC at certain sites can improve the annual capture rate by reducing the annual CSO volume without the need for additional storage facilities or further combined sewer separation. By providing control on key reaches and over the largest inflows to the interceptor network, the RTC can make better use of the available capacity of existing interceptors and trunk sewers. It should be noted that this study was conducted with the existing system including all projects identified in phase 1 of the LTCP and were incorporated in the latest 2010 XP-SWMM model provided by Malcolm Pirnie.

During frequent events, the analysis showed that certain interceptors are generally underutilized while overflow is occurring as the existing static regulators are set primarily to protect the collection system against excessive flow for significant and critical events. Therefore, the benefits of RTC are most evident during these types of events. The use of RTC prevents or reduces CSOs by increasing threshold interception capacities adapting to different types of rainfall and at the same time ensuring the interceptor capacities are not exceeded in order to protect against any excessive surcharge conditions that could cause unwanted flooding.

During larger events, there is less residual interceptor capacity and consequently local reactive and extended local reactive RTC approaches do not significantly improve on the level of CSO reduction. In this case, only a more sophisticated global optimal RTC approach would be able to make use of weather predictions and coordinated management to anticipate flows and effectively balance system capacity to reduce CSO discharge volumes.

On a system-wide and typical year basis, the application of RTC has the potential of reducing typical seasonal overflow volumes by over 20% annually. The performance of RTC with regards to overflow reduction is analyzed on a district basis, and volumetrically, the most significant gains would be achieved in the South-Central district.

The results from the North Sewer District analysis demonstrate that in-line storage can be most effective in the presence of very large trunk sewers where the residual capacity during frequent rainfall events is significant. In the cost-benefit analysis, the downstream in-line storage location at the intersection of Hertel Rd and Military Ave rated well between the two potential branches. It should be noted that a few CSO locations in the North District continue to overflow during all events. Since these locations discharge considerably less volume than CSO 055, they were not considered in this analysis.

The results from the Scajaquada Sewer District analysis demonstrate that the use of the Amherst Quarry as an off-line storage facility contributes major reductions in CSO volumes at the junction of the Bailey Trunk regulator and the STI when RTC is applied. This was later confirmed by simulation with the XP-SWMM Model. This further demonstrates that RTC can be used to identify locations and volumes for future storage facilities when considering the preferred alternatives of the LTCP.

The results from the South-Central Sewer District analysis demonstrate that when top CSO sites are in proximity to the main interceptor and the WWTP, as in the case of CSOs 011 and 012 (Albany), the use of RTC for maximizing interception has the potential for significantly reducing CSO volumes. The application of RTC at this site ranked the highest in the cost-benefit analysis with a CPI of $69 per 1000 gallons of CSO reduction.

In summary, the RTC approach improves the capture rate and helps reduce system-wide CSO volumes by:

- Maximizing the use of residual capacity of the existing network (large trunk sewers, interceptors and WWTP);
- Maximizing the use of existing off-line storage facilities by temporarily diverting potential CSO volume out of the system until DWF conditions are re-established;
- Helping to identify locations and volumes for future storage facilities when considering the preferred alternatives of the LTCP.

7.2 RTC IMPLEMENTATON AND COSTS

Table 6-2 summarizes the cost estimates of all potential RTC sites identified in the study area. A total of 21 sites were chosen to conduct the preliminary assessment for RTC potential using 3 approaches: increasing regulated interception capacity, in-line storage, and the use of an existing off-line storage facility. The total cost is approximately $66.5 M while the annual operation and maintenance costs are about $0.5M, which takes into consideration a life cycle cost over 40 years.

The knee-of-the-curve analysis presented in Section 6.3 (Figure 6-1) demonstrates that certain RTC sites could be discarded from the preferred list since their overall CSO reductions are not cost effective. These sites include the in-line storage branches on Colorado, Bailey, and Hazelwood. The total cost of these sites is estimated at $7.22 M for a total corresponding CSO reduction of less than 1%. The selection and prioritization of potential RTC sites will be based on the Cost Performance Indicators (Table 6-3) in conjunction with factors such as combined benefits with other control sites, constructability and coordination with other BSA projects.

The Amherst Quarry demonstrates an interesting benefit for CSO volume reduction, but this facility is most effective during large rainfall events. During smaller events, most overflows are generated by areas downstream of the Quarry, which could be captured by the proposed RTC interception and in-line storage sites. Therefore, the planning of the implementation of this site needs to be carried out in coordination with these other RTC sites in order to reduce CSO volumes over a broader range of events.

Based on our previous experience, we recommend a phased approach for any RTC implementation. If the BSA wishes to evaluate dynamic control with a pilot implementation project as it is a new technology for its staff, we suggest a pilot RTC project at SPPs 296, 023, 024, which would yield the best value with the lowest Cost Performance Indicator to benefit overflow capture at CSOs 011 and 012. These sites can be controlled independently through a local reactive control approach, maximizing interception based on the downstream water level in the interceptor. The control site status (gate position, flow intercepted) and monitoring data (water level) should be centralized through SCADA so they are available for operators to monitor and supervise. Ideally, the central station should be located at the WWTP. The local station and SCADA should include manual override capabilities so that operators can close or open gates remotely.

As additional RTC sites are implemented, a Decision Support System would help process large quantities of data and present only relevant information to operators in a concise and easy to understand manner through the human machine interface (HMI). This support will allow operators to better understand and gradually adapt to condition changes in the new system. The centralized data can also be processed to support engineering and planning to evaluate the performance of the implemented sites and to make any adaptive changes to the LTCP accordingly.

Proposed LTCP alternatives, such as grey or green infrastructure, increases to the WWTP capacity, would change the hydraulic conditions of the system and thus benefit from complementary opportunities and synergies with a RTC system in place. Consequently, the cost-benefit analysis would require updates to draft a comprehensive implementation plan.

7.3 NEXT STEPS: INTEGRATION OF RTC WITH LTCP

At this stage, the findings of the current study are based on the use and maximization of the existing sewer system and do not include the consideration and optimization of LTCP alternatives. The current LTCP proposes various solutions to alleviate local capacity issue, such as sewer separation, green infrastructure, increased overall system conveyance, storage facilities, increased treatment capacity, including new sewers, satellite storage and treatment basins, and upgrades to the treatment plant. There is certainly potential for RTC to provide better flow management, such as more optimized filling and dewatering strategies, and the improved utilization of new planned infrastructures. More importantly, there could be opportunities to reduce the number of the storage sites or the length of interceptors using RTC to provide significant cost savings of the overall program and still comply with regulatory terms and conditions. For example: The City of Ottawa in Canada implemented a RTC strategy that maximizes interceptor storage and conveyance capacity and better management of the inflow pump station at the treatment plant to meet their minimum CSO control requirements (the capture and treatment of 90% of wet weather flow). RTC has allowed the City to defer the construction of a very costly central storage tunnel.

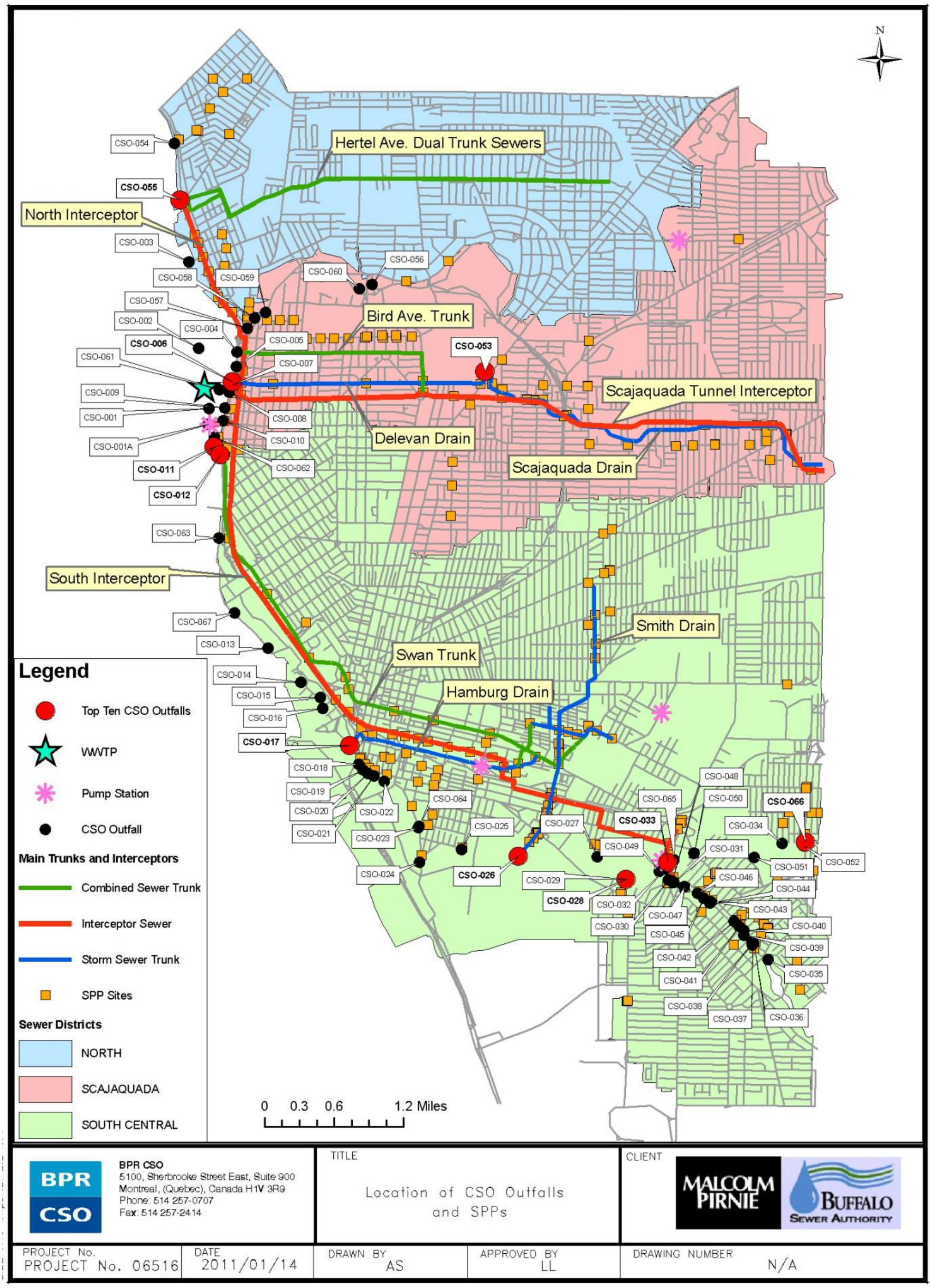
Furthermore, our recent RTC evaluation for the MDC in Hartford, CT demonstrated that the consolidation of pipes and overflows using RTC at specific sites provides flexibilities in the design of the LTCP solutions, which permits the reduction of the length and alignment of consolidation conduits and tunnels. In general, BPR CSO's numerous implementation projects (9 RTC systems in the US, Canada and Europe) show considerable cost reductions in the order of 25 to 75% in each city's LTCP while still achieving the same environmental objectives.

The current study results confirm the potential of RTC for the existing combined sewer system and provide orientation for additional analysis. For example, for CSO sites with small overflow volumes that are frequently activated, there could be simple hydraulic solutions, such as raising the weir to eliminate overflow occurrences. Alternatively, these sites could be prioritized for green infrastructure solutions. For other sites, such as the Hamburg Drain or the Amherst Quarry, coordinated real time control with upstream and downstream sites would provide the most benefits.

We are committed to working closely with BSA and its consultants to optimize its LTCP in time for regulatory review in June 2011. Specifically, we will support Malcolm Pirnie for the integration of RTC strategies into the LTCP to achieve additional performance benefits and cost reductions.

APPENDIX A: BASELINE OVERFLOW RESULTS

Figure A-1: Location of CSO Outfalls and SPPs



BPR CSO BPR CSO 5100, Sherbrooke Street East, Suite 900 Montreal, (Quebec), Canada H1V 3R9 Phone: 514 257-0707 Fax: 514 257-2414	TITLE Location of CSO Outfalls and SPPs		CLIENT MALCOLM PIRNIE BUFFALO SEWER AUTHORITY	
PROJECT No. PROJECT No. 06516	DATE 2011/01/14	DRAWN BY AS	APPROVED BY LL	DRAWING NUMBER N/A

Table A-1:
Typical Year Overflow Volumes (9-mth Period) - (ranked by District & Overflow Volume)

CSO Outfall ID	Sewer District	Overflow Volume (9-month Period) (MG)	% of District Subtotal	% of System-Wide Total
055	North	712	95%	25%
054	North	20	2.6%	1%
058	North	10	1.3%	0.3%
003	North	3	0.4%	0.1%
059	North	2	0.2%	0.1%
056	North	1	0.2%	0.04%
057	North	0	0%	0%
North District Subtotal:		***748***	**100%**	***26%***
006	Scajaquada	395	47%	14%
053	Scajaquada	342	41%	12%
004	Scajaquada	34	4%	1%
061	Scajaquada	49	6%	2%
010	Scajaquada	10	1%	0%
008	Scajaquada	7	1%	0%
060	Scajaquada	1	0%	0%
005	Scajaquada	0	0%	0%
Scajaquada District Subtotal:		***838***	**100%**	***29%***
026	South-Central	255	20%	9%
017	South-Central	236	18%	8%
011	South-Central	122	10%	4%
012	South-Central	115	9%	4%
028	South-Central	114	9%	4%
066	South-Central	92	7%	3%
033	South-Central	68	5%	2%
027	South-Central	56	4%	2%
037	South-Central	42	3%	1%
015	South-Central	26	2%	1%
052	South-Central	19	1%	1%
064	South-Central	19	1%	1%
022	South-Central	19	1%	1%
013	South-Central	19	1%	1%
035	South-Central	18	1%	1%
014	South-Central	14	1%	0%
047	South-Central	9	1%	0%
016	South-Central	8	1%	0%
044	South-Central	6	0%	0%
050	South-Central	6	0%	0%
025	South-Central	6	0%	0%
051	South-Central	4	0%	0%
046	South-Central	2	0%	0%

CSO Outfall ID	Sewer District	Overflow Volume (9-month Period) (MG)	% of District Subtotal	% of System-Wide Total
063	South-Central	1	0%	0%
029	South-Central	1	0%	0%
049	South-Central	0	0%	0%
048	South-Central	0	0%	0%
039	South-Central	0	0%	0%
001a	South-Central	0	0%	0%
032	South-Central	0	0%	0%
034	South-Central	0	0%	0%
South-Central District Subtotal:		***1,278***	**100%**	***45%***
SYSTEM-WIDE TOTAL:		**2,863**	**100%**	***100%***

Table A-2:
2009 Reference Event Overflow Volumes - (ranked by District & Overflow Volume)

CSO Outfall ID	Sewer District	Model Link	Overflow Volume (MG)			
			3-month Event (Oct 23, 2009)	1-month Event (July 17, 2009)	2-week Event (Aug 28, 2009)	1-week Event (April 28, 2009)
055	North	P8	76.31	38.14	2.71	0.00
054	North	17	1.21	0.60	0.21	0.13
058	North	6892	0.66	0.29	0.16	0.07
003	North	5500	0.24	0.13	0.02	0
059	North	10254	0.07	0	0	0
056	North	2604	0.03	0.02	0	0
057	North	N33	0	0	0	0
North District Event Subtotals:			***78.5***	***39.2***	***3.1***	***0.2***
006	Scajaquada	5710	30.9	16.5	4.6	0
053	Scajaquada	5943	12.9	10.1	5.5	1.0
061	Scajaquada	OF61B.1	7.0	0.6	0	0
004	Scajaquada	10213 + 10221	4.4	0.1	0.1	0
010	Scajaquada	5553	1.1	0.2	0.1	0.01
008	Scajaquada	5906	0.5	0.2	0.1	0.1
060	Scajaquada	5781	0.04	0.02	0.01	0.01
005	Scajaquada	5873	0	0	0	0
Scajaquada District Event Subtotals:			***56.9***	***27.8***	***10.4***	***1.1***
017	South-Central	14584	13.4	7.8	4.4	0.4
026	South-Central	12620	13.3	5.3	2.3	0.5
011	South-Central	6729	8.1	6.5	1.1	0.0
012	South-Central	6363	8.6	2.4	2.2	0.2
066	South-Central	14982	1.9	1.6	0.7	0.7
028	South-Central	7511 + 7512	1.5	2.1	0.7	0.6
015	South-Central	15670	1.2	1.1	0.8	0
016	South-Central	14968 + SPP39w	0.5	0.3	0.3	0.03
064	South-Central	SPP135aw + L14809	0.5	0.3	0.2	0.01
022	South-Central	L14678	0.5	0.3	0.2	0
025	South-Central	15468	0.4	0.2	0.2	0
035	South-Central	7263	0.2	0.3	0.1	0.1
013	South-Central	10047	0.0	0.0	0.5	0.0
047	South-Central	SPP114OF + SPP113OF	0.02	0.23	0.11	0.02
037	South-Central	7075	0	0.23	0	0
033	South-Central	14414	0	0.14	0	0
027	South-Central	10065	0.1	0.04	0.01	0.01
014	South-Central	L9201	0.1	0	0	0
050	South-Central	7141	0	0.03	0.03	0
063	South-Central	16139	0	0.01	0.05	0
046	South-Central	7631	0.01	0.01	0	0
001a	South-Central	WETWELLOF	0	0	0	0

CSO Outfall ID	Sewer District	Model Link	Overflow Volume (MG)			
			3-month Event (Oct 23, 2009)	1-month Event (July 17, 2009)	2-week Event (Aug 28, 2009)	1-week Event (April 28, 2009)
029	South-Central	7735	0	0	0	0
032	South-Central	SPP120w	0	0	0	0
034	South-Central	SPP344w	0	0	0	0
039	South-Central	7528	0	0	0	0
044	South-Central	8118	0	0	0	0
048	South-Central	SPP118OF	0	0	0	0
049	South-Central	7571	0	0	0	0
051	South-Central	16184	0	0	0	0
052	South-Central	7751	0	0	0	0
South-Central District Event Subtotals:			***50.4***	***29.0***	***14.1***	***2.5***
SYSTEM-WIDE TOTALS:			**185.8**	**95.9**	**27.6**	**3.8**

Table A-3: 2009 Reference Event SPP Volumes - (Ranked by District & Overflow Volume)

Sewer Patrol Point (SPP)			Associated CSO Outfall ID	Sewer District	Overflow Volume (ft^3)			
SPP ID	Model Link	SPP Node			3-month Event (Oct 23, 2009)	1-month Event (July 17, 2009)	2-week Event (Aug 28, 2009)	1-week Event (April 28, 2009)
1	P8	350	055	North	10,152,670	5,097,922	362,496	5
5	5509	5506	003	North	11,295	7,228	0	0
192	N18	9302	054	North	10,219	5,522	1,961	1,292
183	10259	10185	059	North	8,760	0	0	0
213	6893	6890	058	North	8,623	1,252	1,705	0
4	5510	5479	003	North	8,019	4,908	0	0
11	N11	N1	003	North	7,079	1,858	2,400	0
187	SPP187	200	054	North	3,368	43	0	0
245	N22	9231	056	North	2,875	1,143	0	0
7	5582	5576	003	North	2,836	1,298	0	0
244	N21	9218	056	North	1,317	1,876	0	0
10	6020	6014	003	North	701	170	0	0
190	SPP190	116	054	North	480	0	0	0
182	10267	10189	059	North	368	0	0	0
186	10527	10525	003	North	16	8	0	0
195	N33	N32	057	North	0	0	2	0
185	5978	5976	003	North	0	0	0	0
3	5515	5513	003	North	0	0	0	0
8	5594	5579	003	North	0	0	0	0
9	5492	5489	003	North	0	0	0	0
189	SPP189	179	054	North	0	0	0	0
191	SPP191	P1	054	North	0	0	0	0
181	10274	10194	059	North	0	0	0	0
188	66	65	054	North	-2	0	0	0
North District Subtotal:					***10,218,623***	***5,123,227***	***368,564***	***1,297***
17	CHME5713	5719	006	Scajaquada	7,451,092	4,201,007	2,742,550	-1
170A	SPP170.2	SPP170	053	Scajaquada	3,382,636	2,206,148	1,613,742	11,827
336B	4400	4392	053	Scajaquada	985,891	608,102	397,177	4,801
330	4739	4738	061	Scajaquada	932,541	78,390	0	0
340	2633	2632	053	Scajaquada	819,876	613,047	153,538	41,083
339	SPP339.4	2790	053	Scajaquada	807,296	539,770	136,304	37,767
170B	3397	3291	053	Scajaquada	708,772	395,126	141,051	23,289
337	8213	2973	053	Scajaquada	678,830	485,539	114,269	418
338	8005	7942	053	Scajaquada	627,727	370,755	38,290	0
13	10234	10196	004	Scajaquada	594,138	12,723	15,460	0
332	6033	4824	006	Scajaquada	535,217	257,814	139,019	0
180	SPP180OF.1	3637	006	Scajaquada	426,068	191,359	97,838	663
254	6715	4076	QUARRY	Scajaquada	252,874	187,900	38,357	6,044
331	SPP331.3	SPP331	006	Scajaquada	251,967	58,616	25,201	1,350
165B	165WWF1	4150	053	Scajaquada	216,245	123,018	52,593	13,179
179	5831	4853	006	Scajaquada	176,390	68,119	18,260	0
341A	3698	3697	053	Scajaquada	158,755	66,181	145,932	6,993
21	5555	5554	010	Scajaquada	153,543	29,464	18,478	842
336A	3463	3460	053	Scajaquada	149,525	73,296	34,994	1,816
163	SPP163.2	SPP163	053	Scajaquada	142,300	79,341	50,762	323
174	5444	4017	053	Scajaquada	115,083	42,641	12,459	0
229A	4006	4004	053	Scajaquada	94,341	27,235	3,553	0
165	4039	SPP165	053	Scajaquada	94,133	73,090	20,703	860
274	4813	SPP274	QUARRY	Scajaquada	78,748	51,804	11,848	0
203	9148	4107	053	Scajaquada	74,304	29,631	24,303	0
255 (1) and (2)	4714	4713	QUARRY	Scajaquada	73,613	53,575	0	0
175	5096	4953	053	Scajaquada	73,428	50,763	30,102	0
178	3652	4962	053	Scajaquada	60,420	21,820	7,477	0
165A	4253	4228	053	Scajaquada	53,682	34,099	4,704	0
335B	3922	3921	053	Scajaquada	42,203	15,703	11,339	0
164	SPP164.2	SPP164	053	Scajaquada	38,838	34,160	11,193	0
204	9135	3845	053	Scajaquada	38,587	18,330	12,235	0
177	5132	4931	053	Scajaquada	18,694	14,729	6,894	0
345	3200	3199	053	Scajaquada	12,255	1	0	0
176	5106	4941	053	Scajaquada	11,190	10,061	4,855	0
276	SPP276.3	SPP276	QUARRY	Scajaquada	8,485	7,824	0	0
166	3340	3305	053	Scajaquada	7,878	3,411	2,513	0
271, 272	271272.4	SPP271272	QUARRY	Scajaquada	7,470	5,158	926	0
260	SPP260.4	SPP260	QUARRY	Scajaquada	7,046	4,901	953	0
341B	3675	3674	053	Scajaquada	6,259	5,081	5,315	4,430
261	SPP261.4	SPP261	QUARRY	Scajaquada	5,996	5,284	101	0
202	9153	3979	053	Scajaquada	5,229	1	9,656	0
210	SPP210.1	5015	053	Scajaquada	3,006	0	0	0
335A	SPP335A.2	SPP335A	053	Scajaquada	2,916	2,526	1,856	0
275	SPP275.4	SPP275	QUARRY	Scajaquada	1,933	1,387	85	0
269, 270	269270.4	SPP269270	QUARRY	Scajaquada	1,752	1,536	121	0
266, 267	266267.7	SPP266267	QUARRY	Scajaquada	1,388	1,272	54	0
263	SPP263.5	SPP263	QUARRY	Scajaquada	850	788	0	0

Sewer Patrol Point (SPP)			Associated CSO Outfall ID	Sewer District	Overflow Volume (ft^3)			
SPP ID	Model Link	SPP Node			3-month Event (Oct 23, 2009)	1-month Event (July 17, 2009)	2-week Event (Aug 28, 2009)	1-week Event (April 28, 2009)
No ID	3940	3939	053	Scajaquada	782	0	0	0
262	SPP262.5	SPP262	QUARRY	Scajaquada	712	736	0	0
268	SPP268.3	SPP268	QUARRY	Scajaquada	694	795	4	0
265	SPP265.3	SPP265	QUARRY	Scajaquada	565	674	0	0
259	SPP259.4	SPP259	QUARRY	Scajaquada	395	459	0	0
342B	3551	3550	053	Scajaquada	376	2,472	13,312	0
19	5910	5909	008	Scajaquada	300	0	0	0
200A	9175	9173	053	Scajaquada	34	0	26,206	0
264	SPP264.6	SPP264	QUARRY	Scajaquada	5	60	0	0
157	4419	3593	053	Scajaquada	0	0	14,853	0
201	9160	4146	053	Scajaquada	0	0	6,733	0
342A	3749	3748	053	Scajaquada	0	1,039	6,612	0
200B	9167	4156	053	Scajaquada	0	0	362	0
156	3920	4495	053	Scajaquada	0	0	194	0
14A	5882	5857	005	Scajaquada	0	0	0	0
240	3624	5751	060	Scajaquada	0	0	0	0
230	5890	5628	060	Scajaquada	0	0	0	0
231	5881	5636	060	Scajaquada	0	0	0	0
232	5874	5644	060	Scajaquada	0	0	0	0
233	5862	5654	060	Scajaquada	0	0	0	0
234	5855	5668	060	Scajaquada	0	0	0	0
235	SPP235.2	5682	060	Scajaquada	0	0	0	0
236	5821	5692	060	Scajaquada	0	0	0	0
237	5834	5705	060	Scajaquada	0	0	0	0
238	5822	5771	060	Scajaquada	0	0	0	0
239	5813	5761	060	Scajaquada	0	0	0	0
Old 259	COMAMH.4	COMAMH	QUARRY	Scajaquada	0	0	0	0
Scajaquada District Subtotal:					***20,395,274***	***11,168,756***	***6,225,336***	***155,683***
24	6729	6074	011	South-Central	1,088,809	864,018	152,438	0
296	6049	6048	012	South-Central	829,078	284,133	238,390	23,270
217	16100	11628	026	South-Central	564,950	249,011	109,952	0
67	10495	10492	017	South-Central	544,318	277,044	41,473	0
317	13178	10436	026	South-Central	460,562	118,620	32,656	0
281	10864	SPP281	017	South-Central	342,791	132,421	62,726	0
23	6877	P13	012	South-Central	317,239	39,417	57,463	0
326	11508	11500	017	South-Central	141,364	69,414	19,267	0
35	14092	14088	015	South-Central	139,093	132,541	89,667	0
199B	12817	12813	026	South-Central	122,232	24,009	14,939	0
131	14728	14726	064	South-Central	101,312	59,781	40,922	0
198B	12758	12757	026	South-Central	82,441	18,646	0	0
135A	SPP135Aw	SPP135A	064	South-Central	63,616	42,795	32,397	1,400
199C	13306	12819	026	South-Central	60,015	16,912	9,111	0
218	L12868	12866	026	South-Central	59,465	25,741	7,674	0
123B	SPP123bOF	8070	028	South-Central	57,469	71,592	20,781	17,157
209	15468	15465	025	South-Central	51,967	30,726	27,054	0
130	SPP130w	SPP130	017	South-Central	44,677	30,470	23,076	514
199A	13061	13008	026	South-Central	40,350	8,035	3,532	0
314	SPP314w	SPP314	026	South-Central	38,780	16,126	9,886	11
133	15454	15320	064	South-Central	29,763	21,534	15,815	0
145	SPP145w	SPP145	022	South-Central	29,079	16,179	11,632	0
129	SPP129w	SPP129	064	South-Central	25,532	17,880	14,315	3
36	15744	15741	015	South-Central	24,940	18,798	20,495	0
39	SPP39w	SPP39	016	South-Central	18,381	12,483	11,311	0
138	SPP138w	SPP138	022	South-Central	17,698	12,164	8,879	0
69	SPP69w	SPP69	026	South-Central	16,806	6,889	4,444	0
53	15004	13982	017	South-Central	15,345	12,262	14,568	0
128	SPP128w	SPP128	017	South-Central	13,659	13,910	11,152	0
144	SPP144w	SPP144	022	South-Central	13,599	8,795	7,029	0
75	SPP75w	SPP75	026	South-Central	13,402	12,489	3,630	4,258
248	16134	16127	026	South-Central	12,864	0	0	0
123C	SPP123Cw	SPP123C	028	South-Central	11,896	21,665	5,924	4,559
88	SPP88w	SPP88	026	South-Central	11,342	6,876	6,407	0
150	12722	12715	026	South-Central	11,204	0	0	0
206A&B	6778w	6778		South-Central	11,197	0	0	0
55	14903	14900	017	South-Central	9,834	2,107	0	0
148	13604	13598	026	South-Central	9,388	1,988	1,048	0
318	SPP318w	SPP318	026	South-Central	8,478	13,976	2,005	0
197C	12903b	SPP197c	026	South-Central	7,267	3	1	0
79	SPP79w	SPP79	026	South-Central	6,730	4,018	4,617	0
97	10066	8736	027	South-Central	6,461	677	40	0
68	SPP68w	SPP68	026	South-Central	5,287	947	383	0
77	SPP77w	SPP77	026	South-Central	4,713	2,105	2,990	0
149	12705	12704	026	South-Central	4,183	0	0	0
84	SPP84w	SPP84	026	South-Central	4,177	2,083	2,032	0
151	12739	12738	026	South-Central	4,133	0	0	0

Sewer Patrol Point (SPP)			Associated CSO Outfall ID	Sewer District	Overflow Volume (ft^3)			
SPP ID	Model Link	SPP Node			3-month Event (Oct 23, 2009)	1-month Event (July 17, 2009)	2-week Event (Aug 28, 2009)	1-week Event (April 28, 2009)
132	15074	15071	064	South-Central	4,057	5,036	5,010	0
51	15049	15044	017	South-Central	3,949	3,203	4,700	0
78	SPP78w	SPP78	026	South-Central	3,814	2,047	2,800	0
114	SPP114OF	8191o	047	South-Central	3,186	31,369	14,963	3,088
149	12890	12704	026	South-Central	3,079	0	0	0
87	SPP87w	SPP87	026	South-Central	2,741	1,037	2,436	0
97A	SPP97Aw	SPP97A	027	South-Central	1,189	4,115	1,398	792
94	SPP94w	SPP94	026	South-Central	698	0	188	0
90	SPP90w	SPP90	026	South-Central	99	1,579	0	0
277	13155	10380	026	South-Central	87	0	0	0
152	12752	12749	026	South-Central	1	0	0	0
122	7075	7069	037	South-Central	0	30,962	0	0
304	10047	9702	013	South-Central	0	2,970	67,704	0
283	16139	SPP283	063	South-Central	0	1,122	6,060	0
105	7141	7138	050	South-Central	0	4,207	4,296	0
50	15937	14304	017	South-Central	0	0	3,854	0
113	SPP113OF	8193	047	South-Central	0	0	48	0
104	14414	8822	033	South-Central	0	18,650	33	0
42	14983	14981A	016	South-Central	0	0	0	0
282	SPP282w*	SPP282	017	South-Central	0	0	0	0
65	6842w*	6842	017	South-Central	0	0	0	0
74	SPP74w	SPP74	026	South-Central	0	0	0	0
80	SPP80w	SPP80	026	South-Central	0	0	0	0
81	SPP81w	SPP81	026	South-Central	0	0	0	0
82	SPP82w	SPP82	026	South-Central	0	0	0	0
85	SPP85w	SPP85	026	South-Central	0	0	0	0
89	SPP89w	SPP89	026	South-Central	0	0	0	0
91	SPP91w	SPP91	026	South-Central	0	0	0	0
92	SPP92w	SPP92	026	South-Central	0	0	0	0
197A	SPP197aw2	12971	026	South-Central	0	0	0	0
249	13059	13057	026	South-Central	0	0	0	0
319	13195	13194	026	South-Central	0	1	0	0
208	SPP208w	SPP208	028	South-Central	0	0	0	0
124	7558	7557	028	South-Central	0	17,153	0	0
125A	SPP125Aw	SPP125A	028	South-Central	0	0	0	0
125	SPP125w	7958	029	South-Central	0	0	0	0
126	7735	7729	029	South-Central	0	0	0	0
120	SPP120w	7449o	032	South-Central	0	0	0	0
107	L7277	7276	035	South-Central	0	0	0	0
107A	L7280	7279	035	South-Central	0	0	0	0
311	7528	7523	039	South-Central	0	0	0	0
121	8118	8085	044	South-Central	0	0	0	0
308	7551	7544	046	South-Central	0	0	0	0
309	SPP309w	7704	046	South-Central	0	0	0	0
310	7597	7115	046	South-Central	0	0	0	0
118	SPP118OF	7830	048	South-Central	0	0	0	0
119	7571	7568	049	South-Central	0	0	0	0
307	16184	6902	051	South-Central	0	0	0	0
106	8259	7486A	052	South-Central	0	0	0	0
106A	7388	7385	052	South-Central	0	0	0	0
291	SPP291w	SPP291	066	South-Central	0	0	0	0
292	SPP292w	SPP292	066	South-Central	0	0	0	0
293	SPP293w	SPP293	066	South-Central	0	0	0	0
294	SPP294w	SPP294	066	South-Central	0	0	0	0
295	SPP295w	SPP295	066	South-Central	0	0	0	0
329	SPP329w	SPP329	066	South-Central	0	0	0	0
211	16115	16106	066	South-Central	0	339	0	0
322	L15231	12997	066	South-Central	0	0	0	0
197B	13232	12964	026	South-Central	-9	0	0	0
48	14349	14346	017	South-Central	-13,256	8,791	14,933	0
53	13984	13982	017	South-Central	-13,522	10,760	12,794	0
139	L15434	15431	021	South-Central	0	0	0	0
123A	SPP123aw	7464	028	South-Central	0	0	0	0
344	SPP344w	SPP344	034	South-Central	0	0	0	0
South-Central District Subtotal:					***5,494,002***	***2,864,623***	***1,283,338***	***55,052***
TOTAL:					**36,107,898**	**19,156,606**	**7,877,238**	**212,033**

APPENDIX B: RAINFALL DATA

Table B-1: 1986 Rainfall Data

Event # (by Date)	Rank (by depth)	Event Start Date	Event Cumulative Depth (in)	Total Event Duration (hr)	Max 1hr Event Intensity (in/hr)
25	1	19/05/1986 7:00	3.63	30.00	1.710
81	2	03/10/1986 6:00	1.73	13.00	0.660
62	3	15/08/1986 12:00	1.50	4.00	0.900
28	4	01/06/1986 14:00	1.07	10.00	0.530
80	5	30/09/1986 3:00	1.02	17.00	0.740
85	6	13/10/1986	1.01	10.00	0.250
106	7	26/11/1986 5:00	1.00	20.00	0.160
29	8	05/06/1986 9:00	0.99	14.00	0.620
17	9	16/04/1986 1:00	0.98	25.00	0.160
19	10	20/04/1986 13:00	0.80	19.00	0.130
73	11	15/09/1986 7:00	0.80	16.00	0.200
74	12	16/09/1986 12:00	0.75	4.00	0.450
79	13	29/09/1986 2:00	0.68	13.00	0.350
46	14	12/07/1986	0.67	9.00	0.210
44	15	07/07/1986 14:00	0.66	3.00	0.640
57	16	01/08/1986 6:00	0.55	6.00	0.230
59	17	07/08/1986 2:00	0.54	12.00	0.170
61	18	10/08/1986 16:00	0.54	7.00	0.270
12	19	05/04/1986 6:00	0.52	24.00	0.200
76	20	23/09/1986 2:00	0.52	6.00	0.170
95	21	01/11/1986 20:00	0.49	11.00	0.090
60	22	07/08/1986 14:00	0.45	9.00	0.420
16	23	15/04/1986 4:00	0.44	13.00	0.160
34	24	11/06/1986 17:00	0.44	16.00	0.150
70	25	11/09/1986 4:00	0.44	24.00	0.080
82	26	04/10/1986 11:00	0.43	17.00	0.210
4	27	10/03/1986 18:00	0.41	12.00	0.150
26	28	22/05/1986 15:00	0.41	14.00	0.070
48	29	13/07/1986 21:00	0.38	3.00	0.350
101	30	15/11/1986 12:00	0.35	4.00	0.210
2	31	06/03/1986	0.30	20.00	0.030
36	32	16/06/1986 16:00	0.30	2.00	0.290
3	33	09/03/1986 17:00	0.28	3.00	0.160
5	34	12/03/1986 23:00	0.28	10.00	0.070
8	35	18/03/1986 23:00	0.27	11.00	0.070
32	36	07/06/1986 23:00	0.26	3.00	0.150
39	37	22/06/1986 20:00	0.26	3.00	0.220
41	38	27/06/1986 11:00	0.26	5.00	0.090
83	39	05/10/1986 21:00	0.26	2.00	0.250
104	40	20/11/1986 9:00	0.25	22.00	0.040
24	41	18/05/1986 20:00	0.24	3.00	0.120
65	42	26/08/1986 17:00	0.24	5.00	0.100

Event # (by Date)	Rank (by depth)	Event Start Date	Event Cumulative Depth (in)	Total Event Duration (hr)	Max 1hr Event Intensity (in/hr)
63	43	21/08/1986 15:00	0.22	1.00	0.220
55	44	29/07/1986 16:00	0.21	2.00	0.200
68	45	05/09/1986 1:00	0.20	2.00	0.190
98	46	11/11/1986 6:00	0.20	11.00	0.050
13	47	07/04/1986 20:00	0.19	4.00	0.150
42	48	29/06/1986 16:00	0.18	2.00	0.150
51	49	18/07/1986 18:00	0.18	7.00	0.120
96	50	03/11/1986 22:00	0.17	6.00	0.110
47	51	12/07/1986 23:00	0.16	8.00	0.090
86	52	14/10/1986 1:00	0.16	4.00	0.080
84	53	09/10/1986 2:00	0.14	5.00	0.070
94	54	29/10/1986 15:00	0.13	4.00	0.090
15	55	09/04/1986 4:00	0.12	36.00	0.020
30	56	06/06/1986 22:00	0.12	3.00	0.090
58	57	03/08/1986 5:00	0.12	1.00	0.120
93	58	27/10/1986 15:00	0.12	7.00	0.070
91	59	26/10/1986 1:00	0.11	4.00	0.070
99	60	12/11/1986 19:00	0.11	5.00	0.050
49	61	17/07/1986 9:00	0.10	2.00	0.090
87	62	14/10/1986 15:00	0.10	3.00	0.060
10	63	26/03/1986 20:00	0.09	2.00	0.060
43	64	01/07/1986 23:00	0.09	6.00	0.050
102	65	16/11/1986 16:00	0.09	4.00	0.040
7	66	14/03/1986 18:00	0.08	11.00	0.030
27	67	01/06/1986	0.08	1.00	0.080
50	68	18/07/1986 2:00	0.08	5.00	0.050
100	69	14/11/1986 9:00	0.08	4.00	0.030
40	70	24/06/1986 5:00	0.07	6.00	0.060
54	71	29/07/1986 4:00	0.07	1.00	0.070
88	72	16/10/1986 11:00	0.07	5.00	0.040
103	73	18/11/1986 17:00	0.07	5.00	0.020
23	74	16/05/1986 2:00	0.06	4.00	0.040
78	75	26/09/1986 14:00	0.06	1.00	0.060
97	76	09/11/1986 3:00	0.06	3.00	0.040
11	77	27/03/1986 6:00	0.05	2.00	0.030
66	78	28/08/1986 15:00	0.05	3.00	0.030
75	79	20/09/1986 1:00	0.05	5.00	0.020
90	80	23/10/1986 10:00	0.05	5.00	0.030
6	81	13/03/1986 17:00	0.04	3.00	0.020
18	82	20/04/1986 1:00	0.04	2.00	0.030
37	83	19/06/1986 4:00	0.04	2.00	0.030
52	84	20/07/1986 10:00	0.04	8.00	0.020
69	85	07/09/1986 2:00	0.04	1.00	0.040

Event # (by Date)	Rank (by depth)	Event Start Date	Event Cumulative Depth (in)	Total Event Duration (hr)	Max 1hr Event Intensity (in/hr)
1	86	04/03/1986 5:00	0.03	3.00	0.010
33	87	11/06/1986 7:00	0.03	2.00	0.020
38	88	19/06/1986 15:00	0.03	1.00	0.030
45	89	11/07/1986 14:00	0.03	2.00	0.020
53	90	26/07/1986 10:00	0.03	1.00	0.030
72	91	13/09/1986 12:00	0.03	2.00	0.020
105	92	23/11/1986 21:00	0.03	5.00	0.010
9	93	20/03/1986 6:00	0.02	3.00	0.010
14	94	08/04/1986 16:00	0.02	2.00	0.010
20	95	01/05/1986 11:00	0.02	1.00	0.020
56	96	31/07/1986 15:00	0.02	1.00	0.020
64	97	23/08/1986 14:00	0.02	2.00	0.010
67	98	04/09/1986 12:00	0.02	1.00	0.020
89	99	17/10/1986 10:00	0.02	1.00	0.020
21	100	06/05/1986 5:00	0.01	1.00	0.010
22	101	15/05/1986 17:00	0.01	1.00	0.010
31	102	07/06/1986 12:00	0.01	1.00	0.010
35	103	15/06/1986 11:00	0.01	1.00	0.010
71	104	12/09/1986 12:00	0.01	1.00	0.010
77	105	25/09/1986 15:00	0.01	1.00	0.010
92	106	27/10/1986 2:00	0.01	1.00	0.010

Table B-2: 2009 Rainfall Data

Event # (by Date)	Rank (by Depth)	Event Start Date	Averaged Event Cumulative Depth (in)	Total Event Duration (hr)	Averaged Max 1hr Event Intensity (in/hr)
59	1	08/08/2009 20:00		57.3	0.76
80	2	28/09/2009 8:15	2.54	33.0	0.50
50	3	22/07/2009 22:30	1.58	37.3	0.32
82	4	02/10/2009 10:45	1.58	60.0	0.25
89	**5**	**23/10/2009 6:15**	**1.44**	**22.3**	**0.52**
78	6	26/09/2009 15:30	1.28	23.3	0.40
51	7	25/07/2009 14:15	0.93	12.3	0.58
47	**8**	**17/07/2009 6:00**	**0.92**	**24.3**	**0.42**
65	9	20/08/2009 15:30	0.85	7.5	0.75
2	10	20/04/2009 3:45	0.84	25.5	0.19
29	11	17/06/2009 11:30	0.72	31.5	0.28
33	12	25/06/2009 13:45	0.67	6.5	0.50
37	13	01/07/2009 22:30	0.59	16.3	0.33
71	**14**	**29/08/2009 0:00**	**0.55**	**11.8**	**0.32**
34	15	26/06/2009 2:30	0.53	10.8	0.49
31	16	20/06/2009 4:45	0.52	19.3	0.16
91	17	28/10/2009 6:00	0.52	11.8	0.24
94	18	31/10/2009 4:00	0.51	14.5	0.17
35	19	28/06/2009 10:15	0.51	15.5	0.42
11	20	06/05/2009 19:15	0.45	26.0	0.10
49	21	21/07/2009 12:00	0.39	23.8	0.15
36	22	29/06/2009 22:15	0.36	37.0	0.15
24	23	30/05/2009 20:45	0.36	10.8	0.13
84	24	06/10/2009 19:45	0.36	18.0	0.13
27	25	11/06/2009 18:15	0.35	6.8	0.14
7	**26**	**28/04/2009 10:15**	**0.34**	**6.3**	**0.18**
97	27	04/11/2009 16:30	0.34	24.3	0.13
85	28	09/10/2009 13:45	0.33	17.5	0.05
58	29	04/08/2009 22:45	0.33	15.3	0.31
22	30	28/05/2009 11:00	0.32	22.3	0.11
54	31	29/07/2009 16:15	0.28	4.0	0.25
66	32	22/08/2009 14:00	0.28	14.8	0.23
74	33	21/09/2009 16:30	0.25	3.5	0.14
13	34	09/05/2009 0:45	0.23	2.8	0.16
45	35	11/07/2009 10:30	0.20	9.8	0.13

Event # (by Date)	Rank (by Depth)	Event Start Date	Averaged Event Cumulative Depth (in)	Total Event Duration (hr)	Averaged Max 1hr Event Intensity (in/hr)
8	36	30/04/2009 15:00	0.17	14.0	0.07
21	37	27/05/2009 20:45	0.16	4.8	0.14
25	38	08/06/2009 14:00	0.13	2.5	0.08
26	39	09/06/2009 0:00	0.13	8.5	0.09
69	40	26/08/2009 10:15	0.12	3.8	0.06
3	41	21/04/2009 14:45	0.11	15.8	0.05
15	42	14/05/2009 9:00	0.10	3.8	0.09
9	43	01/05/2009 20:15	0.10	4.3	0.07
23	44	29/05/2009 22:00	0.09	2.5	0.09
87	45	16/10/2009 0:30	0.07	10.8	0.03
67	46	23/08/2009 15:30	0.07	5.8	0.07
5	47	25/04/2009 19:45	0.06	4.3	0.05
63	48	19/08/2009 3:30	0.05	2.0	0.05
72	49	29/08/2009 22:15	0.04	0.8	0.04
88	50	22/10/2009 17:15	0.04	6.5	0.02
60	51	12/08/2009 15:00	0.04	3.8	0.04
16	52	16/05/2009 9:00	0.04	5.5	0.03
38	53	02/07/2009 20:45	0.04	1.3	0.04
56	54	02/08/2009 2:30	0.04	8.8	0.02
41	55	06/07/2009 1:15	0.04	5.3	0.03
10	56	05/05/2009 14:30	0.03	0.3	0.03
4	57	22/04/2009 12:45	0.03	22.8	0.01
14	58	09/05/2009 12:45	0.02	10.0	0.02
77	59	24/09/2009 12:30	0.02	0.3	0.02
79	60	27/09/2009 22:15	0.02	0.5	0.02
18	61	26/05/2009 15:30	0.01	1.3	0.01
42	62	06/07/2009 16:00	0.01	0.5	0.01
83	63	05/10/2009 9:15	0.01	6.0	0.01
90	64	24/10/2009 17:30	0.01	2.5	0.01
1	65	14/04/2009 8:45	0.01	0.5	0.01
40	66	03/07/2009 12:30	0.01	5.5	0.01
43	67	07/07/2009 0:30	0.01	1.3	0.01
44	68	07/07/2009 12:30	0.01	3.0	0.01
73	69	30/08/2009 14:45	0.01	0.5	0.01
6	70	26/04/2009 11:30	0.01	0.3	0.01
57	71	04/08/2009 12:30	0.01	3.5	0.01

Event # (by Date)	Rank (by Depth)	Event Start Date	Averaged Event Cumulative Depth (in)	Total Event Duration (hr)	Averaged Max 1hr Event Intensity (in/hr)
62	72	18/08/2009 5:30	0.01	0.8	0.01
76	73	23/09/2009 6:30	0.01	8.0	0.00
17	74	21/05/2009 14:15	0.00	0.3	0.00
64	75	20/08/2009 4:30	0.00	0.8	0.00
86	76	13/10/2009 7:45	0.00	1.8	0.00
12	77	08/05/2009 4:00	0.00	5.3	0.00
48	78	18/07/2009 12:30	0.00	1.8	0.00
53	79	27/07/2009 0:45	0.00	5.8	0.00
81	80	30/09/2009 12:00	0.00	2.5	0.00
92	81	29/10/2009 1:00	0.00	8.3	0.00
93	82	30/10/2009 12:30	0.00	1.0	0.00
96	83	03/11/2009 13:45	0.00	0.3	0.00
28	84	12/06/2009 8:30	0.00	3.8	0.00
32	85	21/06/2009 10:45	0.00	0.3	0.00
55	86	30/07/2009 6:00	0.00	0.5	0.00
95	87	02/11/2009 20:45	0.00	2.0	0.00
19	88	27/05/2009 4:45	0.00	0.3	0.00
20	89	27/05/2009 11:45	0.00	0.3	0.00
30	90	19/06/2009 13:15	0.00	0.3	0.00
39	91	03/07/2009 4:30	0.00	0.3	0.00
46	92	13/07/2009 14:30	0.00	0.3	0.00
52	93	26/07/2009 11:30	0.00	0.3	0.00
61	94	13/08/2009 7:00	0.00	0.3	0.00
68	95	24/08/2009 8:15	0.00	0.3	0.00
70	96	27/08/2009 6:45	0.00	0.3	0.00
75	97	22/09/2009 5:30	0.00	0.3	0.00

APPENDIX C: IN-LINE STORAGE PROFILES

Figure C-1: North District – In-line Storage Profile: Upper Branch from Military Rd.

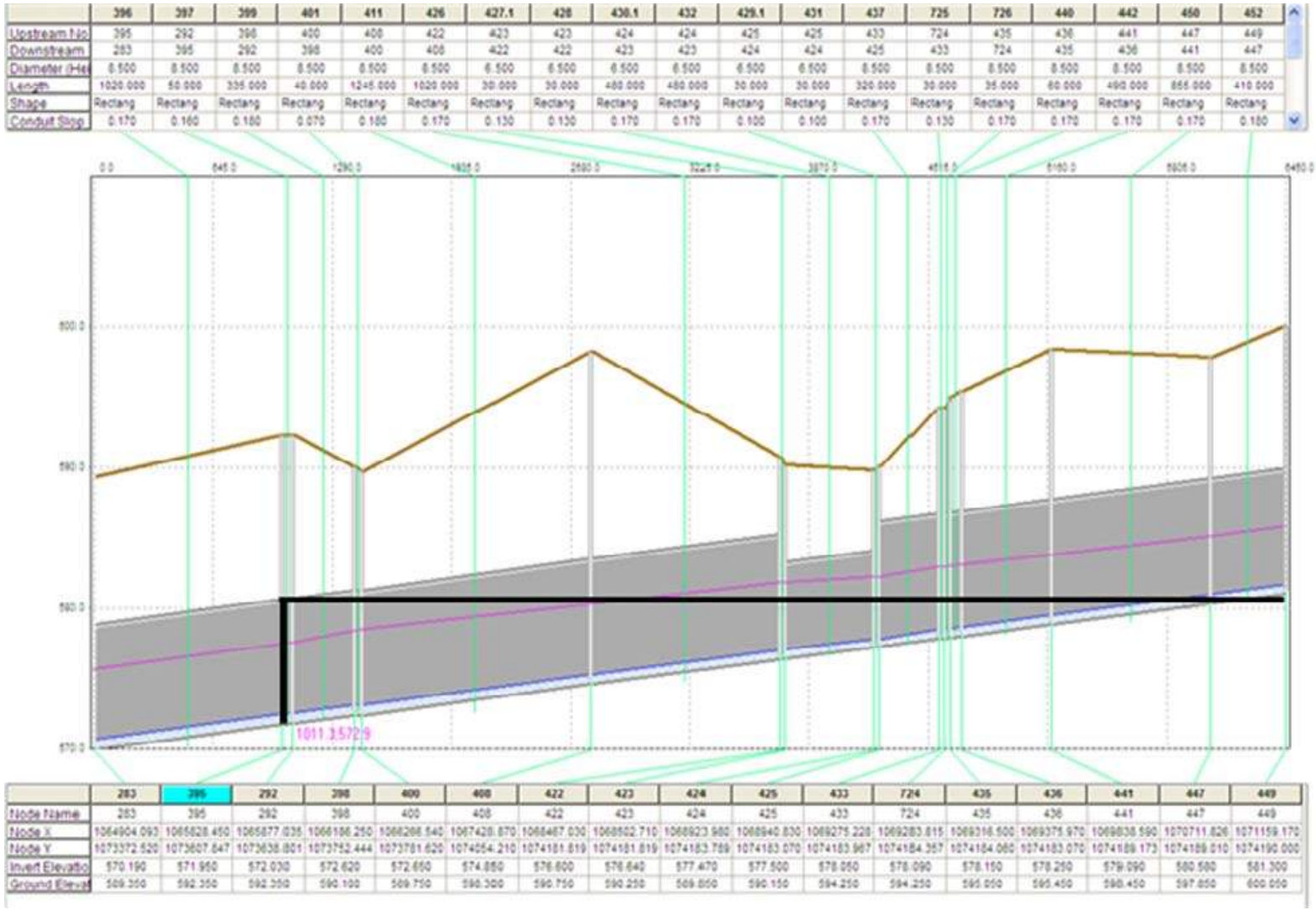


Figure C-2: North District – In-line Storage Profile: Lower Branch from Military Rd.

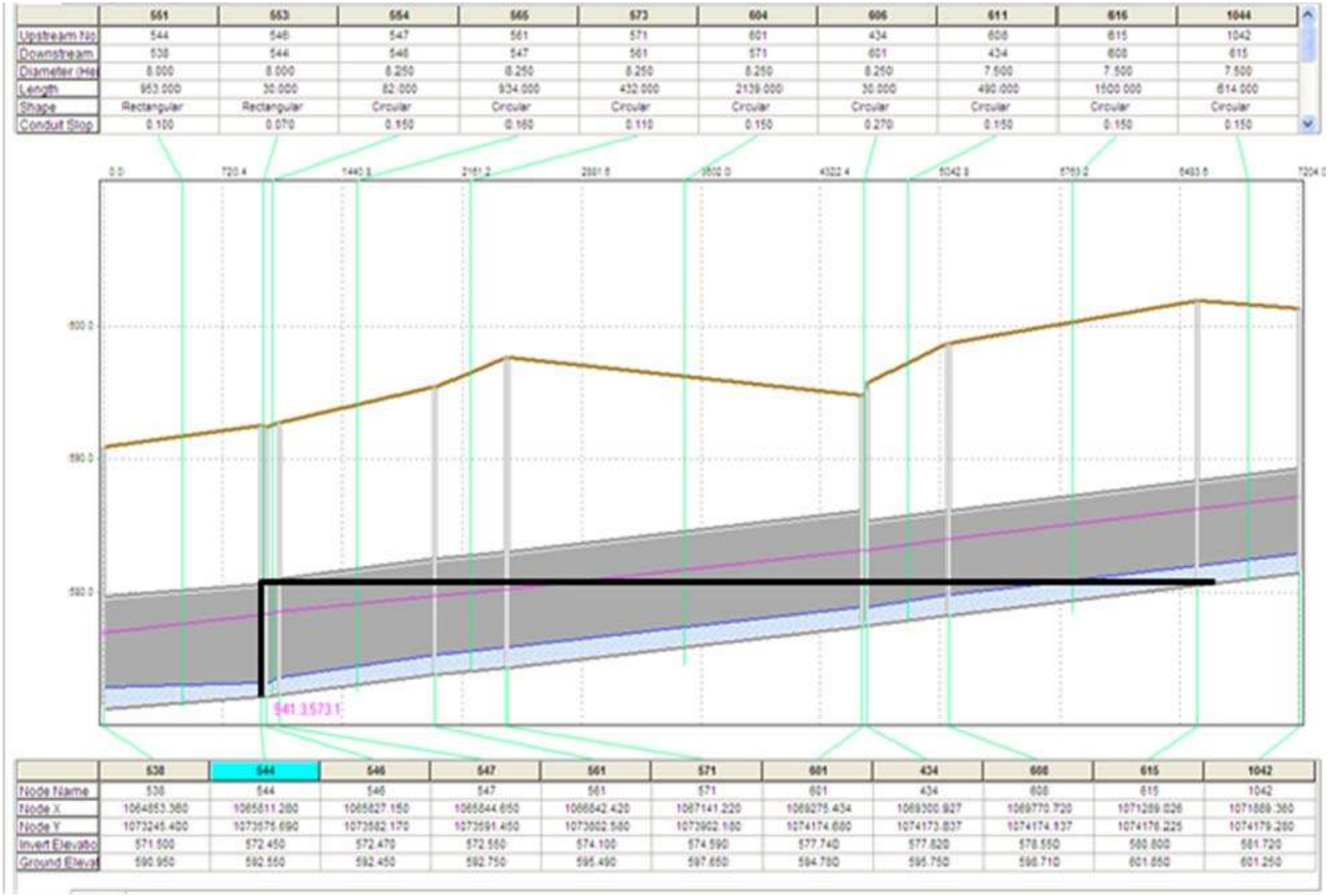


Figure C-3: North District – In-line Storage Profile: Upper Branch from Delaware Ave.

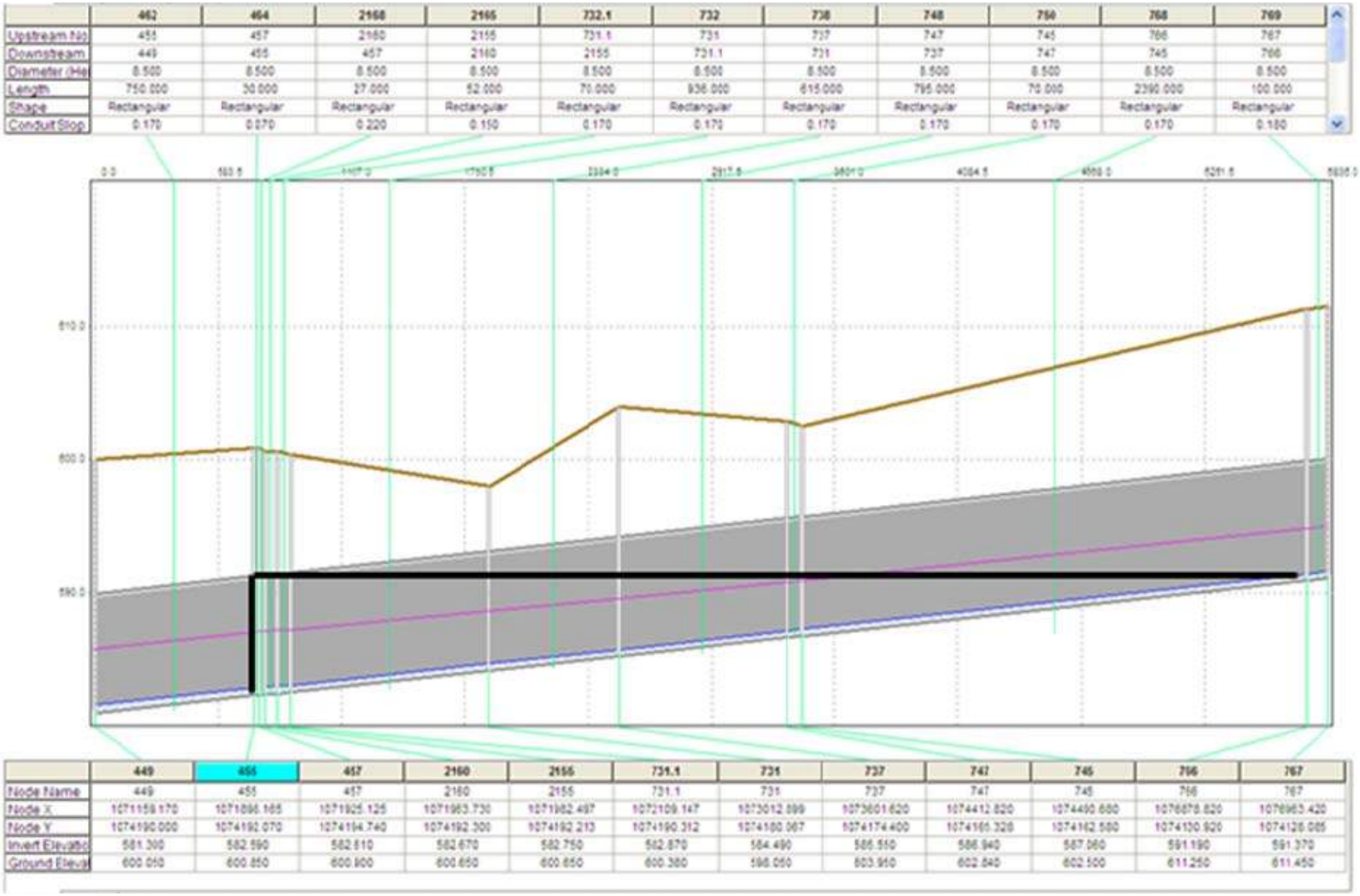


Figure C-4: North District – In-line Storage Profile: Lower Branch from Delaware Ave.

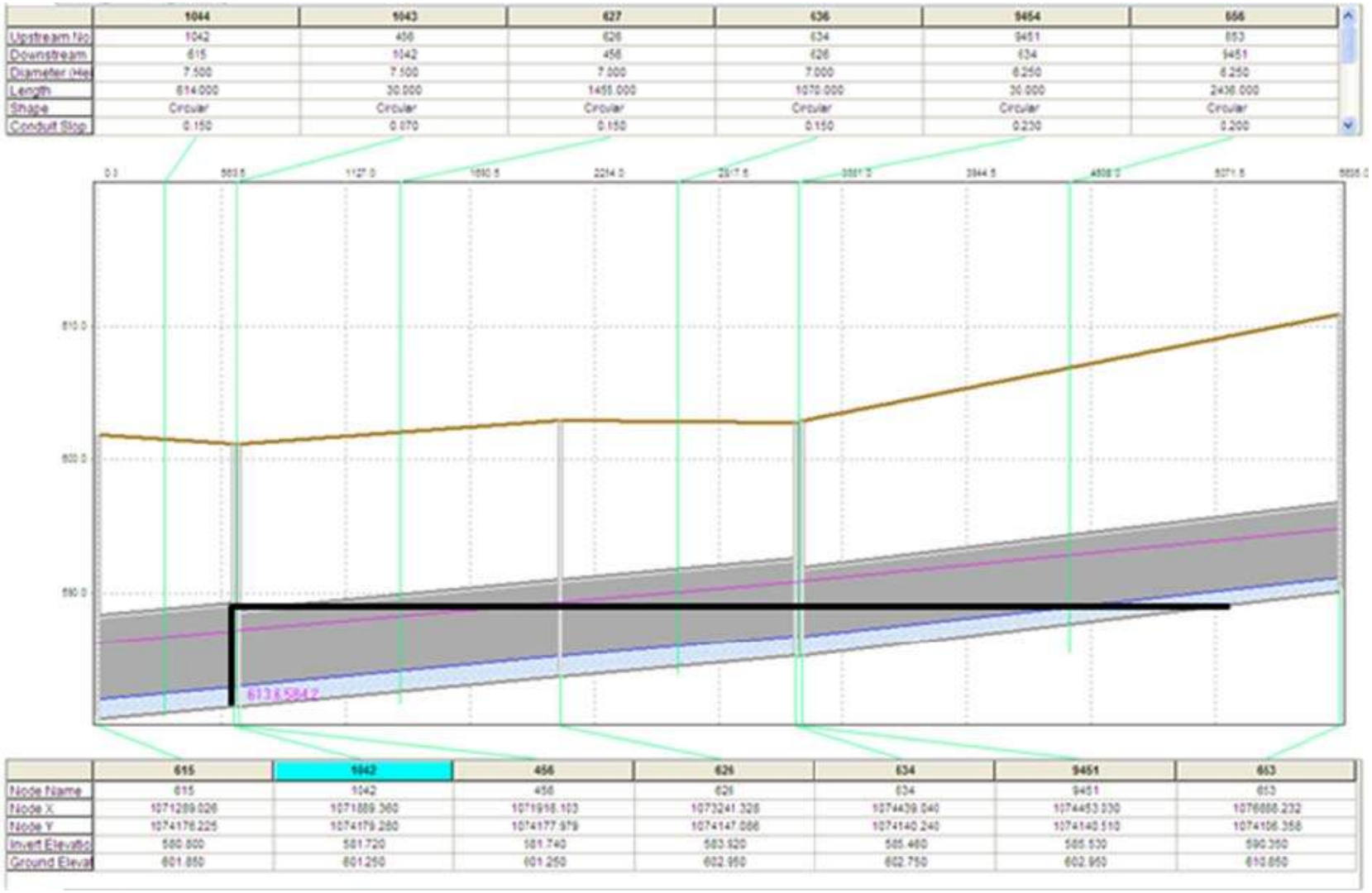


Figure C-5: Scajaquada District – In-line Storage Profile – Bird Trunk

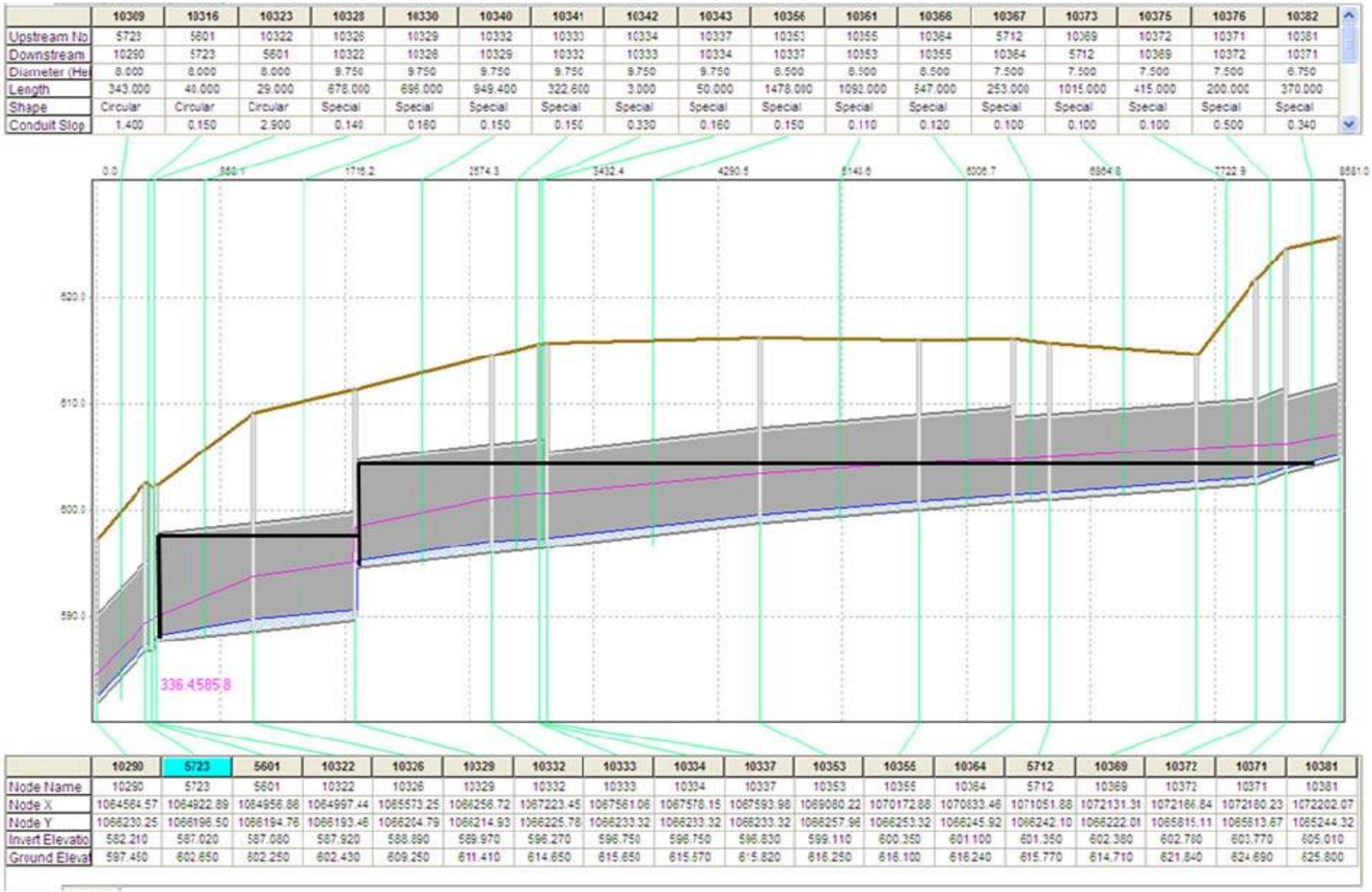


Figure C-6: Scajaquada District – In-line Storage Profile – East Ferry Trunk:

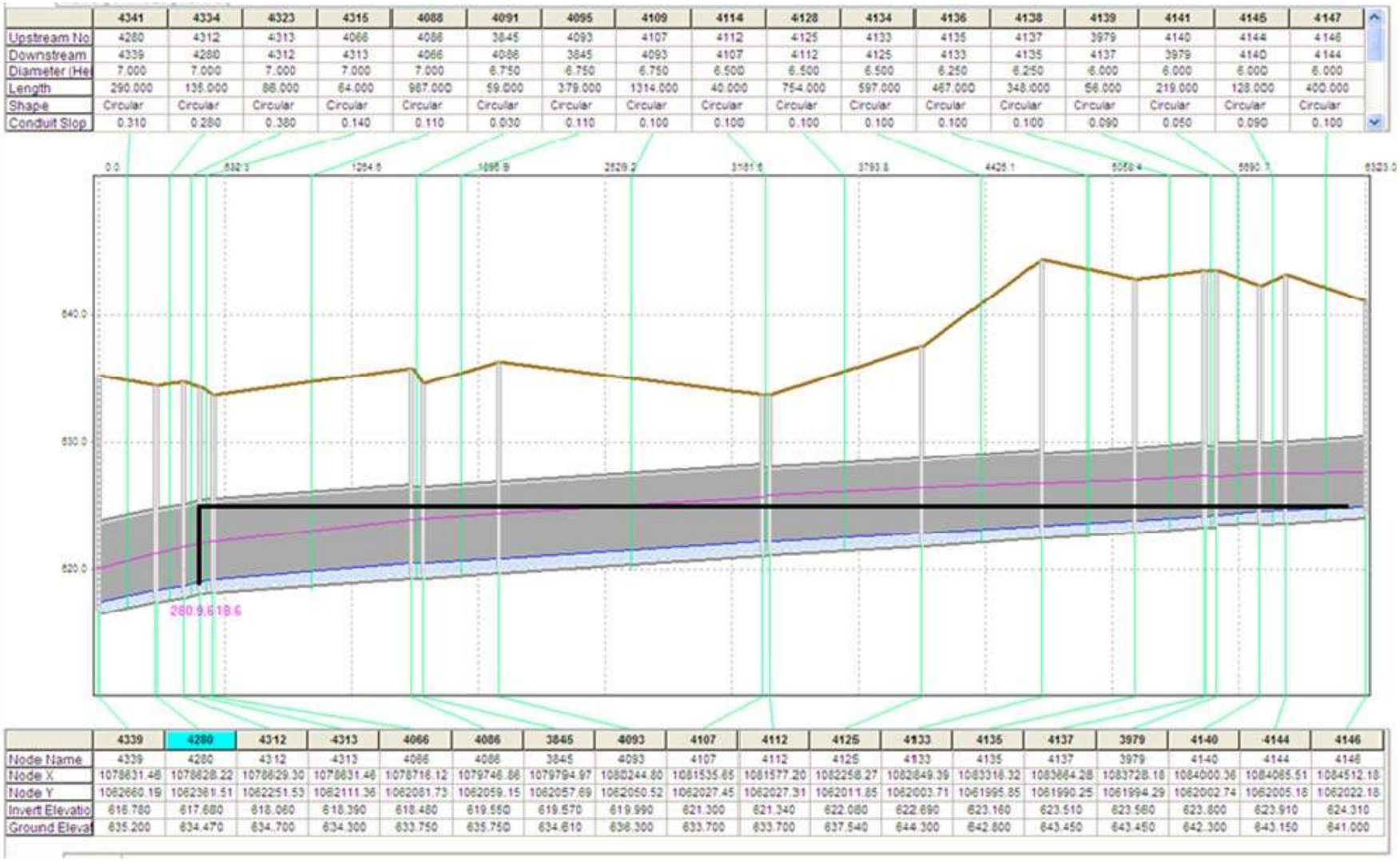


Figure C-7: Scajaquada District – In-line Storage Profile – Colorado Trunk:

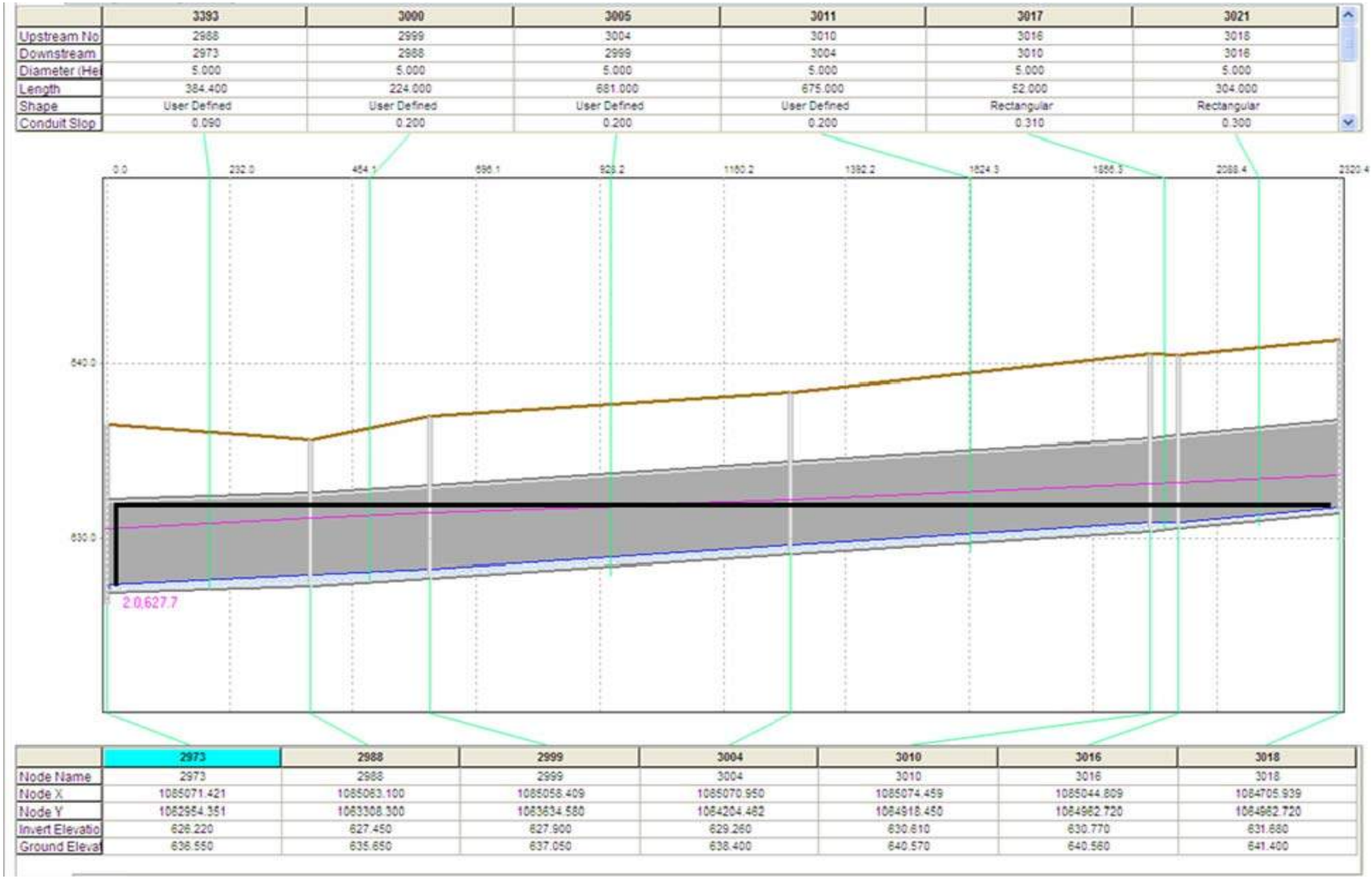


Figure C-8: Scajaquada District – In-line Storage Profile – Bailey Trunk:

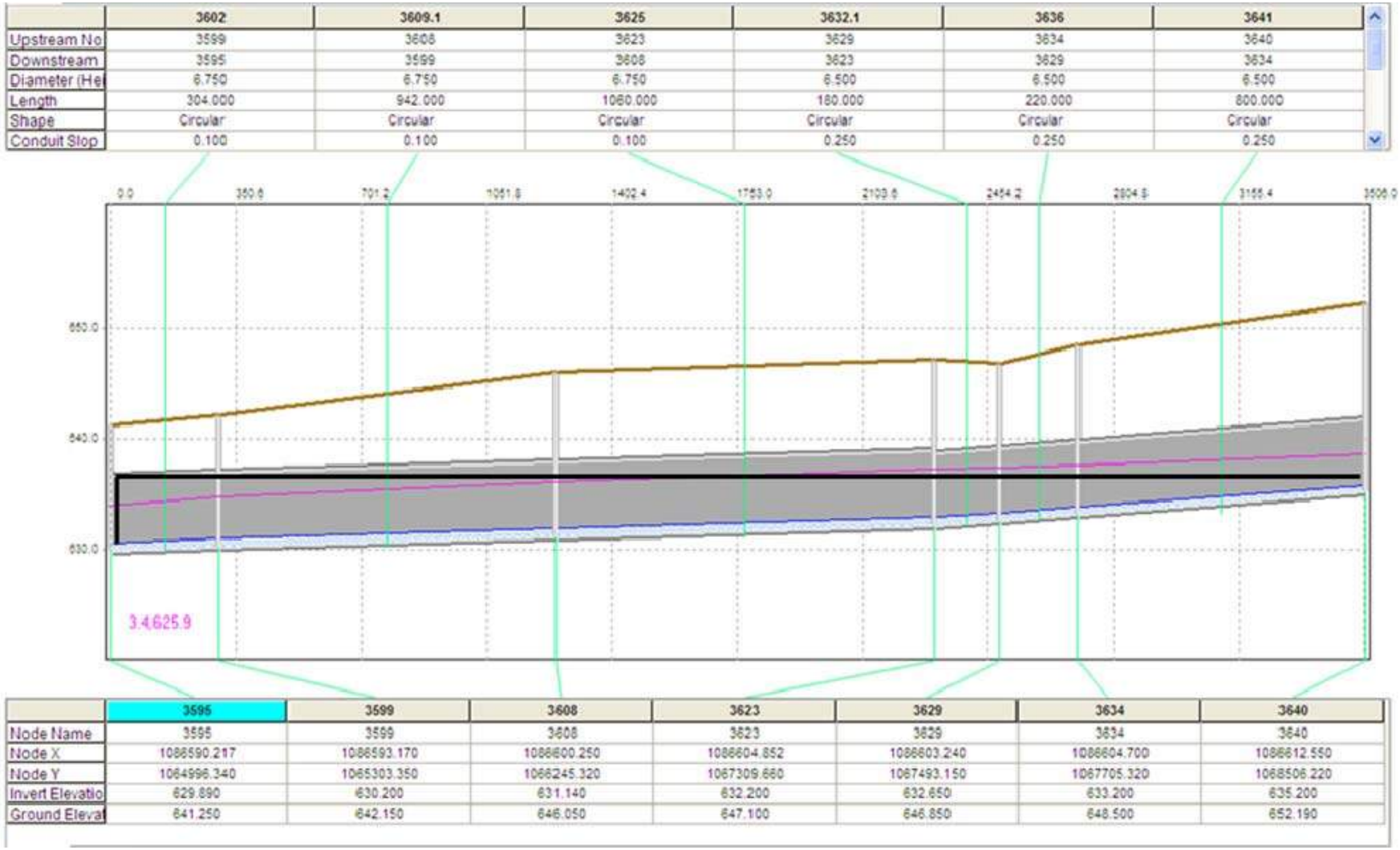


Figure C-9: Scajaquada District – In-line Storage Profile – Texas Trunk:

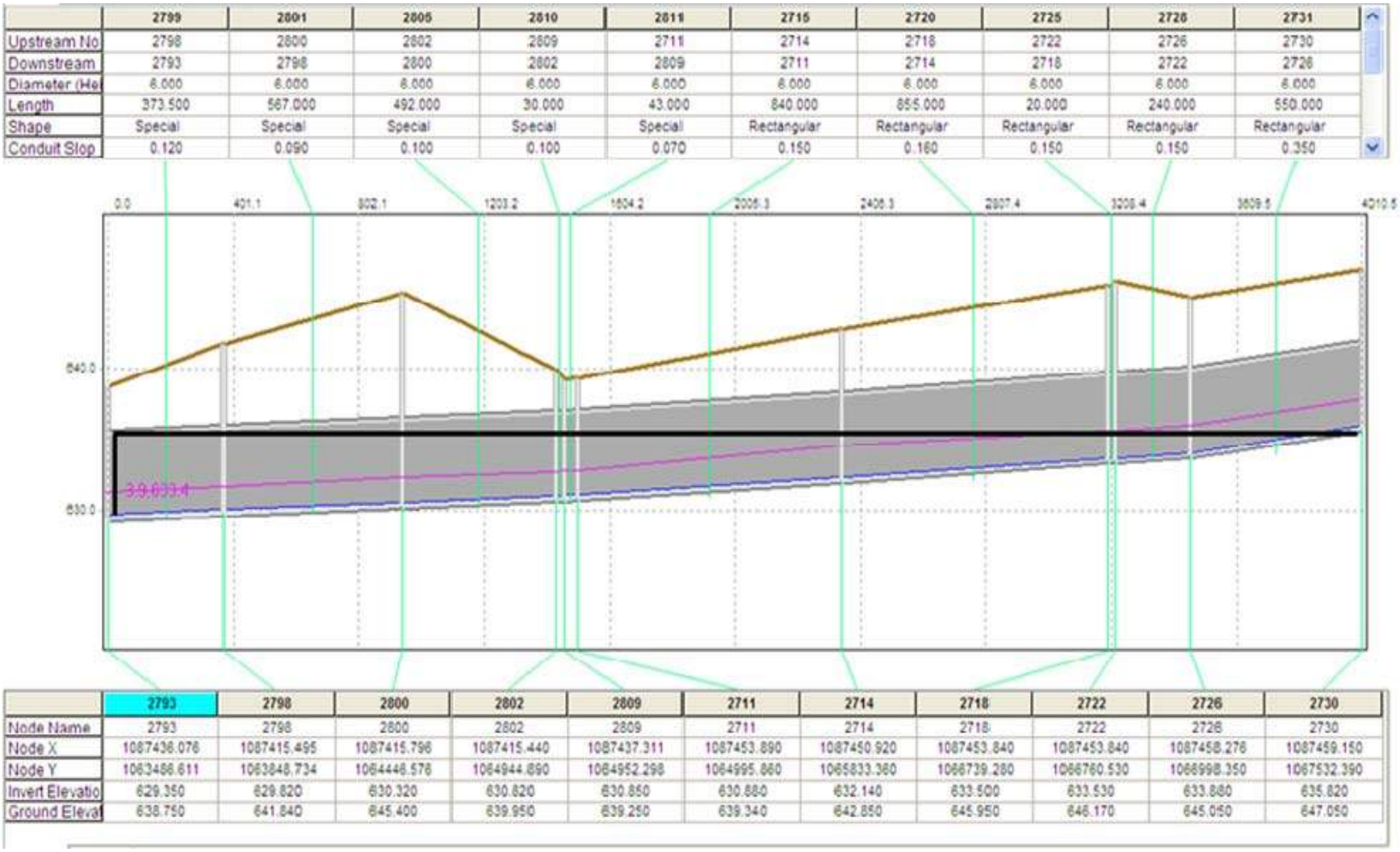
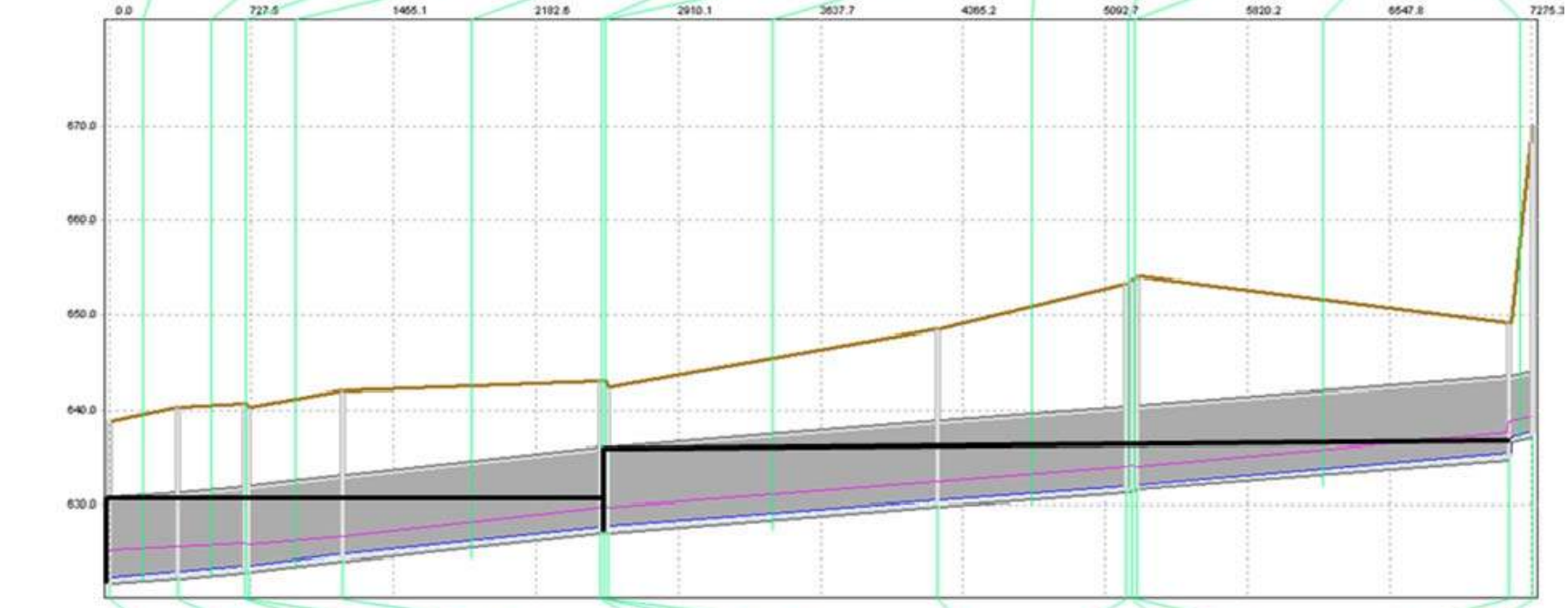


Figure C-10: Scajaquada District – In-line Storage Profile – Hagen/Hazelwood Trunk:

	2635	3765	2639	2651	2659	2661	2663	2671	3775	3777	3779	2751	2754
Upstream No	2634	2638	2636	2650	2658	2660	2662	2670	3774	3776	3778	2750	2752
Downstream	2632	2634	2638	2636	2650	2658	2660	2662	2670	3774	3776	3778	2750
Diameter (He	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.250	8.250	6.500
Length	348.670	348.000	14.000	483.000	1322.000	17.000	17.000	1686.510	965.700	30.960	26.000	1897.560	118.900
Shape	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Special	Circular	Circular
Conduit Slop	0.120	0.180	1.210	0.220	0.220	0.180	0.290	0.160	0.160	0.190	1.040	0.160	0.390



	2632	2634	2638	2636	2650	2658	2660	2662	2670	3774	3776	3778	2750	2752
Node Name	2632	2634	2638	2636	2650	2658	2660	2662	2670	3774	3776	3778	2750	2752
Node X	1088159.531	1088159.320	1088167.048	1088200.977	1088673.317	1088687.280	1088697.230	1088718.880	1088726.710	1089696.406	1089690.700	1089691.400	1089708.593	1089708.230
Node Y	1062926.717	1063269.850	1063629.980	1063648.253	1063649.150	1064971.910	1064990.570	1065016.050	1066749.211	1066750.790	1066776.060	1066797.830	1068781.620	1068902.084
Invert Elevatio	621.540	622.470	623.100	623.270	624.330	627.270	627.300	627.350	630.100	631.640	631.700	631.970	635.050	637.400
Ground Eleva	638.850	640.350	640.750	640.400	642.050	643.100	643.050	642.450	648.550	653.420	653.700	654.100	649.150	670.150
Flow Rate (H	0.000	0.060	0.307	0.000	0.000	0.000	0.000	0.000	0.000	0.160	0.000	0.000	0.000	0.078

APPENDIX D: SUPPLEMENTARY DATA FOR COST ANALYSIS

Table D-1: Contingency and Non-construction Related Fees

Item	Percent	Considered items	Project Cost Estimate Factor
Construction			
Construction (unit cost)			1.000
Engineering Services	24%		
Preliminary Design	5%	of construction cost	0.050
Design & Tendering	7%	of construction cost	0.070
Construction Services	5%	of construction cost	0.050
Utilities Impacts/Relocations	5%	of construction cost	0.050
Project Management and Admin (BSA)	5%	of above (Construction & Eng & Utilities)	0.061
Inspection (BSA)	7%	of above (Construction & Eng & Utilities)	0.085
Project Contingency	25%	of above (Construction & Eng & Utilities & PM & Inspection)	0.342
		Total :	**1.708**

Table D-2: Estimated Construction Costs for RTC Interception Sites

Sewer District	Regulator	Model Link	RTC Threshold Interception Range (cfs)	Construction Costs ($M)	Non-Construction Fees Factor	Total Construction Costs ($M)
Scajaquada	SPP 336B	4400	0-45 cfs	2.00	1.71	3.42
	SPP 337	8213	0-45 cfs	2.00	1.71	3.42
	SPP 339	SPP339.4	0-45 cfs	2.00	1.71	3.42
	SPP 340	2633	0-45 cfs	2.00	1.71	3.42
South-Central	SPP 24	6729	0-200 cfs	2.00	1.71	3.42
	SPPs 23 & 296	6877 & 6049	0-200 cfs	2.00	1.71	3.42
	SPP 317	13187	0-150 cfs	2.00	1.71	3.42
	SPP 217	16100	0-150 cfs	2.00	1.71	3.42
	SPP 281	10864	0-150 cfs	2.00	1.71	3.42

Table D-3: Estimated Construction Costs for RTC In-line Storage Sites

Sewer District	Trunk Sewer	Model Node	RTC Available Volume (MG)	Construction Costs ($M)	Non-Construction Fees Factor	Total Construction Costs ($M)
North	Hertel @ Military (Upper Branch)	395	1.87	1.52	1.71	2.60
	Hertel @ Military (Lower Branch)	544	1.07	1.43	1.71	2.43
	Hertel @ Delaware (Upper Branch)	455	1.34	1.52	1.71	2.60
	Hertel @ Delaware (Lower Branch)	1042	0.66	1.42	1.71	2.43
Scajaquada	Bird	10322	0.46	1.41	1.71	2.40
		10329	1.12	1.11	1.71	1.89
	East Ferry	4312	1.16	1.42	1.71	2.42
	Colorado	2973	0.16	1.41	1.71	2.40
	Bailey	3595	0.59	1.41	1.71	2.40
	Texas	2793	1.06	1.51	1.71	2.57
	Hagen	2658	0.73	1.42	1.71	2.42
		2632	0.99	1.42	1.71	2.42

Table D-4: Estimated Construction Costs for RTC Off-line Storage

Sewer District	Regulator	Model Link	Construction Costs ($M)	Non-Construction Fees Factor	Total Construction Costs ($M)
Scajaquada	SPP 255	4040	2.00	1.71	3.42

Table D-5: Example of Preventive Maintenance Tasks

Equipment	Task	Frequency	Hours Required	Total (man/hr)*
Ultrasonic level meter	Clean-up calibration of 4-20 mA over the entire span	Once a year	3	9
Radar level meter	Clean-up calibration of 4-20 mA over the entire span	Once a year	3	9
Float level switches	Cleaning	Once a year	2	4
Flow Transmitter	Cleaning up, verification of calibration by certified personnel		4	12
Modulating Gate and Actuator	Stem lubrication and torque and limits switches verification	3 times a year (3x1 man/hr)	1	3
	Calibration of 4-20 mA gate positioning and field verification *versus* the real opening. Verification of the travel time and of 2 full closings and openings	Once a year (2 men/hr x 4 hrs)	8	8
Isolation Gate and Actuator	Stem lubrication and torque and limits switches verification	3 times a year (3X1 man/hr)	1	3
	Verification of the travel time and of 2 full closings and openings	Once a year (2 men/hr x 3 hrs)	6	6
SCADA Panel	Verification of the UPS, RTU and telemetry devices, cleaning of filters, air conditioning, etc.	Once a year	2	2

** Per year, per piece of equipment.*

Table D-6: Cost Performance Indicators for Potential RTC Sites

Sewer District	Site	Type	Total CSO Reduction Volume (MG)	Cost ($M)	Cost Performance Indicator ($/1000 gal)
South-Central	SPPs 296, 023, 024	RTC Interception	148.5	10.25	69.01
Scajaquada	Amherst Quarry	Off-line storage	49.4	3.42	69.08
North	Hertel (Military)	In-line storage	56.6	5.04	88.91
Scajaquada	SPP 336B, 337, 339 & 340 (4 locations)	RTC Interception	94.7	13.66	144.31
Scajaquada	East Ferry	In-line storage	16.0	2.42	151.34
South-Central	SPPs 217, 317 & 281 (3 locations)	RTC Interception	63.3	10.25	161.96
Scajaquada	Texas	In-line storage	14.6	2.57	176.08
Scajaquada	Hagen	In-line storage	13.5	2.43	179.76
Scajaquada	Bird	In-line storage	21.8	4.30	197.52
North	Hertel (Delaware)	In-line storage	22.0	5.02	228.26
Scajaquada	Hazelwood (Hagen)	In-line storage	10.1	2.42	240.51
Scajaquada	Bailey	In-line storage	8.0	2.40	299.19
Scajaquada	Colorado	In-line storage	2.3	2.40	1068.77

Appendix 11-8: Sewershed Impervious Surface Maps

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CSO-003 (183.6 acres)

Imperviousness: 47.8%

Total Impervious Area: 87.8 acres

Land Use:

Residential:	50.6 acres	27.6%
Transportation:	44.3 acres	24.1%
Vacant:	37.9 acres	20.6%
Commercial:	23.0 acres	12.5%
Public Service:	9.2 acres	5.0%
No Data:	5.8 acres	3.2%
Industrial:	4.5 acres	2.4%
Community Service:	4.1 acres	2.2%
Recreational:	3.5 acres	1.9%
Conservation Areas / Parks:	0.6 acres	0.3%

Target Green Infrastructure Control:

10% = 8.8 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**44.3 acres**
Public Parcels:	**3.9 acres**
Residential Roof Surfaces:	**15.2 acres**
Public Parcels (Vacant):	**1.7 acres**

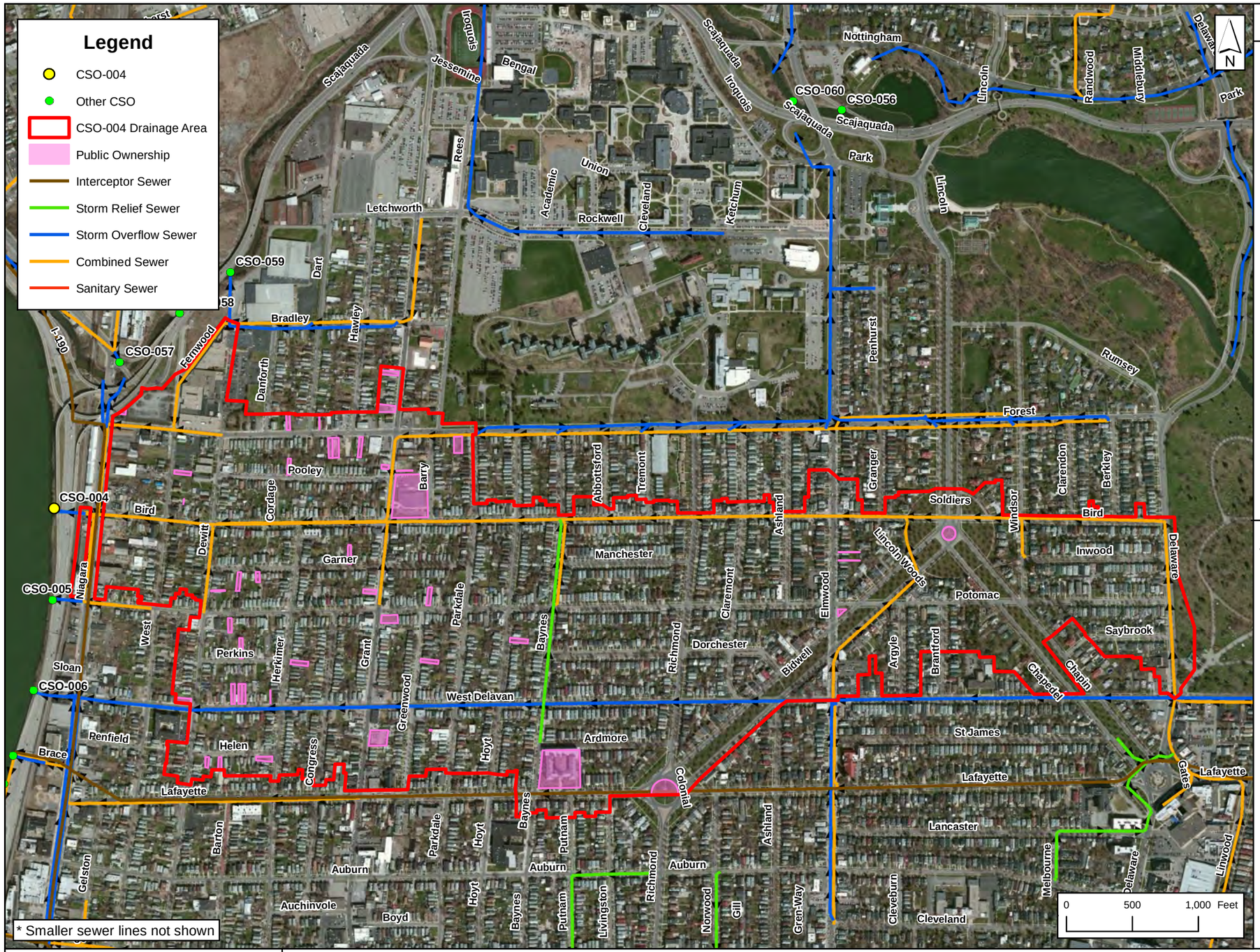
Potential Green Infrastructure Technologies:

MALCOLM PIRNIE | ARCADIS
The Water Division of ARCADIS

2012 1777-114

BUFFALO SEWER AUTHORITY
Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
PARISH DISTRICT
CSO-003



CSO-004 (373.8 acres)

Imperviousness: 54.1%

Total Impervious Area: 202.2 acres

Land Use:

Residential:	196.0 acres	52.4%
Transportation:	113.9 acres	30.5%
Commercial:	28.4 acres	7.6%
Vacant:	13.0 acres	3.5%
Community Service:	11.1 acres	3.0%
Industrial:	9.2 acres	2.5%
No Data:	1.4 acres	0.4%
Conservation Areas / Parks:	0.6 acres	0.2%

Target Green Infrastructure Control:

10% = 20.2 acres

Green Infrastructure Opportunities

Streets and Right of Way:	113.9 acres
Public Parcels:	7.6 acres
Residential Roof Surfaces:	58.8 acres
Public Parcels (Vacant):	1.9 acres

Potential Green Infrastructure Technologies:

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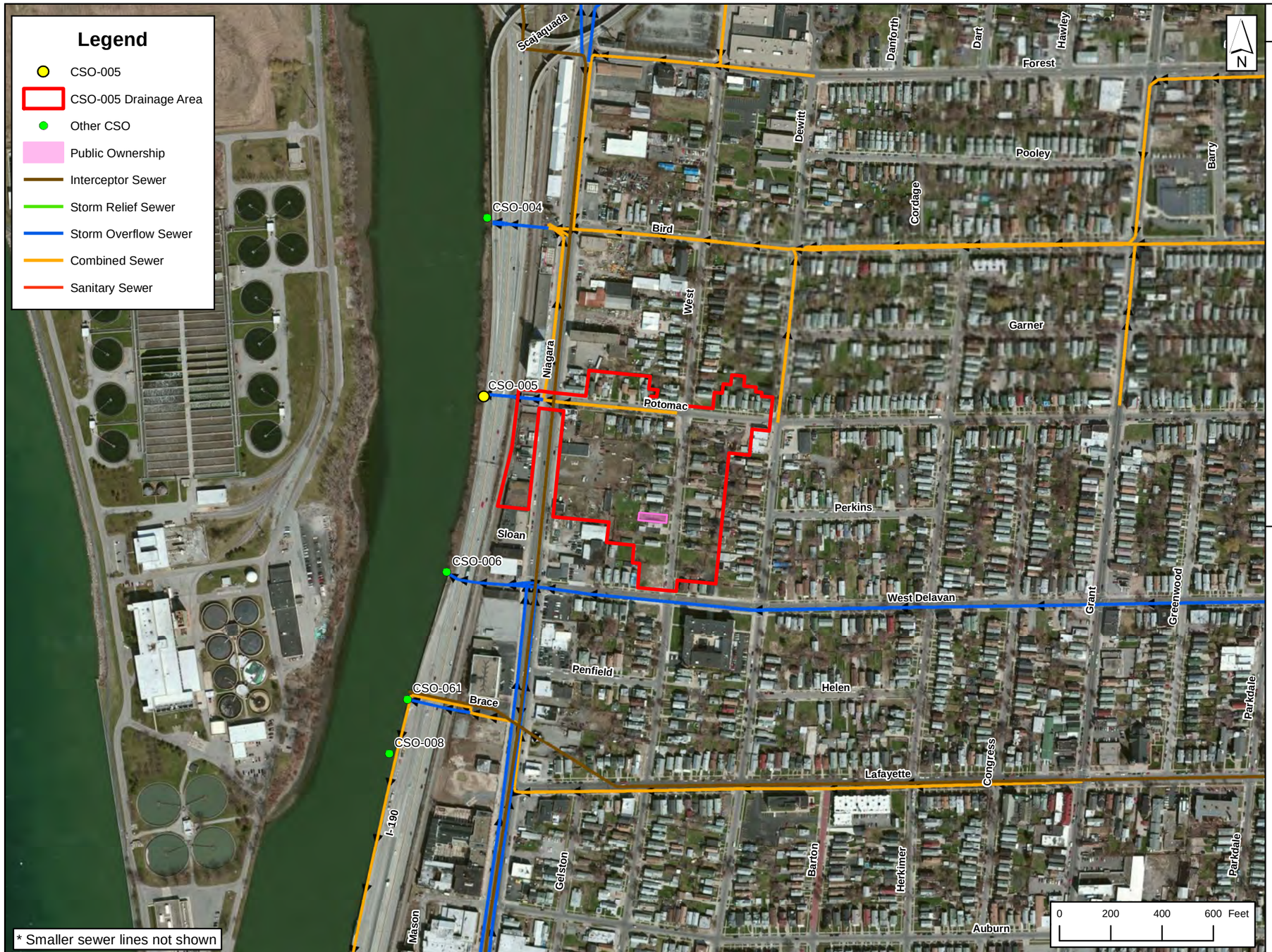
Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
SCAJAQUADA DISTRICT
CSO-004



CSO-005 (11.7 acres)

Imperviousness: 56.5%

Total Impervious Area: 6.6 acres

Land Use:

Residential:	4.5 acres	38.4%
Commercial:	2.7 acres	22.9%
Transportation:	2.4 acres	20.2%
Vacant:	1.8 acres	15.4%
No Data:	0.4 acres	3.1%

Target Green Infrastructure Control:

10% = 0.7 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**2.4 acres**
Public Parcels:	**0.1 acres**
Residential Roof Surfaces:	**1.4 acres**
Public Parcels (Vacant):	**0.1 acres**

Potential Green Infrastructure Technologies:

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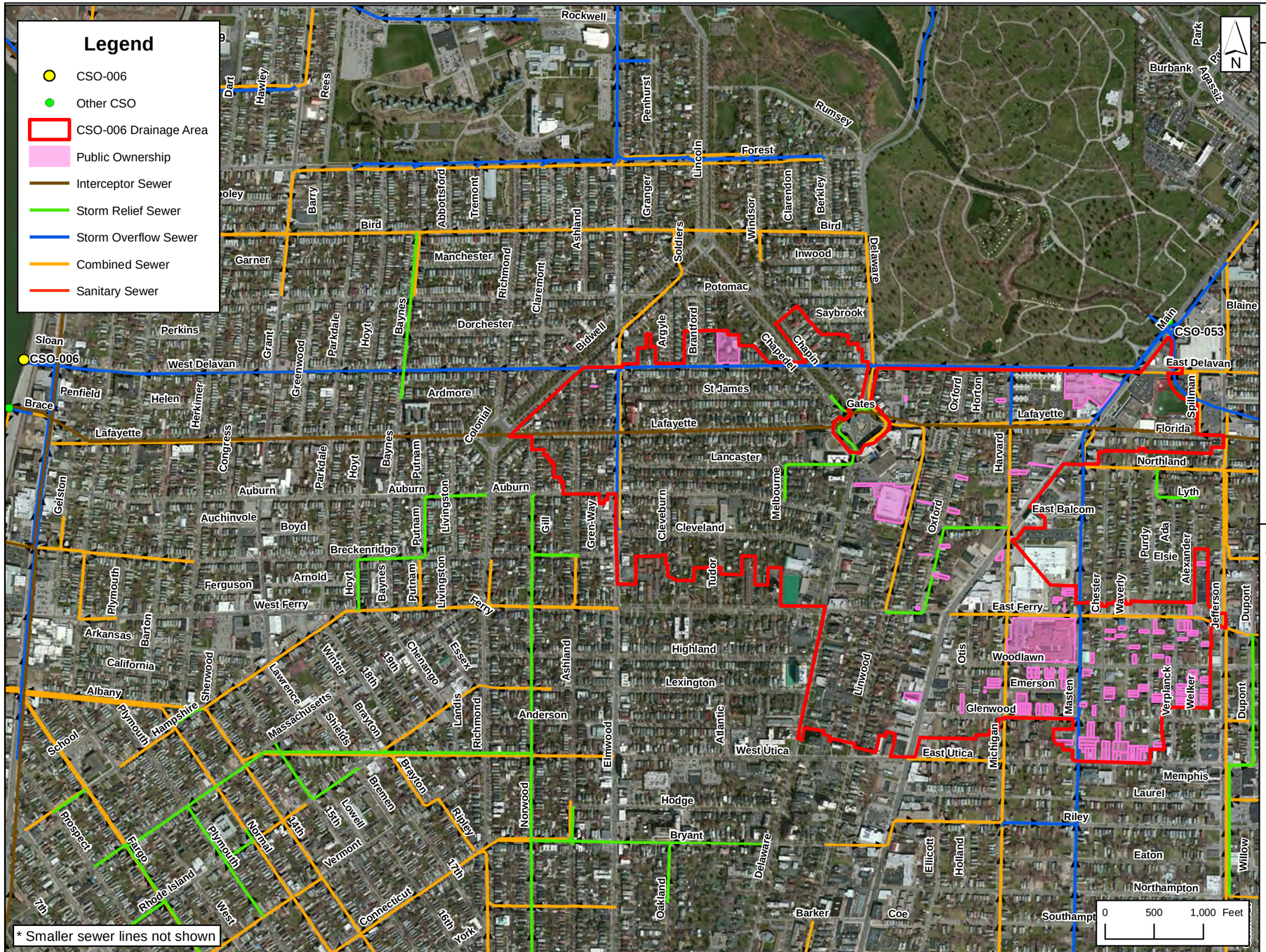
Green Infrastructure Opportunities Analysis

FIGURE 1
SCAJAQUADA DISTRICT
CSO-005



CSO-006 (418.3 acres)

Imperviousness: 58.3%

Total Impervious Area: 243.8 acres

Land Use:

Residential:	148.2 acres	35.4%
Transportation:	99.2 acres	23.7%
Commercial:	70.3 acres	16.8%
Community Service:	54.0 acres	12.9%
Vacant:	35.2 acres	8.4%
Public Service:	5.6 acres	1.3%
No Data:	3.6 acres	0.9%
Recreational:	1.3 acres	0.3%
Industrial:	1.0 acres	0.2%

Target Green Infrastructure Control:

20% = 48.8 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**99.2 acres**
Public Parcels:	**25.1 acres**
Residential Roof Surfaces:	**44.5 acres**
Public Parcels (Vacant):	**8.7 acres**

Potential Green Infrastructure Technologies:

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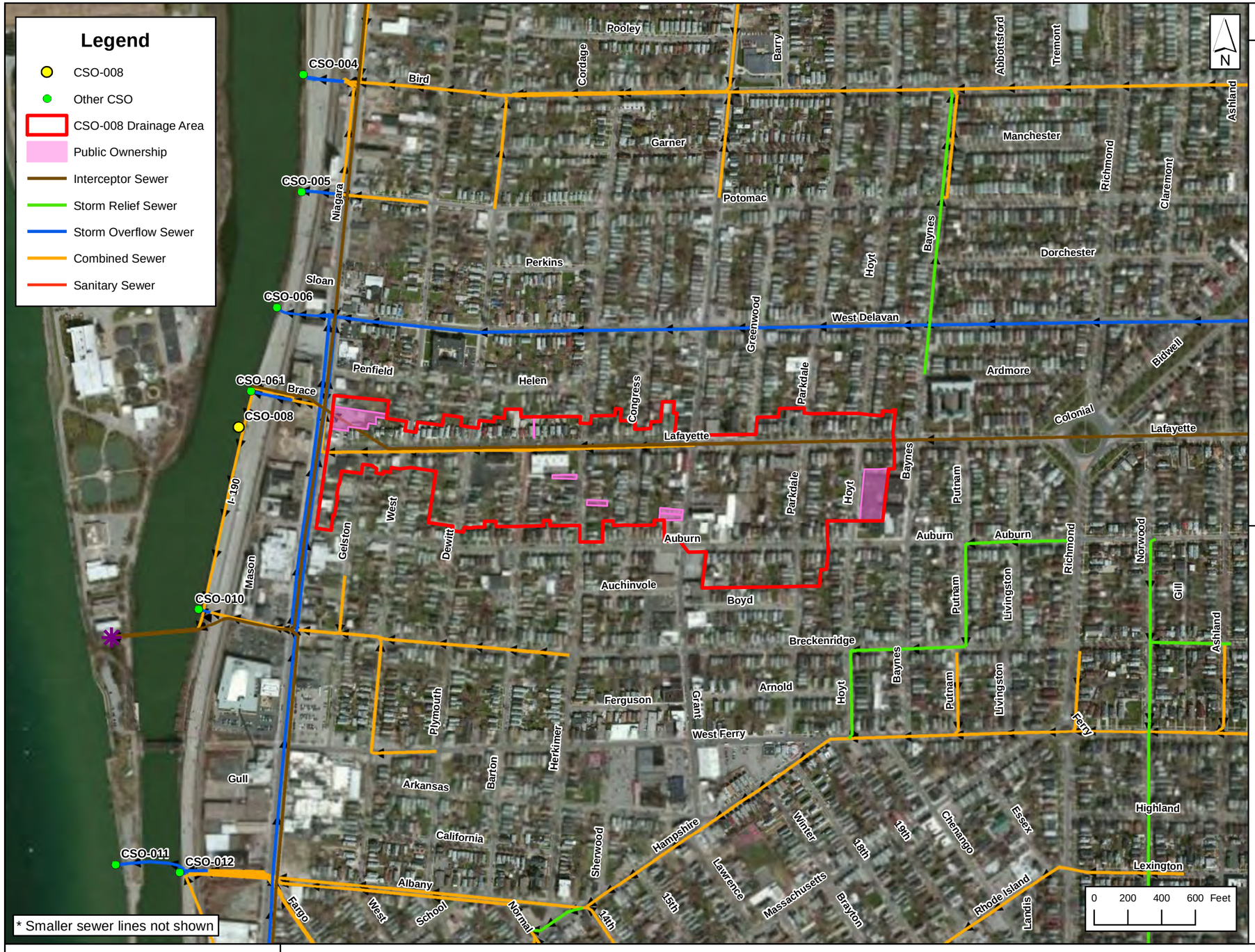
SCAJAQUADA DISTRICT
CSO-006



CSO-008 (51.6 acres)

Imperviousness: 56.7%

Total Impervious Area: 29.3 acres

Land Use:

Residential:	22.4 acres	43.4%
Transportation:	14.8 acres	28.6%
Commercial:	7.6 acres	14.8%
Community Service:	4.3 acres	8.4%
Vacant:	1.3 acres	2.5%
Public Service:	0.7 acres	1.4%
Industrial:	0.3 acres	0.6%
No Data:	0.1 acres	0.2%

Potential Green Infrastructure Control:

20% = 5.9 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**14.8 acres**
Public Parcels:	**2.1 acres**
Residential Roof Surfaces:	**6.7 acres**
Public Parcels (Vacant):	**0.2 acres**

Potential Green Infrastructure Technologies:

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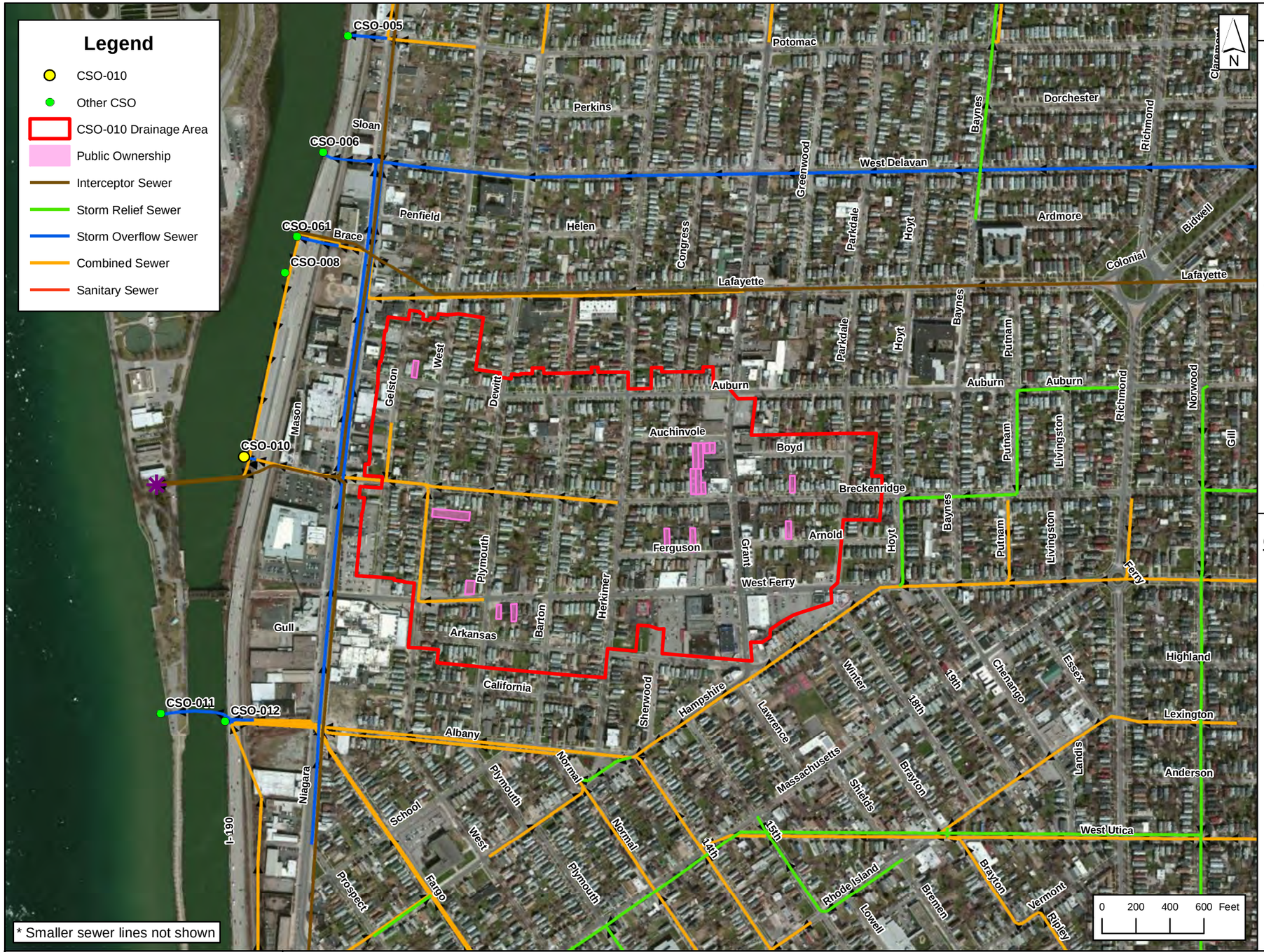
Green Infrastructure Opportunities Analysis

FIGURE 1
SCAJAQUADA DISTRICT
CSO-008



CSO-010 (104.1 acres)

Imperviousness: 69.3%

Total Impervious Area: 72.1 acres

Land Use:

Residential:	48.5 acres	46.6%
Transportation:	30.1 acres	28.9%
Commercial:	16.9 acres	16.2%
Vacant:	6.8 acres	6.5%
Community Service:	1.1 acres	1%
Industrial:	0.3 acres	0.3%
Public Service:	0.3 acres	0.3%
No Data:	0.1 acres	0.1%

Target Green Infrastructure Control:

20% = 14.4 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**30.1 acres**
Public Parcels:	**1.4 acres**
Residential Roof Surfaces:	**14.6 acres**
Public Parcels (Vacant):	**0.9 acres**

Potential Green Infrastructure Technologies:

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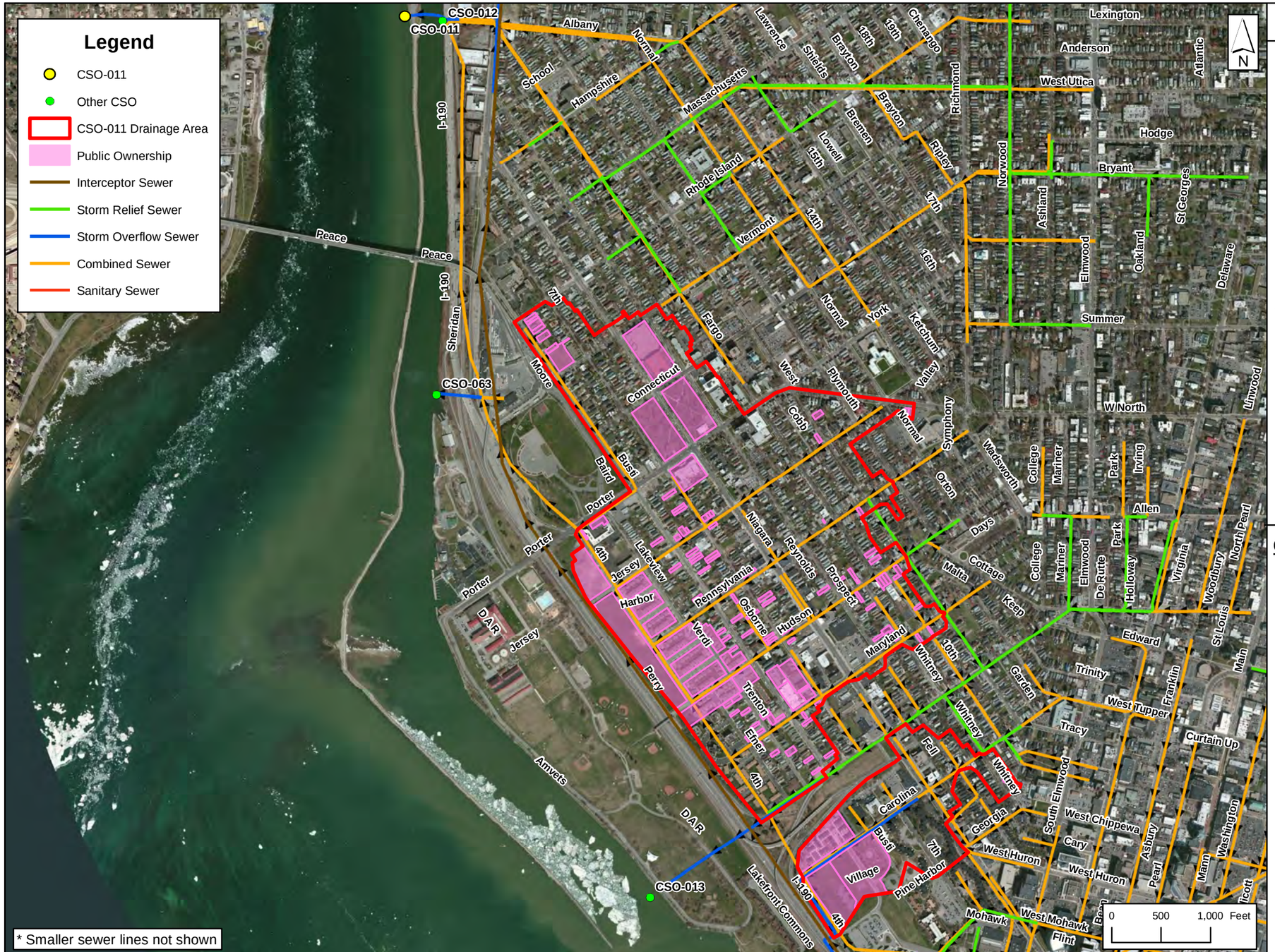
FIGURE 1
SCAJAQUADA DISTRICT
CSO-010



CSO-011 (313.5 acres)

Imperviousness: 43.8%

Total Impervious Area: 137.5 acres

Land Use:

Transportation:	94.7 acres	30.2%
Residential:	79.5 acres	25.4%
Commercial:	68.8 acres	22.0%
Community Service:	27.0 acres	8.6%
Vacant:	17.6 acres	5.6%
Conservation Areas / Parks:	9.6 acres	3.1%
No Data:	8.5 acres	2.7%
Recreational:	7.5 acres	2.4%
Public Service:	0.2 acres	0.1%

Target Green Infrastructure Control:

20% = 27.5 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**94.7 acres**
Public Parcels:	**59 acres**
Residential Roof Surfaces:	**23.9 acres**
Public Parcels (Vacant):	**5.9 acres**

Potential Green Infrastructure Technologies:

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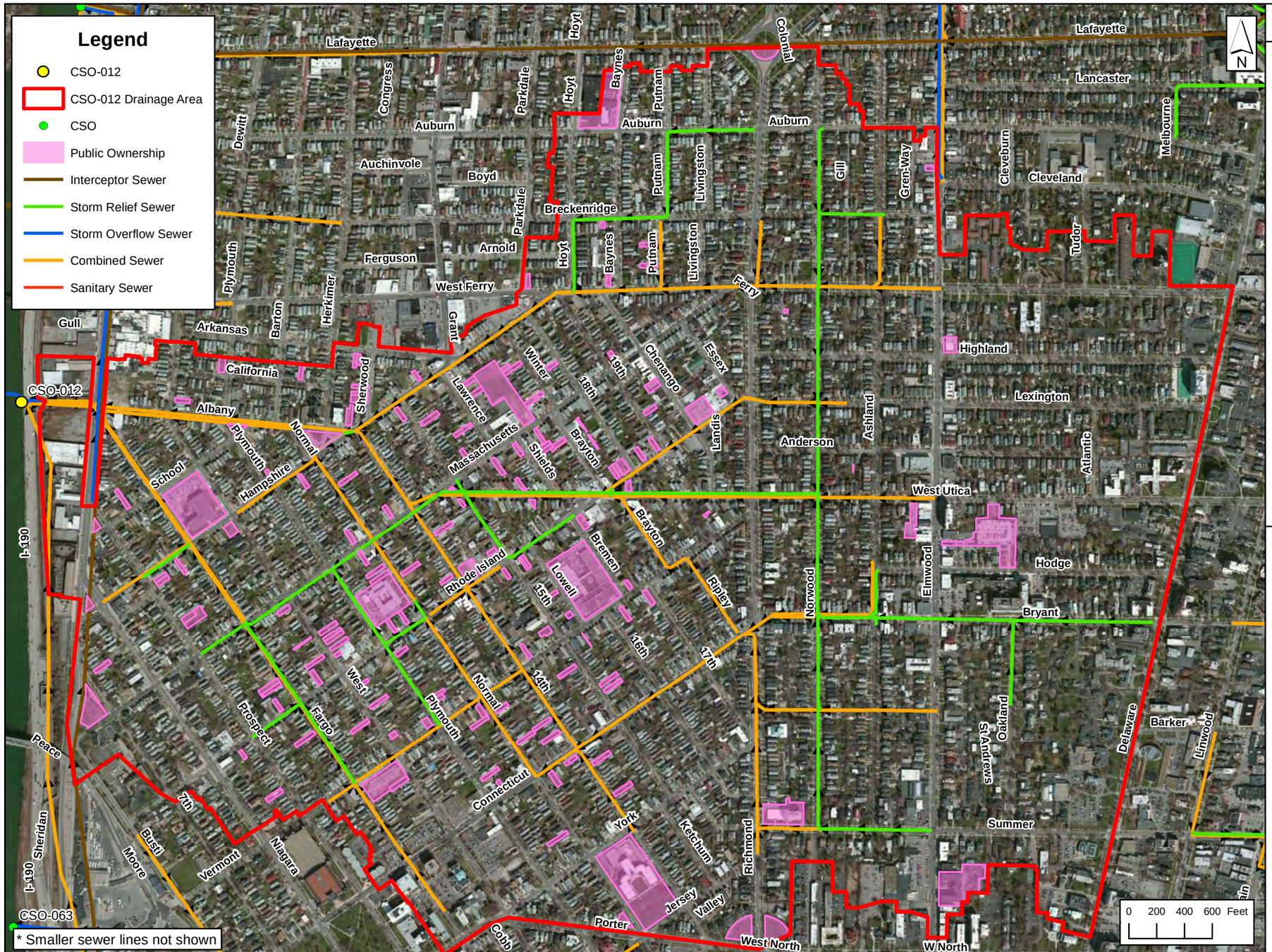
SCAJAQUADA DISTRICT
CSO-011



CSO-012 (867.9 acres)

Imperviousness: 34.5%

Total Impervious Area: 299.5 acres

Land Use:

Residential:	376.1 acres	43.5%
Transportation:	227.1 acres	26.2%
Commercial:	127.3 acres	14.7%
Community Service:	60.3 acres	7%
Vacant:	47.1 acres	5.4%
No Data:	11.3 acres	1.3%
Industrial:	8.6 acres	1%
Recreational:	2.9 acres	0.3%
Public Service:	2.7 acres	0.3%
Conservation Areas / Parks:	2.2 acres	0.3%

Target Green Infrastructure Control:

20% = 59.9 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**227.1 acres**
Public Parcels:	**35.6 acres**
Residential Roof Surfaces:	**112.8 acres**
Public Parcels (Vacant):	**8.6 acres**

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Green Infrastructure Opportunities Analysis

FIGURE 1
ALBANY DISTRICT
CSO-012



* Smaller sewer lines not shown

CSO-013 (309.6 acres)

Imperviousness: 43.7%

Total Impervious Area: 135.2 acres

Land Use:

Residential:	85.3 acres	27.6%
Commercial:	83.3 acres	26.9%
Transportation:	79.9 acres	25.8%
Vacant:	24.7 acres	8.0%
Community Service:	20.2 acres	6.5%
Recreational:	6.9 acres	2.2%
No Data:	4.4 acres	1.4%
Conservation Areas / Parks:	3.6 acres	1.2%
Industrial:	1.0 acres	0.3%
Public Service:	0.2 acres	0.1%

Target Green Infrastructure Control:

10% = 13.5 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**79.9 acres**
Public Parcels:	**20.7 acres**
Residential Roof Surfaces:	**25.6 acres**
Public Parcels (Vacant):	**4.2 acres**

Potential Green Infrastructure Technologies:

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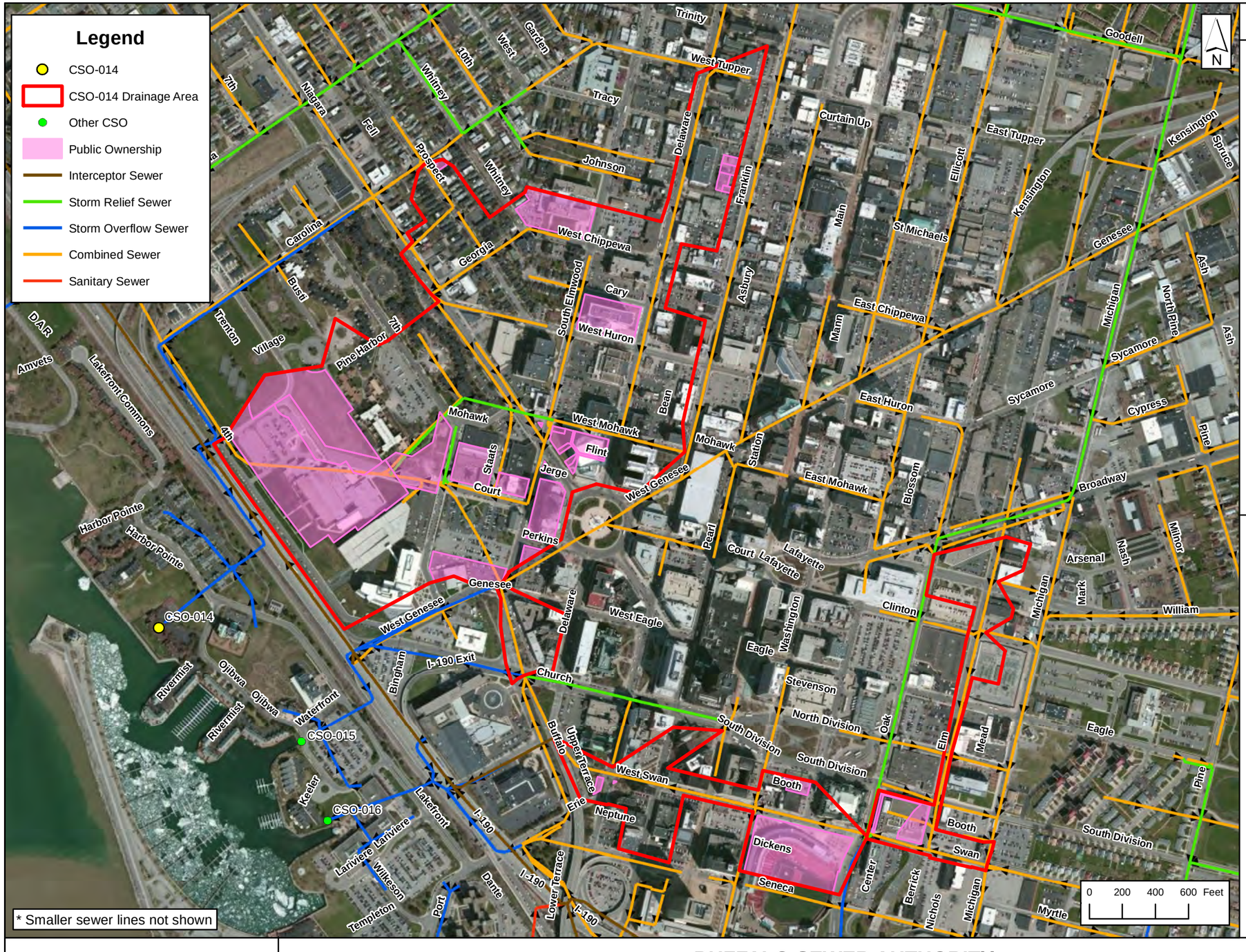
Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-013



CSO-014 (152.5 acres)

Imperviousness: 42.2%

Total Impervious Area: 64.4 acres

Land Use:

Commercial:	60.5 acres	39.7%
Transportation:	43.9 acres	28.8%
Community Service:	22.8 acres	14.9%
Conservation Areas / Parks:	7.7 acres	5.1%
Recreational:	6.3 acres	4.1%
Residential:	5.0 acres	3.3%
Public Service:	3.6 acres	2.3%
Vacant:	1.8 acres	1.2%
No Data:	1.0 acres	0.7%

Target Green Infrastructure Control:

10% = 6.4 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**43.9 acres**
Public Parcels:	**33.2 acres**
Residential Roof Surfaces:	**1.5 acres**
Public Parcels (Vacant):	**0.1 acres**

Potential Green Infrastructure Technologies:

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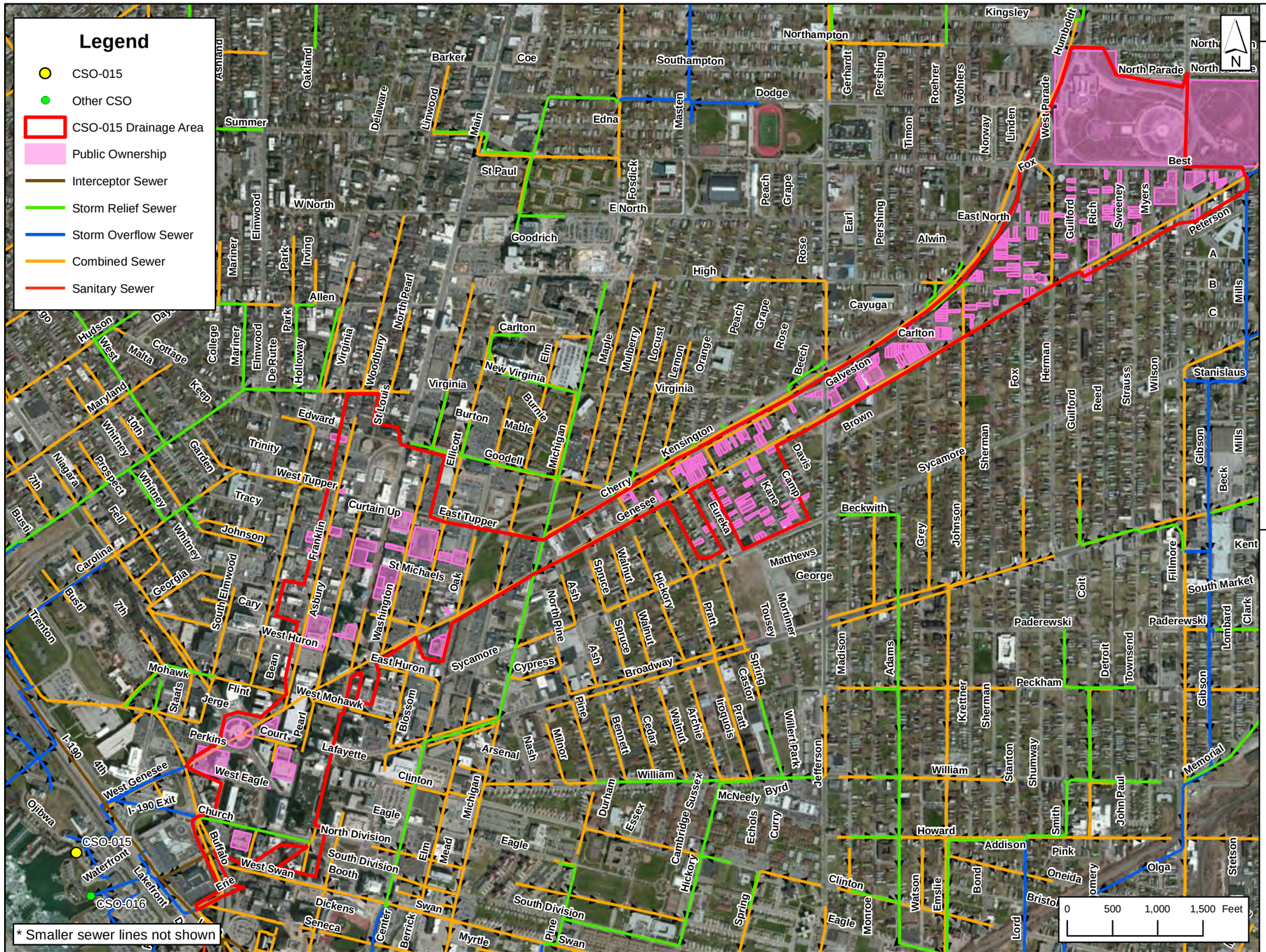
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-014



CSO-015 (338.7 acres)

Imperviousness: 59.6%

Total Impervious Area: 201.9 acres

Land Use:

Transportation:	110.7 acres	32.7%
Commercial:	80.3 acres	23.7%
Vacant:	39.1 acres	11.6%
Conservation Areas / Parks:	34.6 acres	10.2%
Residential:	33.4 acres	9.8%
Community Service:	26.2 acres	7.7%
Recreational:	8.5 acres	2.5%
No Data:	2.6 acres	0.8%
Industrial:	2.1 acres	0.6%
Public Service:	1.2 acres	0.4%

Target Green Infrastructure Control:

20% = 40.4 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	110.7 acres
Public Parcels:	71.8 acres
Residential Roof Surfaces:	10.0 acres
Public Parcels (Vacant):	17.0 acres

Potential Green Infrastructure Technologies:

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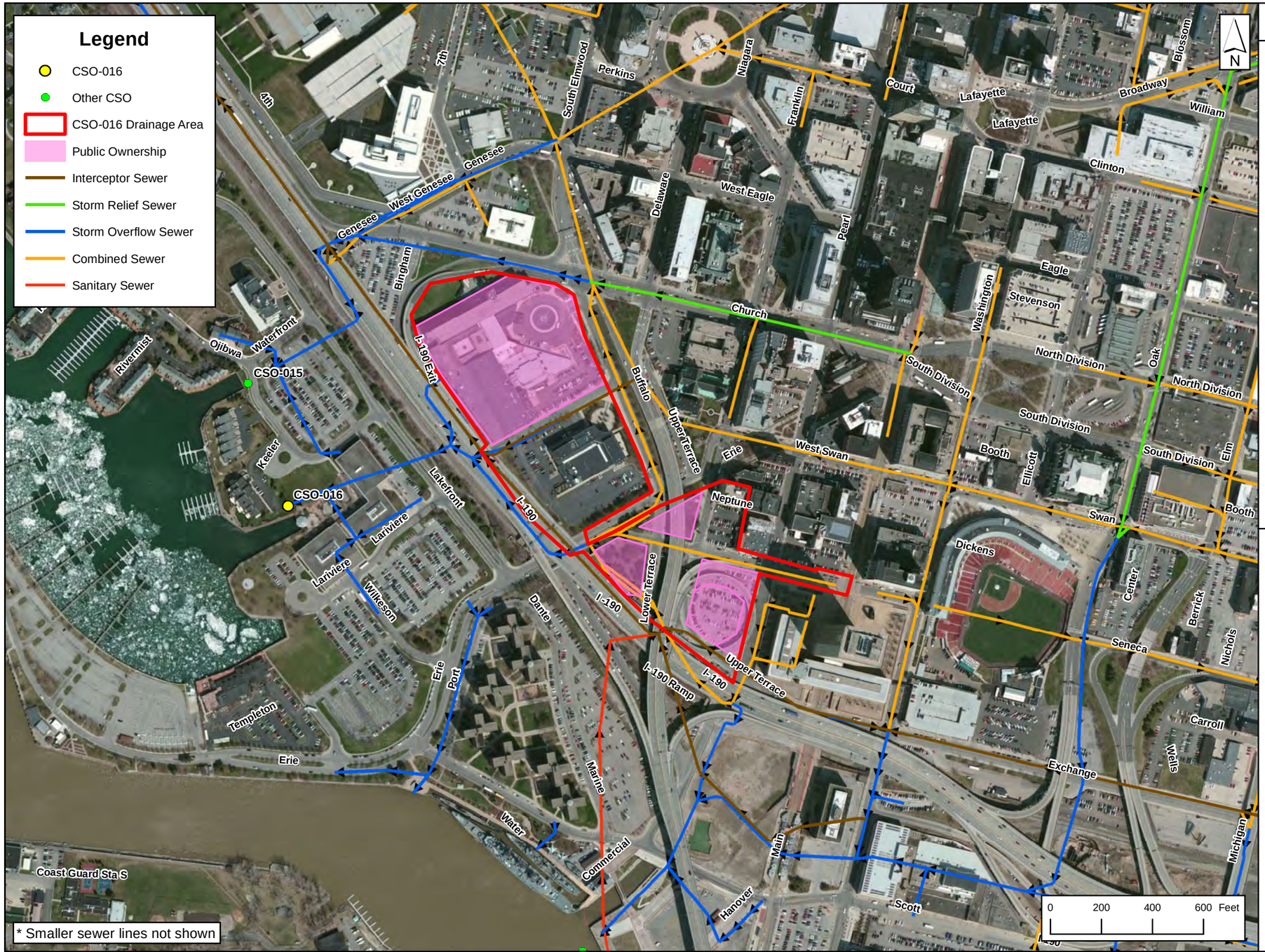
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-015



* Smaller sewer lines not shown

CSO-016 (20.8 acres)

Imperviousness: 52.1%

Total Impervious Area: 10.85 acres

Land Use:

Community Service:	6.8 acres	32.8%
Transportation:	6.6 acres	31.6%
Public Service:	4.0 acres	19.2%
Commercial:	2.6 acres	12.3%
Recreational:	0.5 acres	2.2%
No Data:	0.2 acres	1.2%
Vacant:	0.1 acres	0.7%

Target Green Infrastructure Control:

10% = 1.9 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	6.6 acres
Public Parcels:	9.6 acres
Residential Roof Surfaces:	0 acres
Public Parcels (Vacant):	0 acres

Potential Green Infrastructure Technologies:

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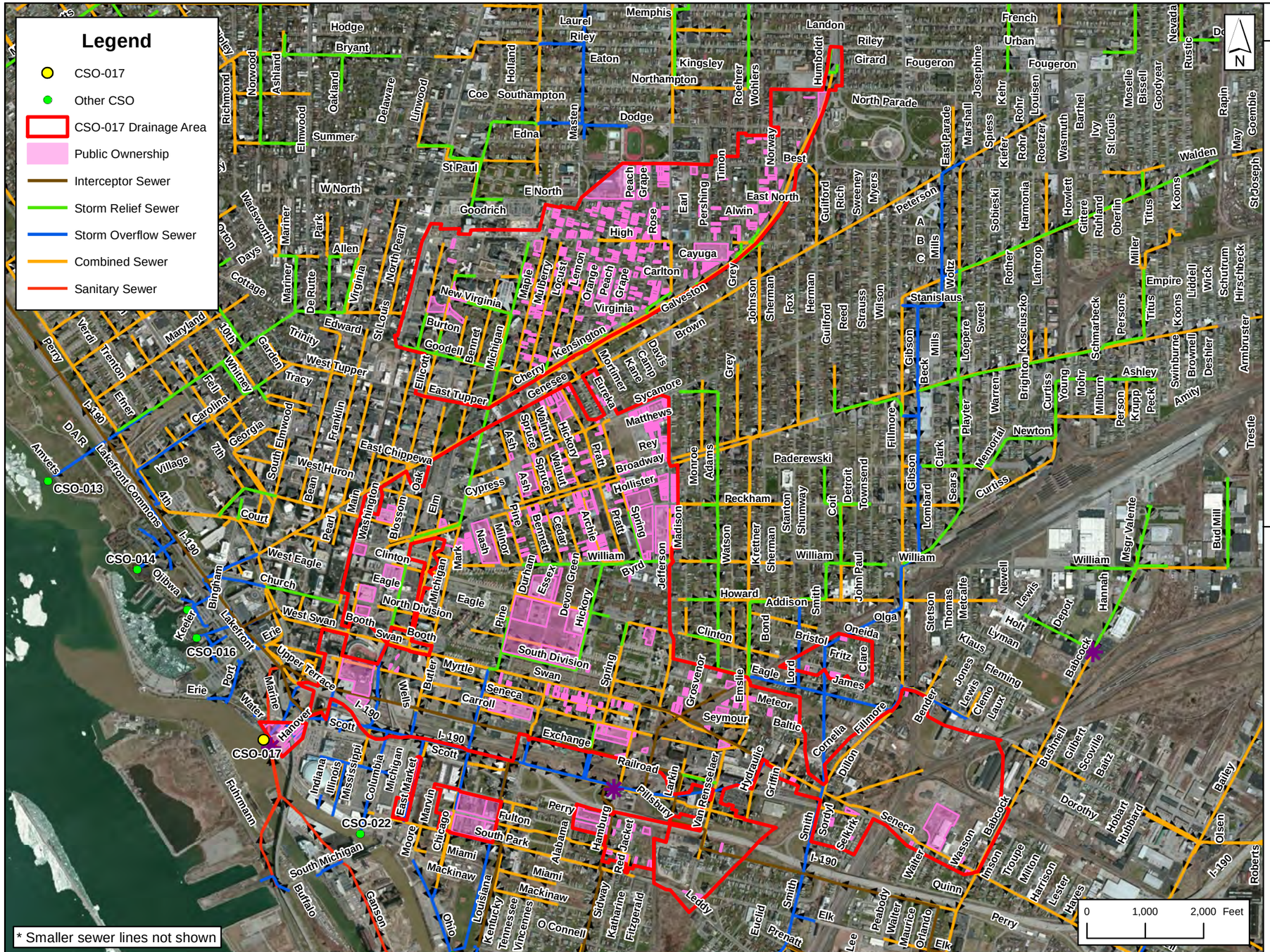
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-016



CSO-017 (1439.1 acres)

Imperviousness: 34.7%

Total Impervious Area: 499.8 acres

Land Use:

Transportation:	414.1 acres	28.5%
Commercial:	268.9 acres	18.5%
Vacant:	248.7 acres	17.1%
Residential:	194.4 acres	13.4%
Community Service:	126.2 acres	8.7%
Industrial:	72.5 acres	5.0%
No Data:	63.0 acres	4.3%
Public Service:	26.4 acres	1.8%
Recreational:	23.7 acres	1.6%
Conservation Areas / Parks:	13.1 acres	0.9%

Target Green Infrastructure Control:

20% = 100.0 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	414.1 acres
Public Parcels:	175.7 acres
Residential Roof Surfaces:	58.3 acres
Public Parcels (Vacant):	66.4 acres

Potential Green Infrastructure Technologies:

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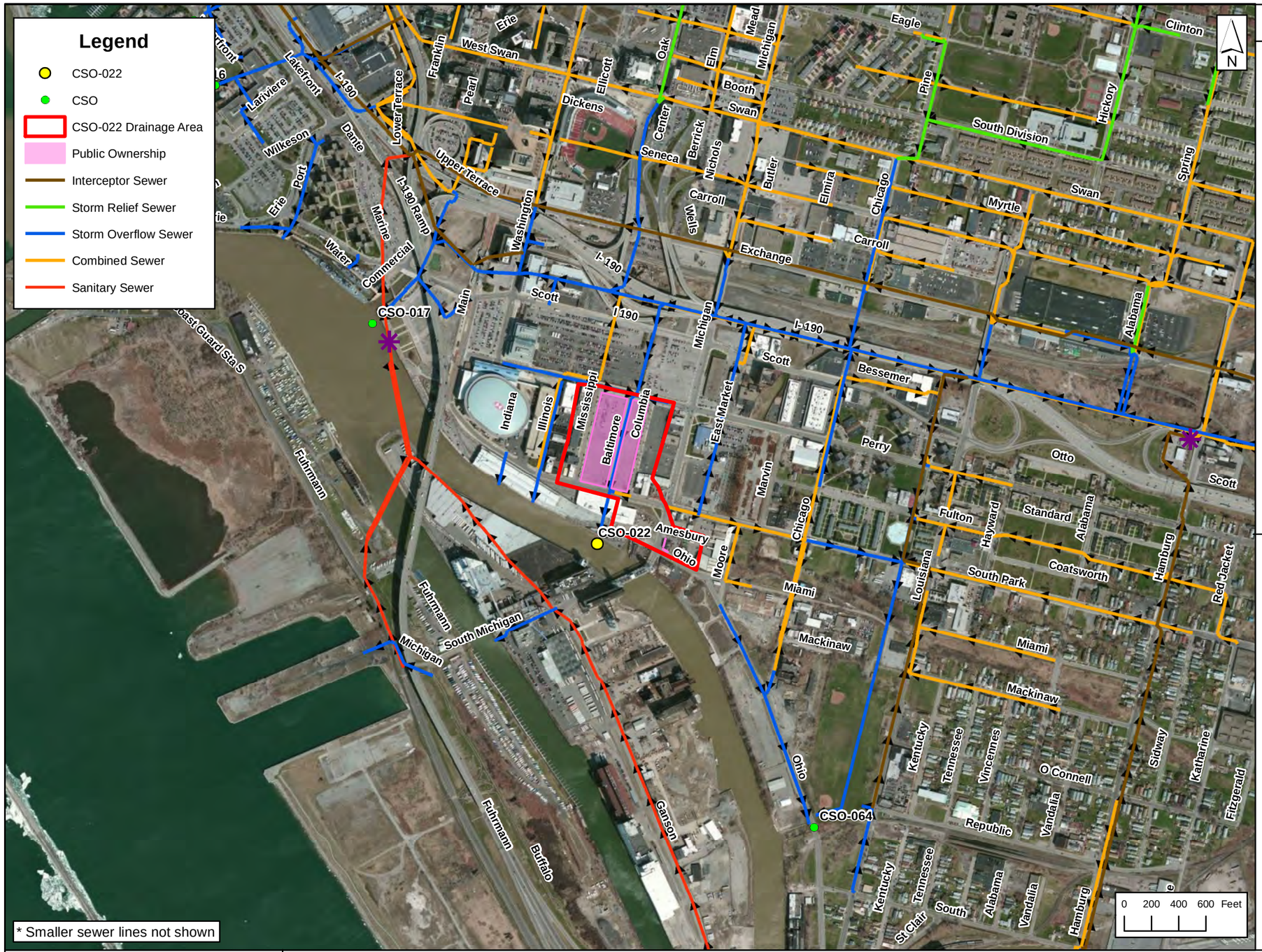
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-017



CSO-022 (16.5 acres)

Imperviousness: 60.0%

Total Impervious Area: 9.9 acres

Land Use:

Commercial:	7.1 acres	43.2%
Transportation:	5.0 acres	30.0%
Vacant:	1.9 acres	11.3%
Public Service:	1.8 acres	11.1%
No Data:	0.7 acres	4%
Residential:	0.1 acres	0.4%

Target Green Infrastructure Control:

20% = 2.0 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**5.0 acres**
Public Parcels:	**4.8 acres**
Residential Roof Surfaces:	**0 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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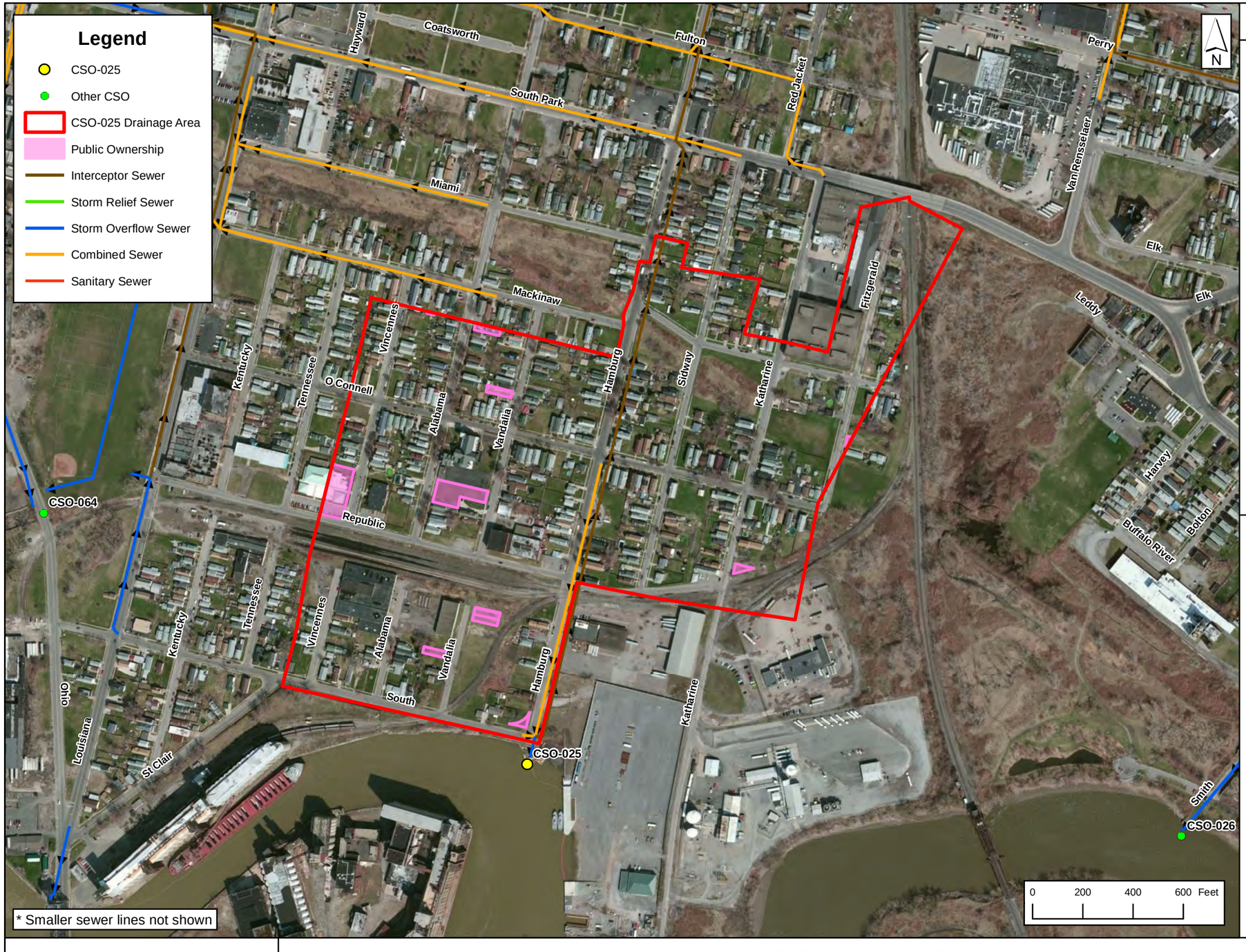
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-022



CSO-025 (68.6 acres)

Imperviousness: 21.1%

Total Impervious Area: 14.5 acres

Land Use:

Residential:	21.9 acres	31.9%
Transportation:	18.9 acres	27.5%
Vacant:	11.7 acres	17.0%
No Data:	8.0 acres	11.6%
Industrial:	4.9 acres	7.1%
Commercial:	1.7 acres	2.5%
Community Service:	1.6 acres	2.4%

Target Green Infrastructure Control:

10% = 1.5 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	18.9 acres
Public Parcels:	1.1 acres
Residential Roof Surfaces:	6.6 acres
Public Parcels (Vacant):	0.5 acres

Potential Green Infrastructure Technologies:

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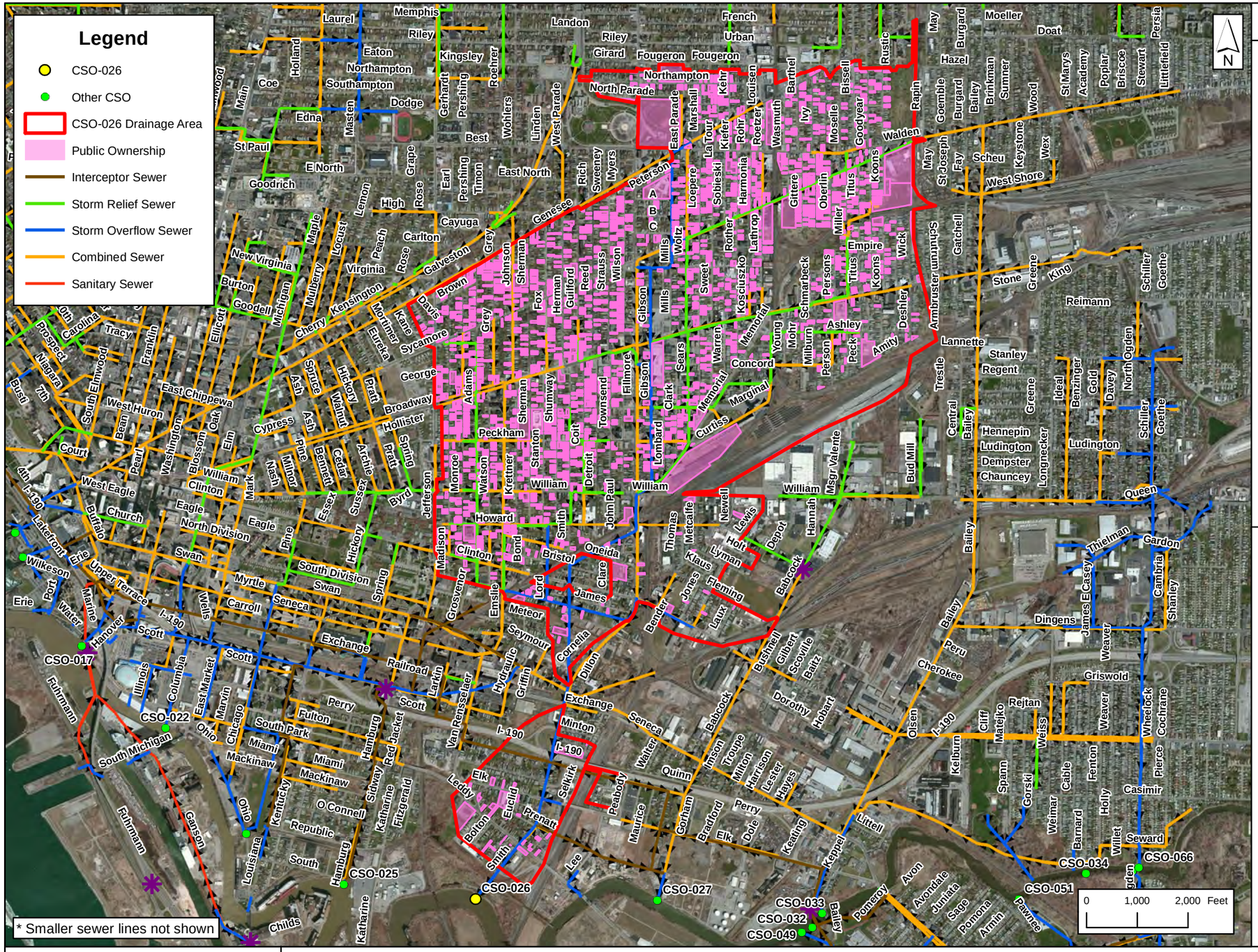
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-025



CSO-026 (1900.8 acres)

Imperviousness: 25.5%

Total Impervious Area: 484.5 acres

Land Use:

Residential:	537.9 acres	28.3%
Transportation:	440.5 acres	23.2%
Vacant:	377.9 acres	19.9%
Commercial:	196.4 acres	10.3%
No Data:	156.8 acres	8.2%
Community Service:	84.4 acres	4.4%
Industrial:	38.7 acres	2.0%
Conservation Areas / Parks:	34.4 acres	1.8%
Public Service:	27.7 acres	1.5%
Recreational:	7.1 acres	0.4%

Potential Green Infrastructure Control:

20% = 96.9 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	440.5 acres
Public Parcels:	311.3 acres
Residential Roof Surfaces:	161.4 acres
Public Parcels (Vacant):	180.5 acres

Potential Green Infrastructure Technologies:

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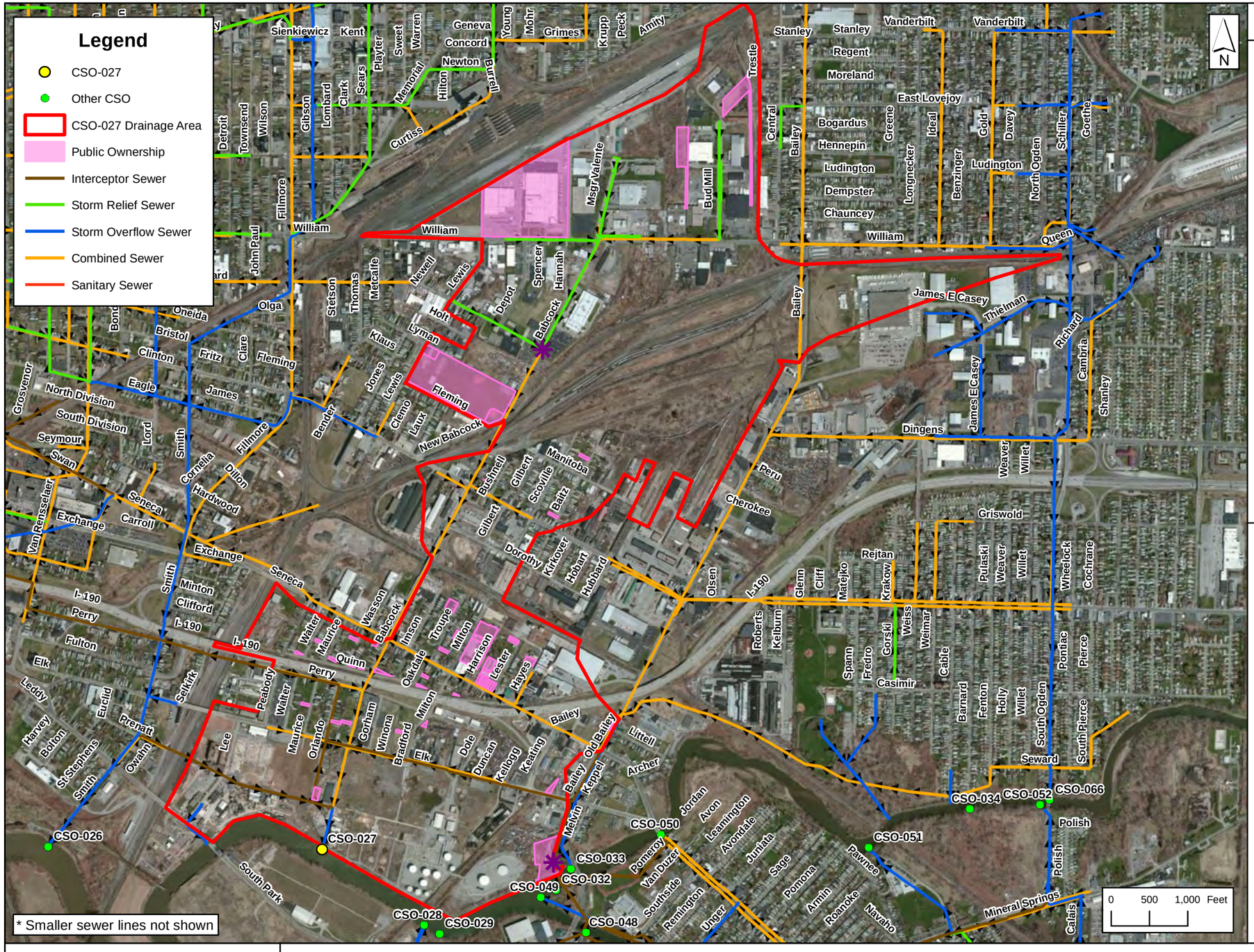
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-026



CSO-027 (930.8 acres)

Imperviousness: 25.5%

Total Impervious Area: 366.9 acres

Land Use:

No Data:	223.2 acres	24.0%
Industrial:	176.3 acres	18.9%
Commercial:	157.0 acres	16.9%
Vacant:	131.9 acres	14.2%
Transportation:	111.7 acres	12.0%
Residential:	47.4 acres	5.1%
Community Service:	40.4 acres	4.3%
Public Service:	26.1 acres	2.8%
Conservation Areas / Parks:	14.8 acres	1.6%
Recreational:	1.8 acres	0.2%

Target Green Infrastructure Control:

20% = 73.3 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	111.7 acres
Public Parcels:	56.0 acres
Residential Roof Surfaces:	14.2 acres
Public Parcels (Vacant):	5.9 acres

Potential Green Infrastructure Technologies:

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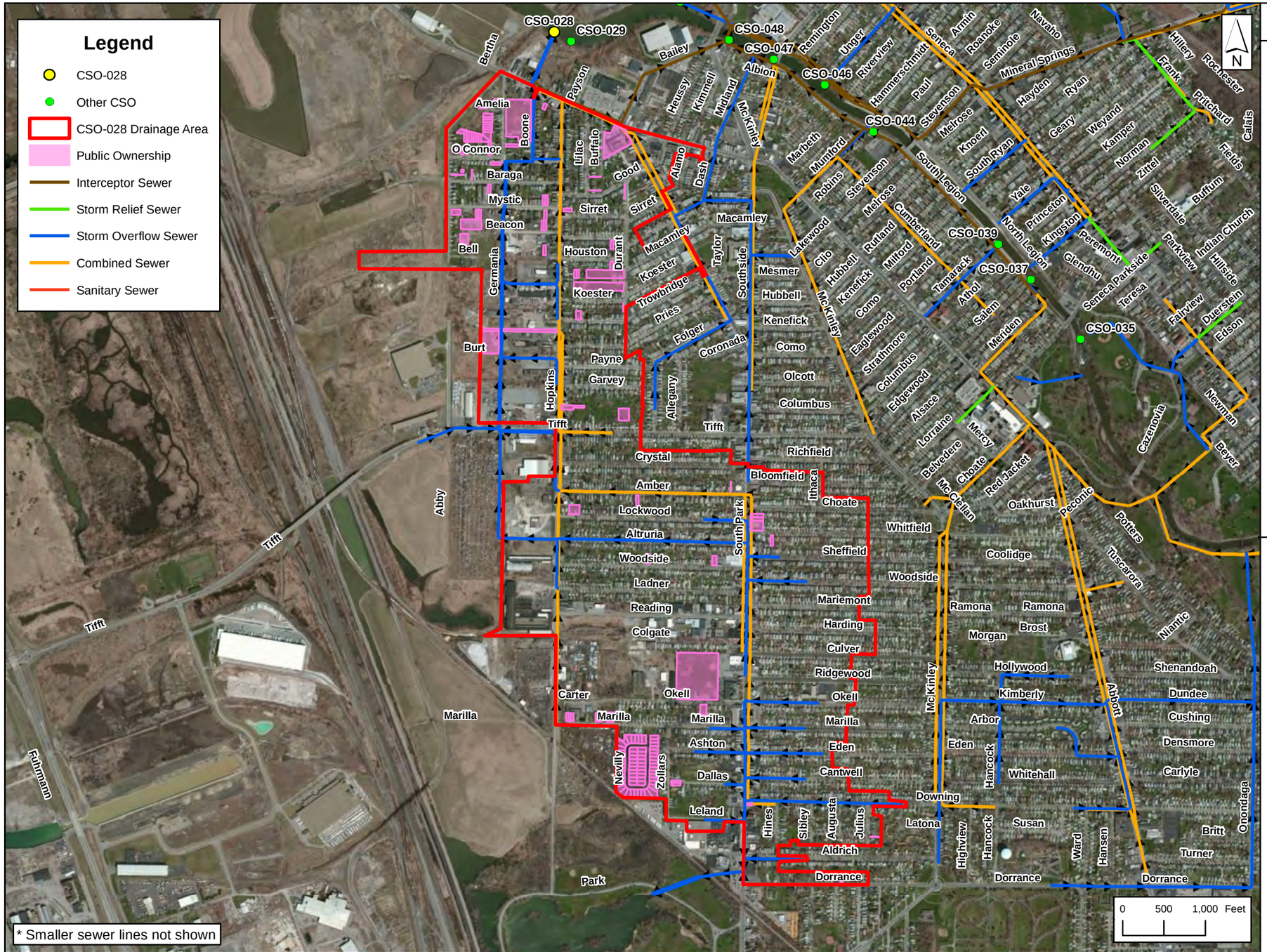
FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-027



CSO-028 (615.4 acres)

Imperviousness: 40.7%

Total Impervious Area: 250.4 acres

Land Use:

Residential:	265.7 acres	43.2%
Transportation:	133.5 acres	21.7%
Commercial:	78.1 acres	12.7%
Vacant:	70.2 acres	11.4%
Industrial:	39.6 acres	6.4%
Conservation Areas / Parks:	12.2 acres	2.0%
Community Service:	9.4 acres	1.5%
No Data:	3.3 acres	0.5%
Recreational:	2.3 acres	0.4%
Public Service:	1.1 acres	0.2%

Target Green Infrastructure Control:

20% = 50.1 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	133.5 acres
Public Parcels:	30.6 acres
Residential Roof Surfaces:	79.7 acres
Public Parcels (Vacant):	14.9 acres

Potential Green Infrastructure Technologies:

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Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-028



CSO-029 (4.0 acres)

Imperviousness: 32.0%

Total Impervious Area: 1.3 acres

Land Use:

No Data:	1.1 acres	27.3%
Vacant:	1.0 acres	24.3%
Residential:	0.7 acres	18.4%
Transportation:	0.6 acres	14.8%
Industrial:	0.4 acres	10.9%
Commercial:	0.2 acres	4.3%

Target Green Infrastructure Control:

10% = 0.1 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**0.6 acres**
Public Parcels:	**0.9 acres**
Residential Roof Surfaces:	**0.2 acres**
Public Parcels (Vacant):	**0.8 acres**

Potential Green Infrastructure Technologies:

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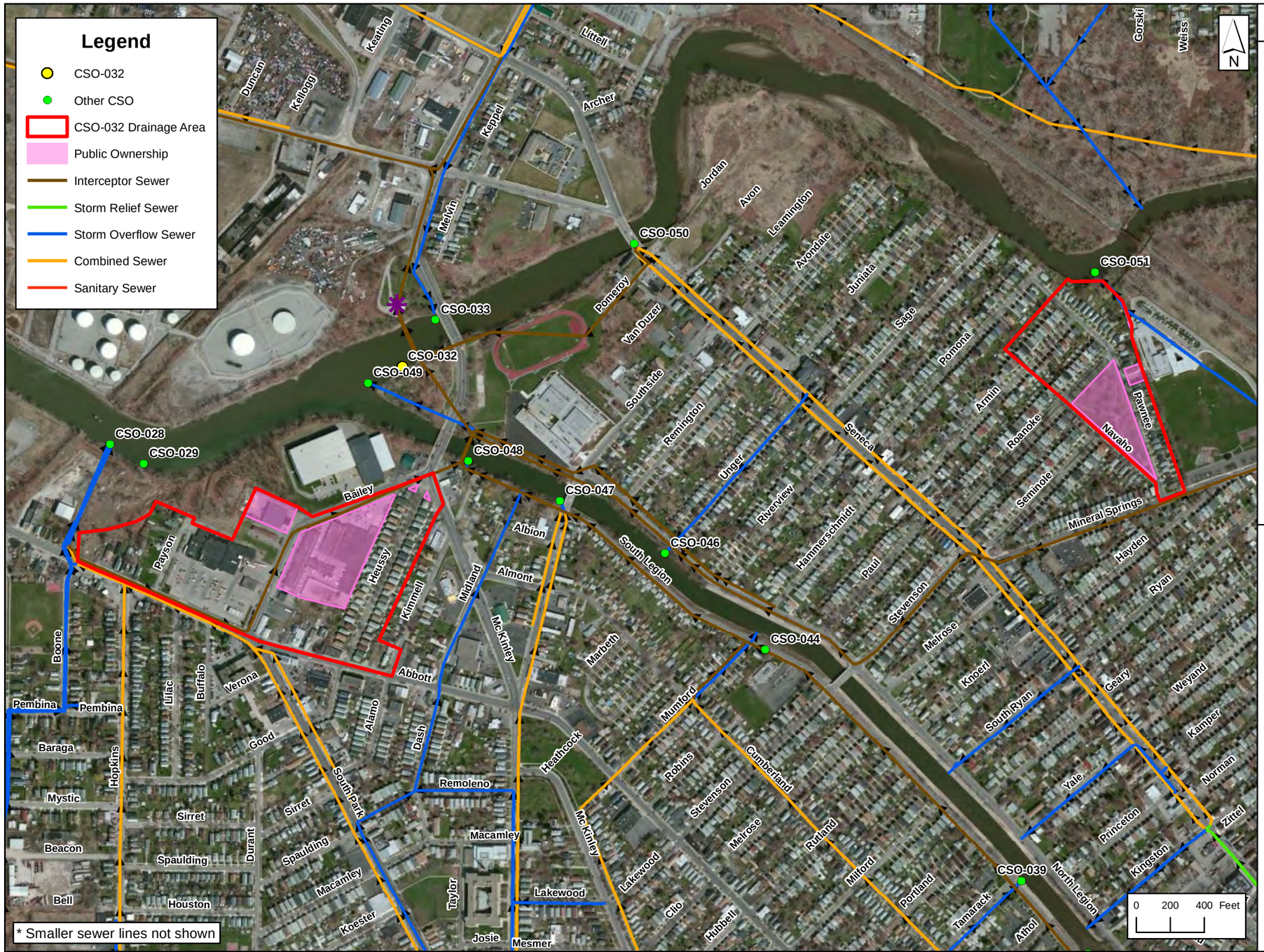
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-029



CSO-032 (44.3 acres)

Imperviousness: 35.2%

Total Impervious Area: 15.6 acres

Land Use:

Residential:	14.1 acres	31.7%
Transportation:	9.2 acres	20.8%
Commercial:	7.7 acres	17.4%
Community Service:	6.9 acres	15.5%
Vacant:	3.6 acres	8.1%
Conservation Areas / Parks:	2.7 acres	6.1%
Public Service:	0.2 acres	0.3%

Target Green Infrastructure Control:

10% = 1.6 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**9.2 acres**
Public Parcels:	**9.3 acres**
Residential Roof Surfaces:	**4.2 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

MALCOLM PIRNIE | ARCADIS
The Water Division of ARCADIS

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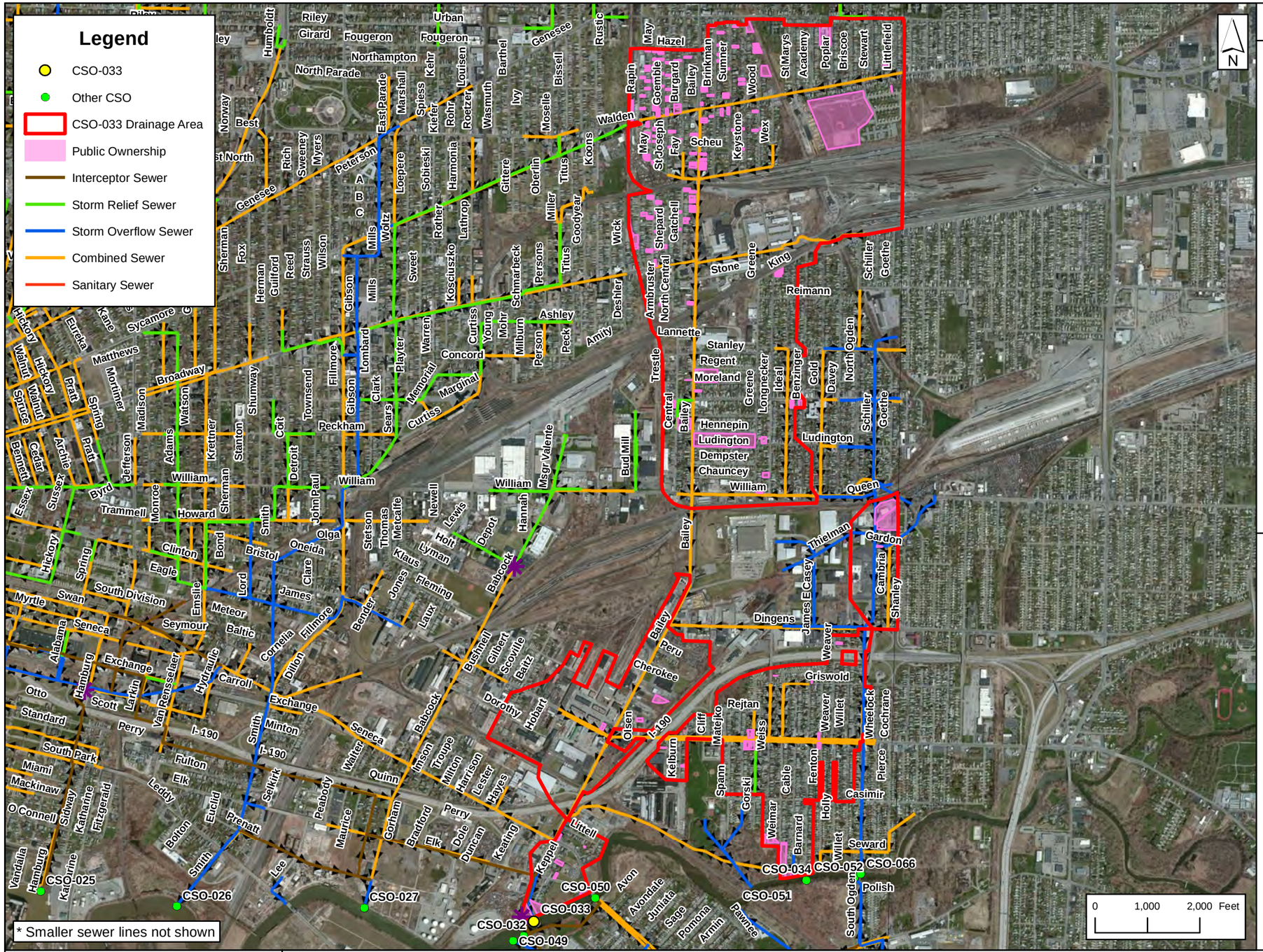
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-032



CSO-033 (1268.7 acres)

Imperviousness: 37.0%

Total Impervious Area: 470.0 acres

Land Use:

Residential:	422.1 acres	33.3%
Transportation:	222.4 acres	17.6%
Commercial:	207.7 acres	16.4%
No Data:	149.5 acres	11.8%
Vacant:	104.2 acres	8.2%
Industrial:	91.7 acres	7.2%
Conservation Areas / Parks:	27.7 acres	2.2%
Community Service:	25.7 acres	2.0%
Public Service:	12.2 acres	1.0%
Recreational:	2.9 acres	0.2%

Target Green Infrastructure Control:

10% = 47.0 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**222.4 acres**
Public Parcels:	**62.5 acres**
Residential Roof Surfaces:	**126.6 acres**
Public Parcels (Vacant):	**17.9 acres**

Potential Green Infrastructure Technologies:

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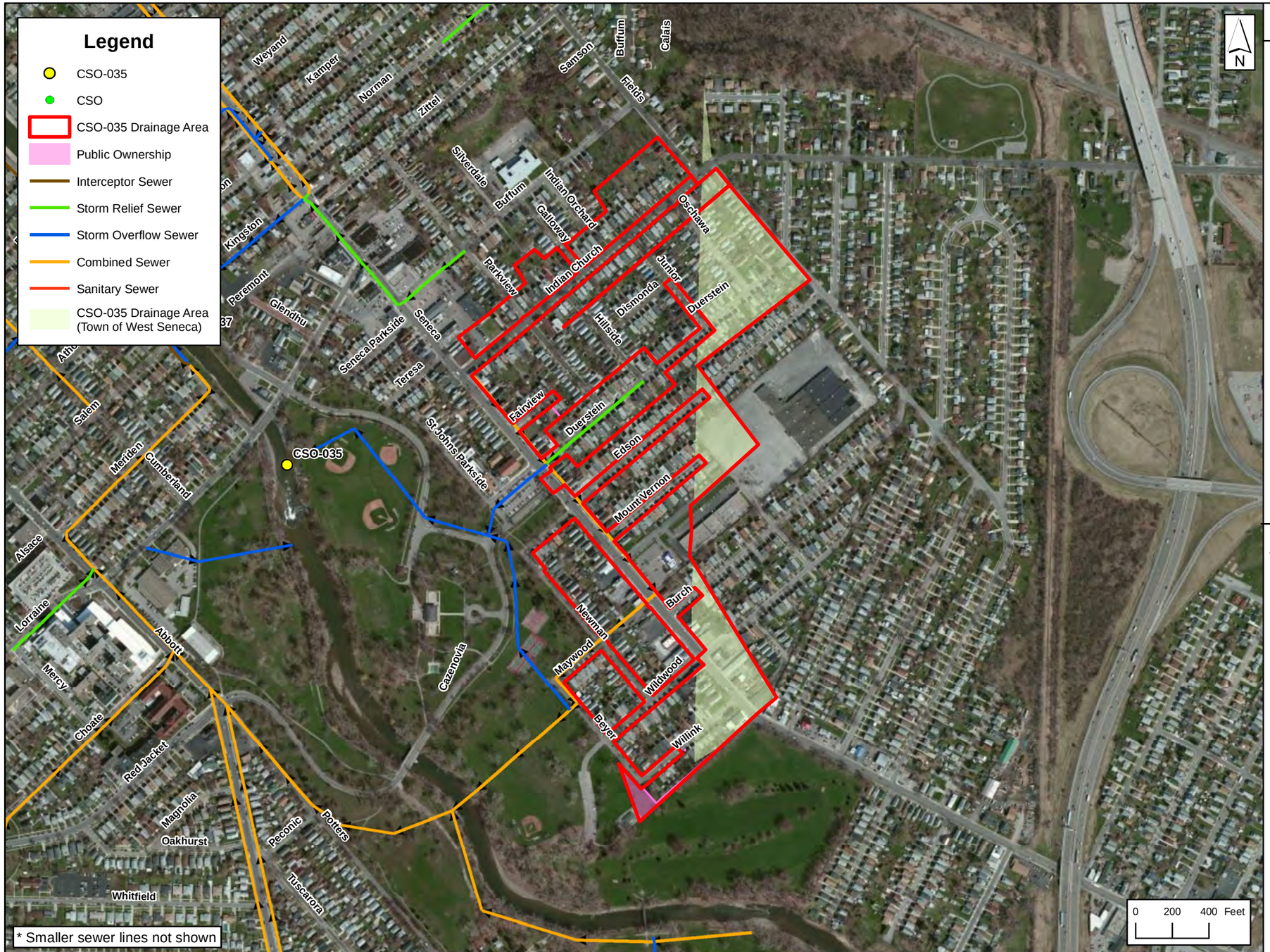
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-033



CSO-035 (63.8 acres)

Imperviousness: 27.6%

Total Impervious Area: 17.6 acres

Land Use:

Residential:	33.8 acres	71.1%
Commercial:	6.1 acres	12.8%
Transportation:	5.2 acres	10.9%
Vacant:	1.0 acres	2.2%
Conservation Areas / Parks:	0.6 acres	1.2%
Public Service:	0.3 acres	0.7%
Community Service:	0.3 acres	0.7%
No Data:	0.3 acres	0.5%

Target Green Infrastructure Control:

10% = 6.4 acres

Note: Land use and public parcel totals do not include the Town of West Seneca portion of the drainage area.

Green Infrastructure Opportunities

Streets and Right of Way:	5.2 acres
Public Parcels:	0.6 acres
Residential Roof Surfaces:	10.1 acres
Public Parcels (Vacant):	0 acres

Potential Green Infrastructure Technologies:

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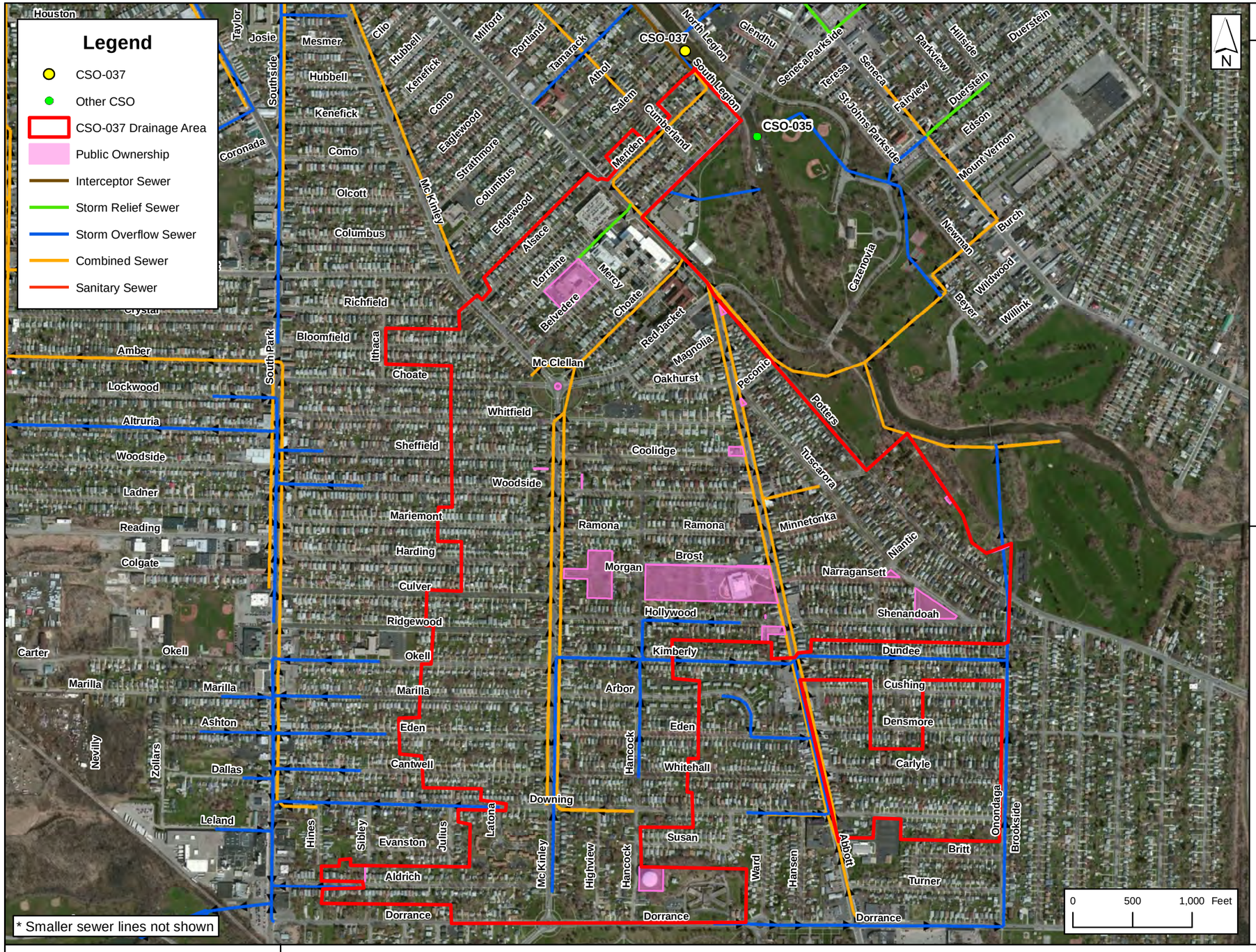
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-035



CSO-037 (455.1 acres)

Imperviousness: 34.2%

Total Impervious Area: 155.6 acres

Land Use:

Residential:	274.8 acres	60.5%
Transportation:	121.7 acres	26.8%
Community Service:	25.7 acres	5.7%
Commercial:	18.5 acres	4.1%
Vacant:	4.7 acres	1.0%
No Data:	4.2 acres	0.9%
Conservation Areas / Parks:	3.7 acres	0.8%
Public Service:	1.1 acres	0.2%

Target Green Infrastructure Control:

20% = 31.1 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**121.7 acres**
Public Parcels:	**15.1 acres**
Residential Roof Surfaces:	**82.4 acres**
Public Parcels (Vacant):	**0.7 acres**

Potential Green Infrastructure Technologies:

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Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-037



CSO-039 (14.3 acres)

Imperviousness: 42.4%

Total Impervious Area: 6.1 acres

Land Use:

Residential:	9.7 acres	68.2%
Transportation:	3.7 acres	25.6%
Commercial:	0.7 acres	5.0%
Community Service:	0.1 acres	0.9%

Target Green Infrastructure Control:

10% = 0.6 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**3.7 acres**
Public Parcels:	**0 acres**
Residential Roof Surfaces:	**2.9 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-039



CSO-044 (112.2 acres)

Imperviousness: 41.1%

Total Impervious Area: 46.1 acres

Land Use:

Residential:	77.0 acres	68.6%
Transportation:	29.3 acres	26.1%
Commercial:	2.0 acres	1.8%
Community Service:	1.8 acres	1.6%
Vacant:	1.1 acres	1.0%
Conservation Areas / Parks:	0.9 acres	0.8%
Recreational:	0.1 acres	0.1%

Target Green Infrastructure Control:

10% = 4.6 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	29.3 acres
Public Parcels:	1.0 acres
Residential Roof Surfaces:	23.1 acres
Public Parcels (Vacant):	0.1 acres

Potential Green Infrastructure Technologies:

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Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-044



CSO-046 (87.2 acres)

Imperviousness: 28.5%

Total Impervious Area: 24.8 acres

Land Use:

Residential:	57.7 acres	66.1%
Transportation:	20.7 acres	23.8%
Commercial:	5.6 acres	6.4%
Vacant:	2.1 acres	2.4%
No Data:	0.8 acres	0.9%
Conservation Areas / Parks:	0.2 acres	0.2%
Public Service:	0.1 acres	0.1%

Target Green Infrastructure Control:

10% = 2.5 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**20.7 acres**
Public Parcels:	**0.2 acres**
Residential Roof Surfaces:	**17.3 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-046



CSO-047 (137.4 acres)

Imperviousness: 47.7%

Total Impervious Area: 65.6 acres

Land Use:

Residential:	66.8 acres	48.7%
Transportation:	40.4 acres	29.4%
Commercial:	17.1 acres	12.4%
Community Service:	5.5 acres	4.0%
Conservation Areas / Parks:	3.6 acres	2.6%
Vacant:	2.8 acres	2.0%
Recreational:	1.0 acres	0.8%
Public Service:	0.1 acres	0.1%

Target Green Infrastructure Control:

20% = 13.1 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**40.4 acres**
Public Parcels:	**6.8 acres**
Residential Roof Surfaces:	**20.0 acres**
Public Parcels (Vacant):	**0.1 acres**

Potential Green Infrastructure Technologies:

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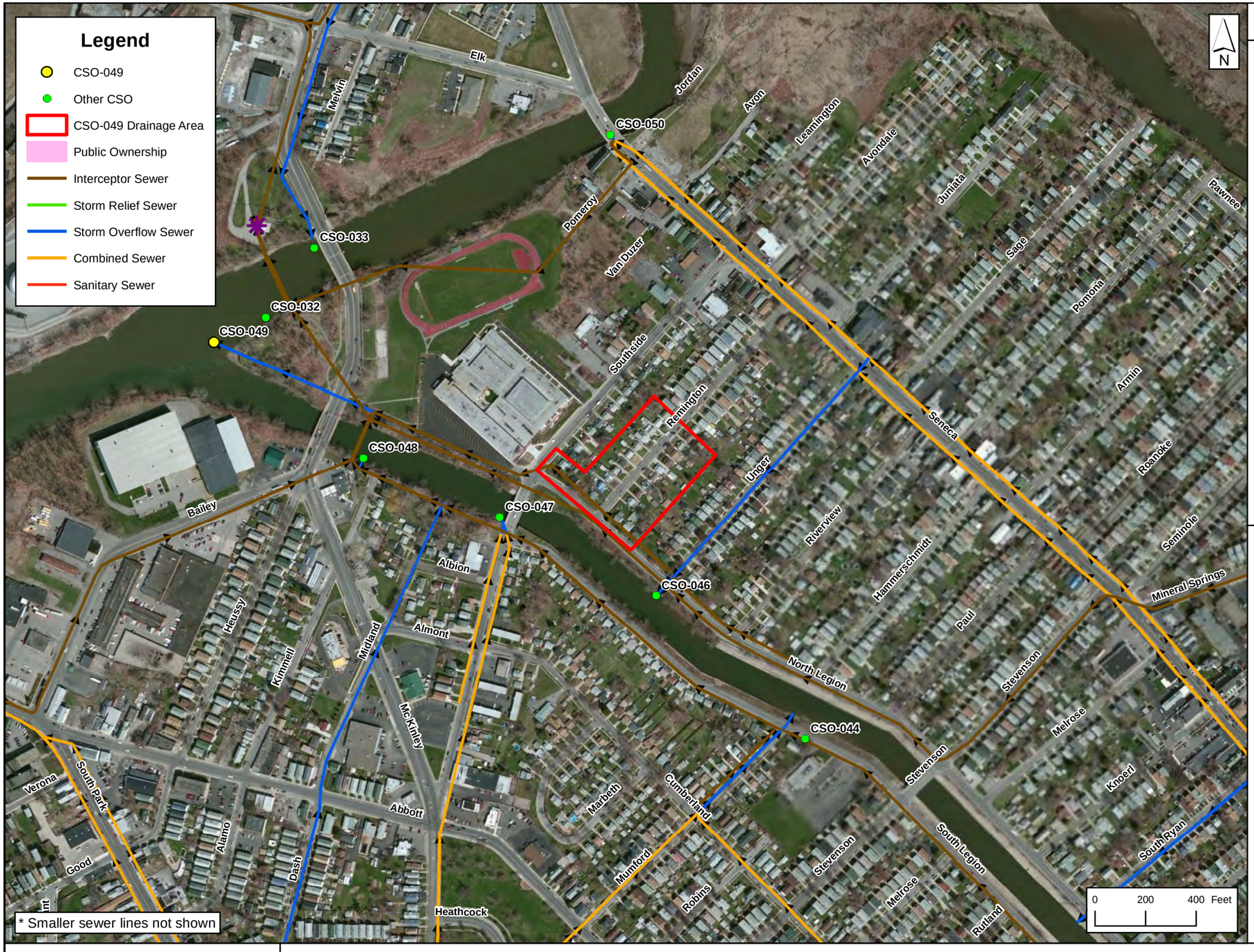
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-047



CSO-049 (4.4 acres)

Imperviousness: 38.6%

Total Impervious Area: 1.7 acres

Land Use:

Residential:	3.3 acres	76.2%
Transportation:	1.0 acres	23.8%

Target Green Infrastructure Control:

10% = 0.2 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**1.0 acres**
Public Parcels:	**0 acres**
Residential Roof Surfaces:	**1.0 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-049



CSO-050 (39.9 acres)

Imperviousness: 30.1%

Total Impervious Area: 12.0 acres

Land Use:

Residential:	22.2 acres	55.6%
Transportation:	9.2 acres	23.1%
Commercial:	3.4 acres	8.4%
Vacant:	2.4 acres	6%
Community Service:	1.5 acres	3.7%
Recreational:	0.7 acres	1.7%
Public Service:	0.3 acres	0.8%
Conservation Areas / Parks:	0.2 acres	0.4%
No Data:	0.1 acres	0.2%

Target Green Infrastructure Control:

20% = 2.4 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**9.2 acres**
Public Parcels:	**2.0 acres**
Residential Roof Surfaces:	**6.7 acres**
Public Parcels (Vacant):	**0.2 acres**

Potential Green Infrastructure Technologies:

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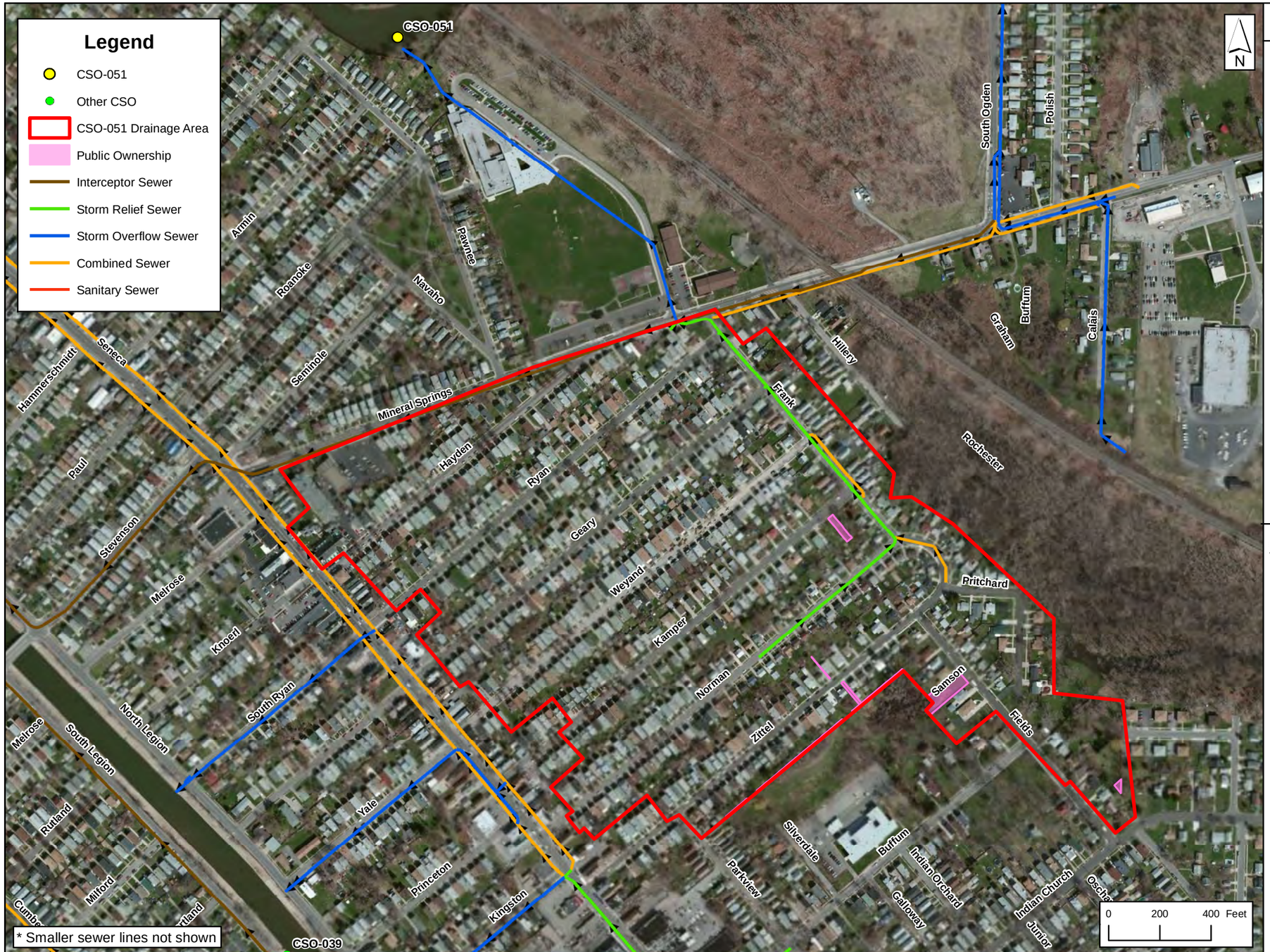
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-050



CSO-051 (83.2 acres)

Imperviousness: 29.6%

Total Impervious Area: 24.7 acres

Land Use:

Residential:	60.6 acres	73.1%
Transportation:	16.7 acres	20.1%
Vacant:	2.7 acres	3.2%
Community Service:	2.2 acres	2.7%
No Data:	0.5 acres	0.6%
Commercial:	0.2 acres	0.2%

Target Green Infrastructure Control:

10% = 2.5 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**16.7 acres**
Public Parcels:	**0.5 acres**
Residential Roof Surfaces:	**18.2 acres**
Public Parcels (Vacant):	**0.2 acres**

Potential Green Infrastructure Technologies:

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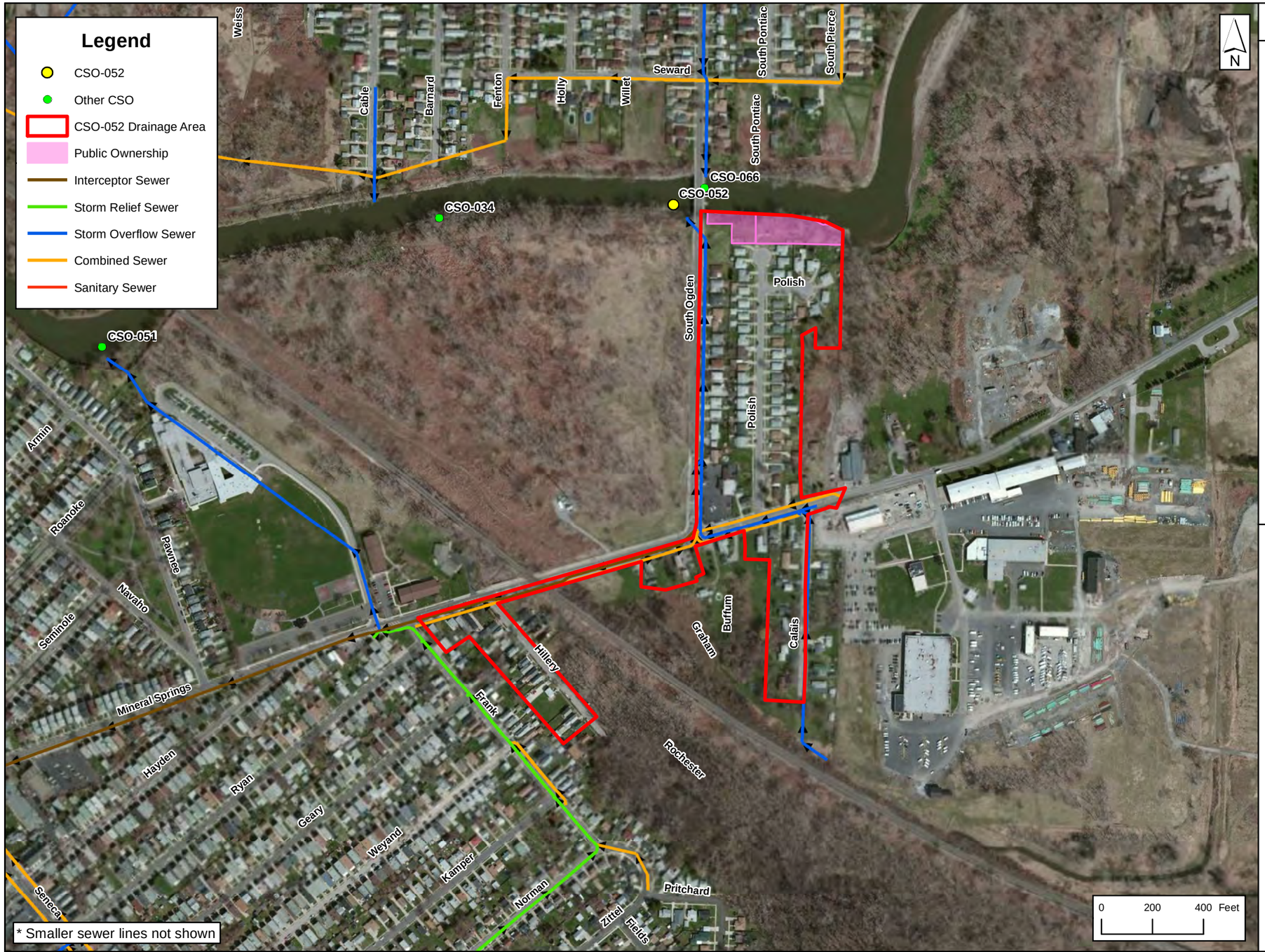
Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-051



CSO-052 (20.5 acres)

Imperviousness: 34.4%

Total Impervious Area: 7.0 acres

Land Use:

Residential:	12.1 acres	59.4%
Transportation:	5.3 acres	26.2%
Vacant:	2.2 acres	11.0%
Commercial:	0.7 acres	3.5%

Target Green Infrastructure Control:

10% = 0.7 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	5.3 acres
Public Parcels:	1.1 acres
Residential Roof Surfaces:	3.6 acres
Public Parcels (Vacant):	1.1 acres

Potential Green Infrastructure Technologies:

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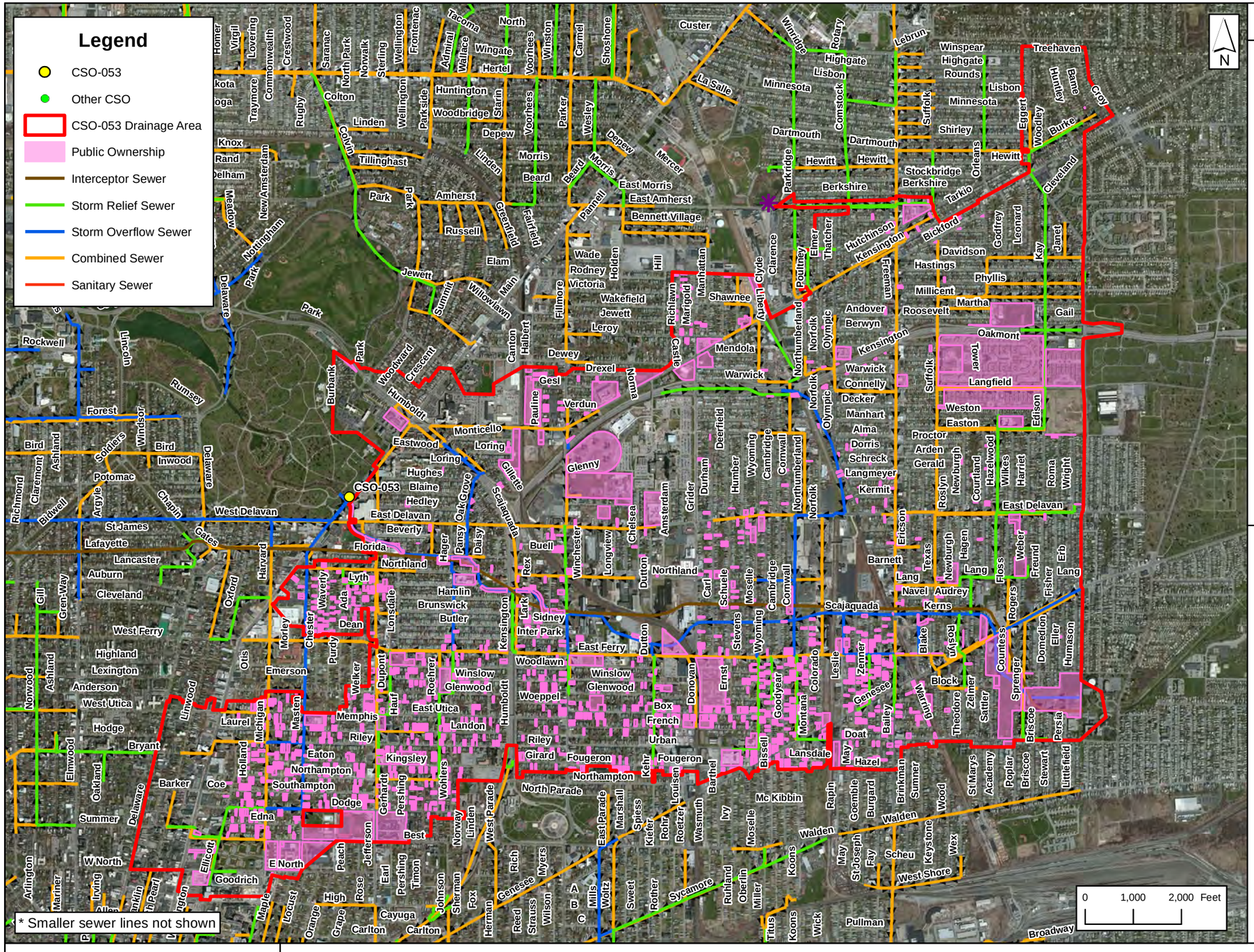
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-052



CSO-053 (3985.2 acres)

Imperviousness: 53.4%

Total Impervious Area: 2128.6 acres

Land Use:

Residential:	1498.2 acres	37.8%
Transportation:	947.4 acres	23.9%
Commercial:	447.2 acres	11.3%
Vacant:	443.0 acres	11.2%
Community Service:	264.5 acres	6.7%
Industrial:	166.6 acres	4.2%
No Data:	86.7 acres	2.2%
Conservation Areas / Parks:	48.8 acres	1.2%
Recreational:	38.4 acres	1.0%
Public Service:	28.0 acres	0.7%

Target Green Infrastructure Control:

20% = 425.7 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	947.4 acres
Public Parcels:	454.5 acres
Residential Roof Surfaces:	449.5 acres
Public Parcels (Vacant):	143.3 acres

Potential Green Infrastructure Technologies:

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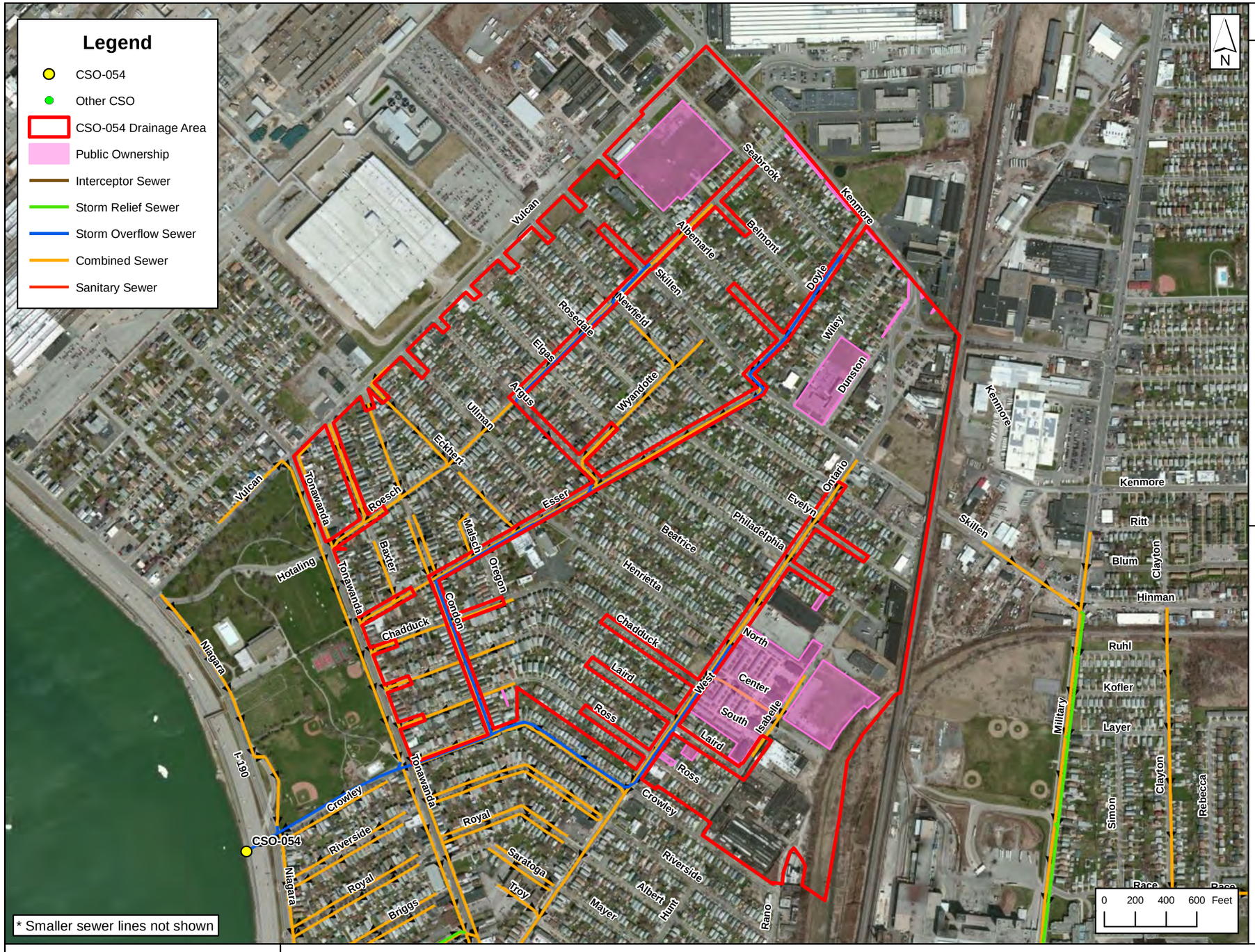
Green Infrastructure Opportunities Analysis

FIGURE 1
SCAJAQUADA DISTRICT
CSO-053



CSO-054 (293.4 acres)

Imperviousness: 38.1%

Total Impervious Area: 111.9 acres

Land Use:

Residential:	160.2 acres	54.7%
Transportation:	47.8 acres	16.3%
Commercial:	29.4 acres	10.0%
Vacant:	18.5 acres	6.3%
Industrial:	15.3 acres	5.2%
Community Service:	8.0 acres	2.7%
No Data:	7.4 acres	2.5%
Recreational:	6.2 acres	2.1%
Public Service:	0.3 acres	0.1%

Target Green Infrastructure Control:

10% = 11.1 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**47.8 acres**
Public Parcels:	**21.1 acres**
Residential Roof Surfaces:	**48.0 acres**
Public Parcels (Vacant):	**4.3 acres**

Potential Green Infrastructure Technologies:

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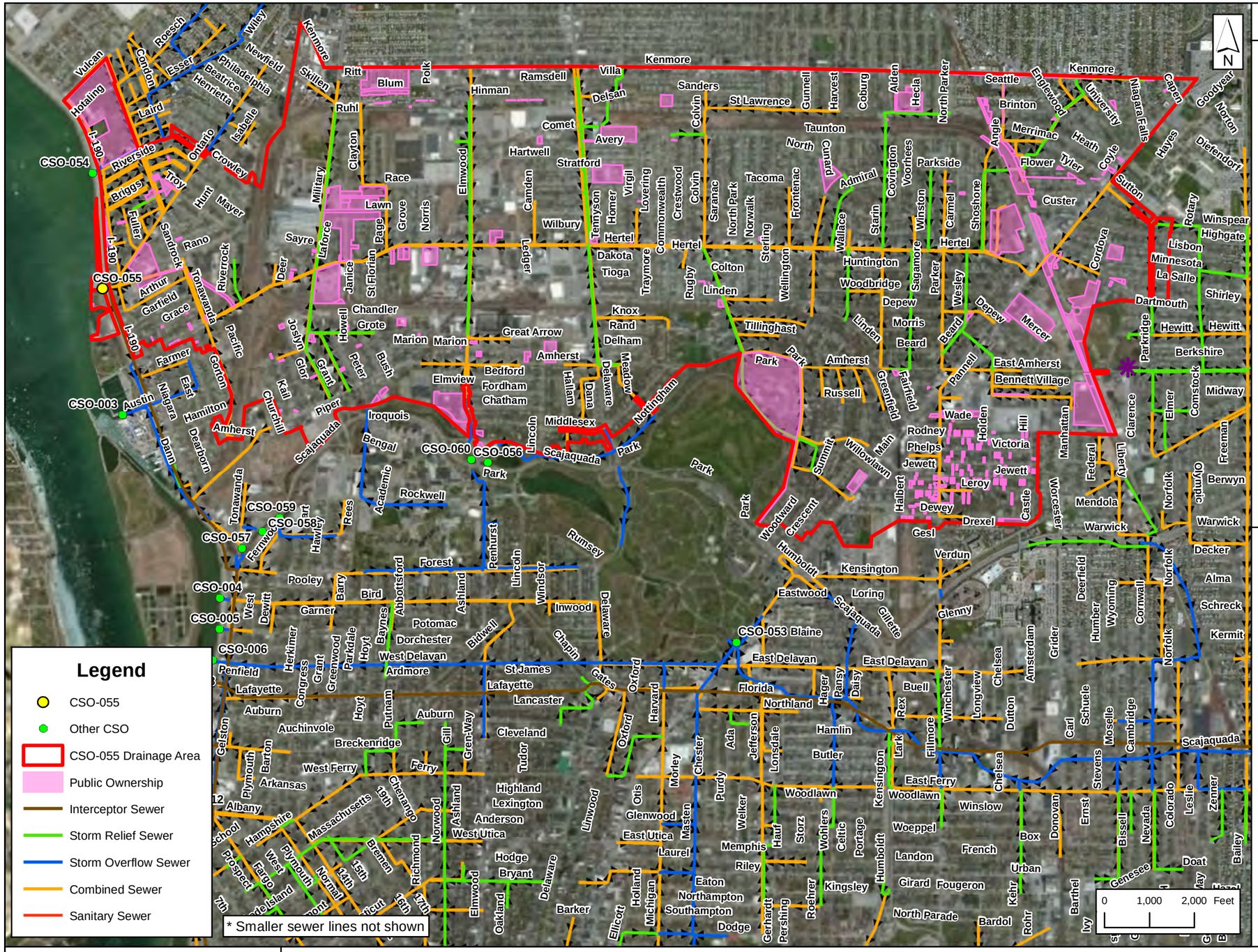
FIGURE 1
ONTARIO DISTRICT
CSO-054



CSO-055 (4198.1 acres)

Imperviousness: 41.8%

Total Impervious Area: 1753.3 acres

Land Use:

Residential:	1661.1 acres	39.6%
Transportation:	836.3 acres	19.9%
Commercial:	641.7 acres	15.3%
Vacant:	332.2 acres	7.9%
Industrial:	211.9 acres	5.1%
Community Service:	200.9 acres	4.8%
No Data:	107.3 acres	2.6%
Conservation Areas / Parks:	105.1 acres	2.5%
Recreational:	53.2 acres	1.3%
Public Service:	45.3 acres	1.1%

Target Green Infrastructure Control:

20% = 350.7 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	836.3 acres
Public Parcels:	301.9 acres
Residential Roof Surfaces:	498.3 acres
Public Parcels (Vacant):	62.2 acres

Potential Green Infrastructure Technologies:

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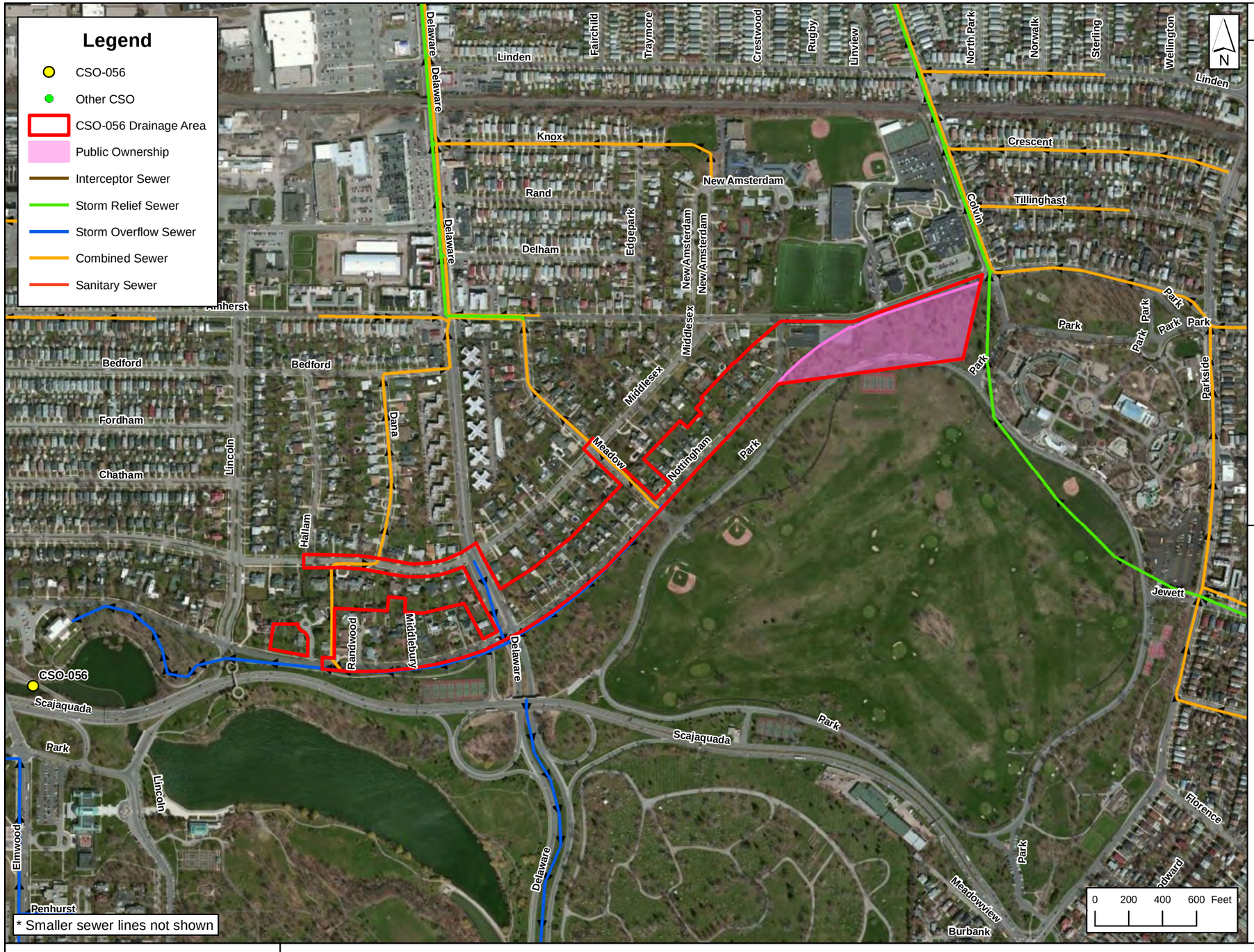
Green Infrastructure Opportunities Analysis

FIGURE 1
HERTEL DISTRICT
CSO-055



CSO-056 (34.8 acres)

Imperviousness: 31.4%

Total Impervious Area: 12.2 acres

Land Use:

Residential:	15.1 acres	43.5%
Transportation:	10.6 acres	30.5%
Conservation Areas / Parks:	7.5 acres	21.6%
Community Service:	1.1 acres	3.3%
Vacant:	0.3 acres	0.9%

Target Green Infrastructure Control:

10% = 1.2 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**10.6 acres**
Public Parcels:	**7.5 acres**
Residential Roof Surfaces:	**4.5 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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Green Infrastructure Opportunities Analysis

FIGURE 1
HERTEL DISTRICT
CSO-056



CSO-057 (4.5 acres)

Imperviousness: 66.4%

Total Impervious Area: 3.0 acres

Land Use:

Transportation:	1.9 acres	43.0%
Industrial:	1.8 acres	41.0%
Residential:	0.4 acres	9.0%
No Data:	0.3 acres	6.3%

Target Green Infrastructure Control:

10% = 0.3 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**1.9 acres**
Public Parcels:	**0 acres**
Residential Roof Surfaces:	**0.1 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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Green Infrastructure Opportunities Analysis

FIGURE 1
PARISH DISTRICT
CSO-057



CSO-058 (30.3 acres)

Imperviousness: 52.7%

Total Impervious Area: 16.0 acres

Land Use:

Vacant:	12.5 acres	41.2%
Commercial:	6.8 acres	22.6%
Transportation:	4 acres	13.4%
Industrial:	1.8 acres	6.1%
No Data:	5.1 acres	16.8%

Target Green Infrastructure Control:

10% = 1.6 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**4 acres**
Public Parcels:	**0 acres**
Residential Roof Surfaces:	**0 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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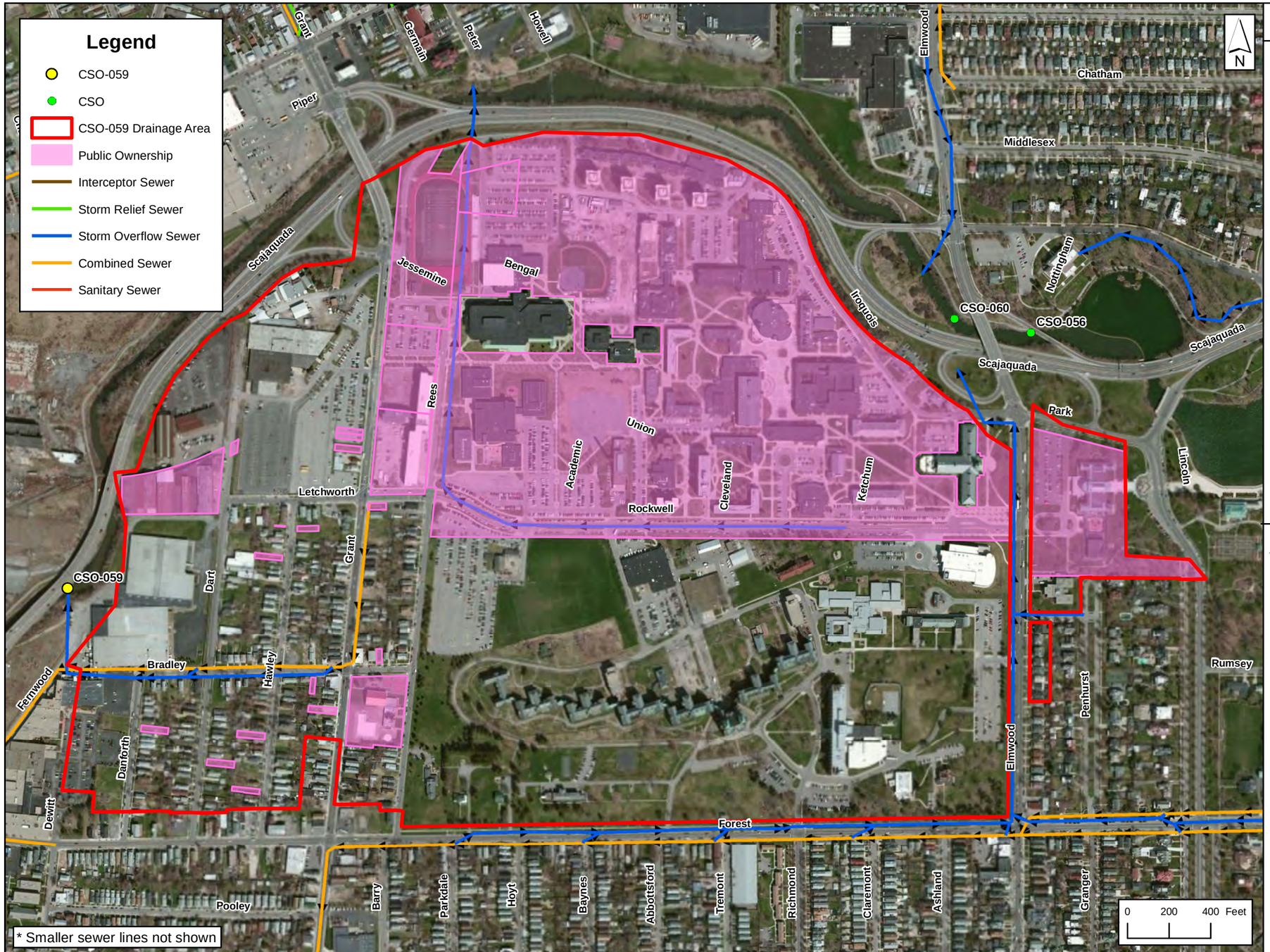
Green Infrastructure Opportunities Analysis

FIGURE 1
PARISH DISTRICT
CSO-058



CSO-059 (183.8 acres*)

Imperviousness: 19.2%*

Total Impervious Area: 35.3 acres*

Land Use:

Community Service:	103.5 acres	36.6%
Recreational:	93.8 acres	33.2%
Residential:	24.3 acres	8.6%
Vacant:	17.9 acres	6.3%
Transportation:	17.4 acres	6.2%
Industrial:	11.6 acres	4.1%
No Data:	8.9 acres	3.2%
Commercial:	5.2 acres	1.8%

Target Green Infrastructure Control:

10% = 3.5 acres

* Note: CSO-059 acreage and impervious area totals presented represent the remaining combined sewer area and percent impervious. The total area tributary to this CSO is 282.7 acres, and includes sewer separation of 35% of this tributary area. The percent impervious presented here and used in the model was also adjusted (reduced) to reflect localized sewer separation.

Green Infrastructure Opportunities

Streets and Right of Way:	17.4 acres
Public Parcels:	111.2 acres
Residential Roof Surfaces:	7.3 acres
Public Parcels (Vacant):	5.5 acres

Potential Green Infrastructure Technologies:

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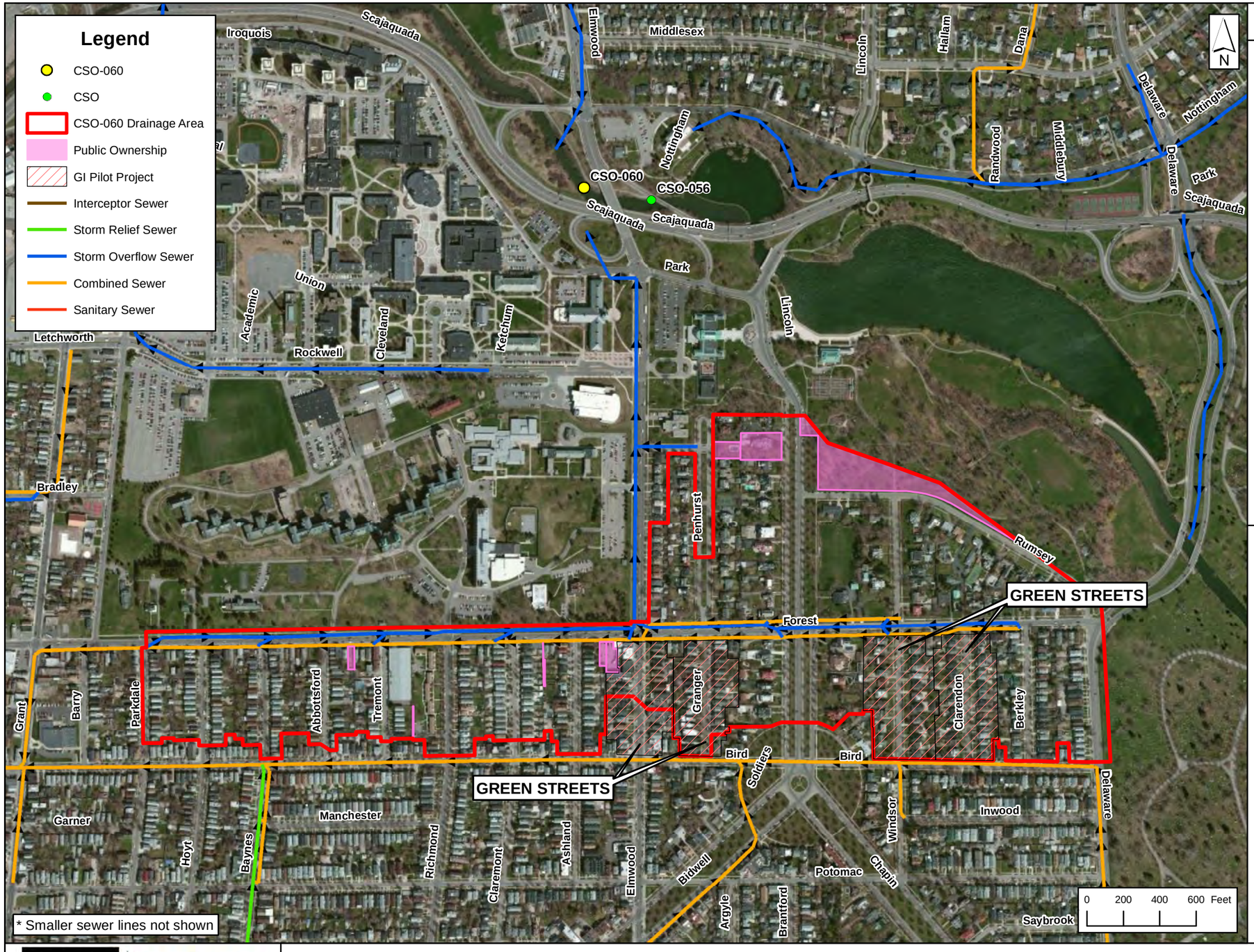
Green Infrastructure Opportunities Analysis

FIGURE 1
SCAJAQUADA DISTRICT
CSO-059



CSO-060 (78.2 acres*)

Imperviousness: 66.3%

Total Impervious Area: 51.8 acres*

Land Use:

Residential:	68.9 acres	57.2%
Transportation:	36.2 acres	30.1%
Commercial:	5.7 acres	4.8%
Community Service:	5.6 acres	4.6%
Vacant:	3.9 acres	3.3%

Target Green Infrastructure Control:
10% = 5.2 acres

* Note: CSO-060 acreage and impervious area totals presented represent the remaining combined sewer area and percent impervious. The total area tributary to this CSO is 120.3 acres, and includes sewer separation of 35% of this tributary area.

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**36.2 acres**
Public Parcels:	**4.8 acres**
Residential Roof Surfaces:	**20.7 acres**
Public Parcels (Vacant):	**0.7 acres**

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Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
SCAJAQUADA DISTRICT
CSO-060



CSO-063 (20 acres)

Imperviousness: 36.6%

Total Impervious Area: 7.3 acres

Land Use:

Public Service:	10.5 acres	52.0%
Conservation Areas / Parks:	8.8 acres	43.8%
Transportation:	0.8 acres	4.1%

Target Green Infrastructure Control:

20% = 1.5 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**0.8 acres**
Public Parcels:	**8.8 acres**
Residential Roof Surfaces:	**0 acres**
Public Parcels (Vacant):	**0 acres**

Potential Green Infrastructure Technologies:

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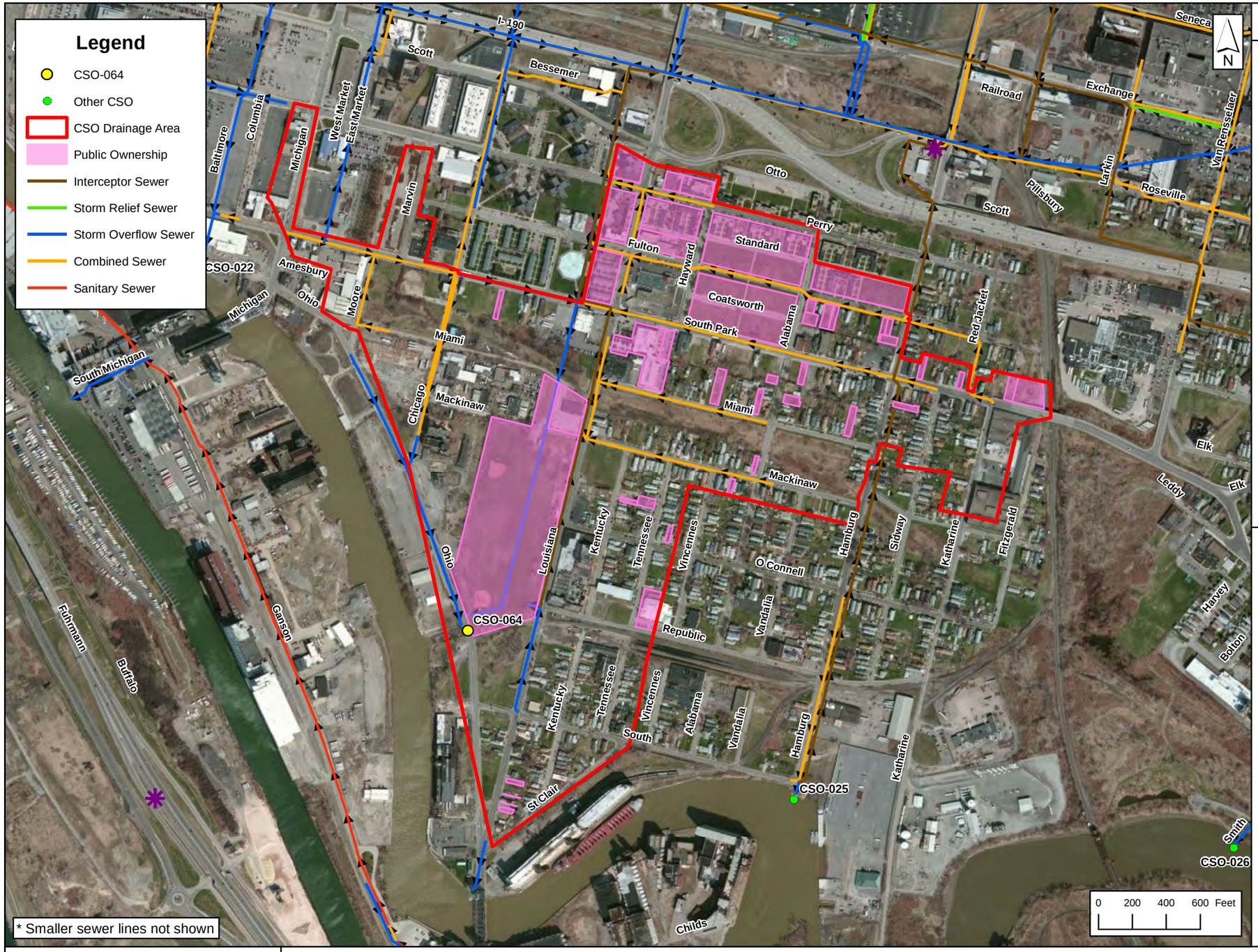
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-063



CSO-064 (178.9 acres)

Imperviousness: 54.7%

Total Impervious Area: 97.9 acres

Land Use:

Vacant:	49.6 acres	27.7%
Transportation:	45.1 acres	25.2%
Residential:	29.5 acres	16.5%
Commercial:	26.6 acres	14.9%
Conservation Areas / Parks:	14.9 acres	8.3%
Community Service:	6.4 acres	3.6%
Industrial:	4.0 acres	2.2%
No Data:	2.8 acres	1.5%

Target Green Infrastructure Control:

20% = 19.6 acres

Green Infrastructure Opportunities

Streets and Rights-of-Way:	**45.1 acres**
Public Parcels:	**38 acres**
Residential Roof Surfaces:	**8.9 acres**
Public Parcels (Vacant):	**14.8 acres**

Potential Green Infrastructure Technologies:

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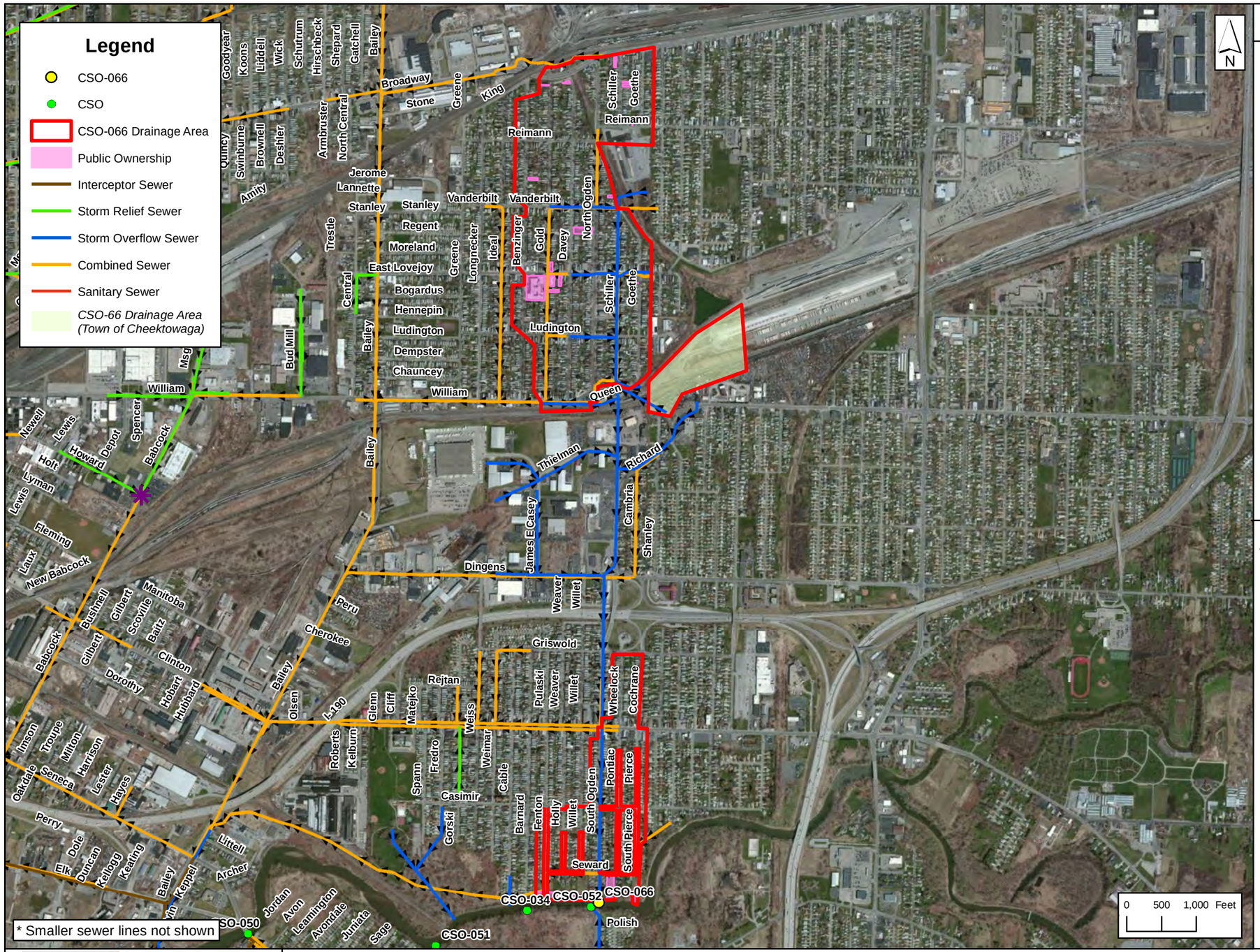
BUFFALO SEWER AUTHORITY
Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-064



* Smaller sewer lines not shown

CSO-066 (291.1 acres)

Imperviousness: 32.7%

Total Impervious Area: 95.1 acres

Land Use:

Residential:	158.3 acres	60.3%
Transportation:	63.6 acres	24.2%
Vacant:	14.2 acres	5.4%
Commercial:	10.3 acres	3.9%
No Data:	9.7 acres	3.7%
Community Service:	5.5 acres	2.1%
Recreational:	1.0 acres	0.4%
Industrial:	0.2 acres	0.1%

Target Green Infrastructure Control:

10% = 9.5 acres

Note: Land use and public parcel totals do not include the Town of Cheektowaga portion of the drainage area.

Green Infrastructure Opportunities

Streets and Right of Way:	**63.6 acres**
Public Parcels:	**6.1 acres**
Residential Roof Surfaces:	**47.5 acres**
Public Parcels (Vacant):	**2.8 acres**

Potential Green Infrastructure Technologies:

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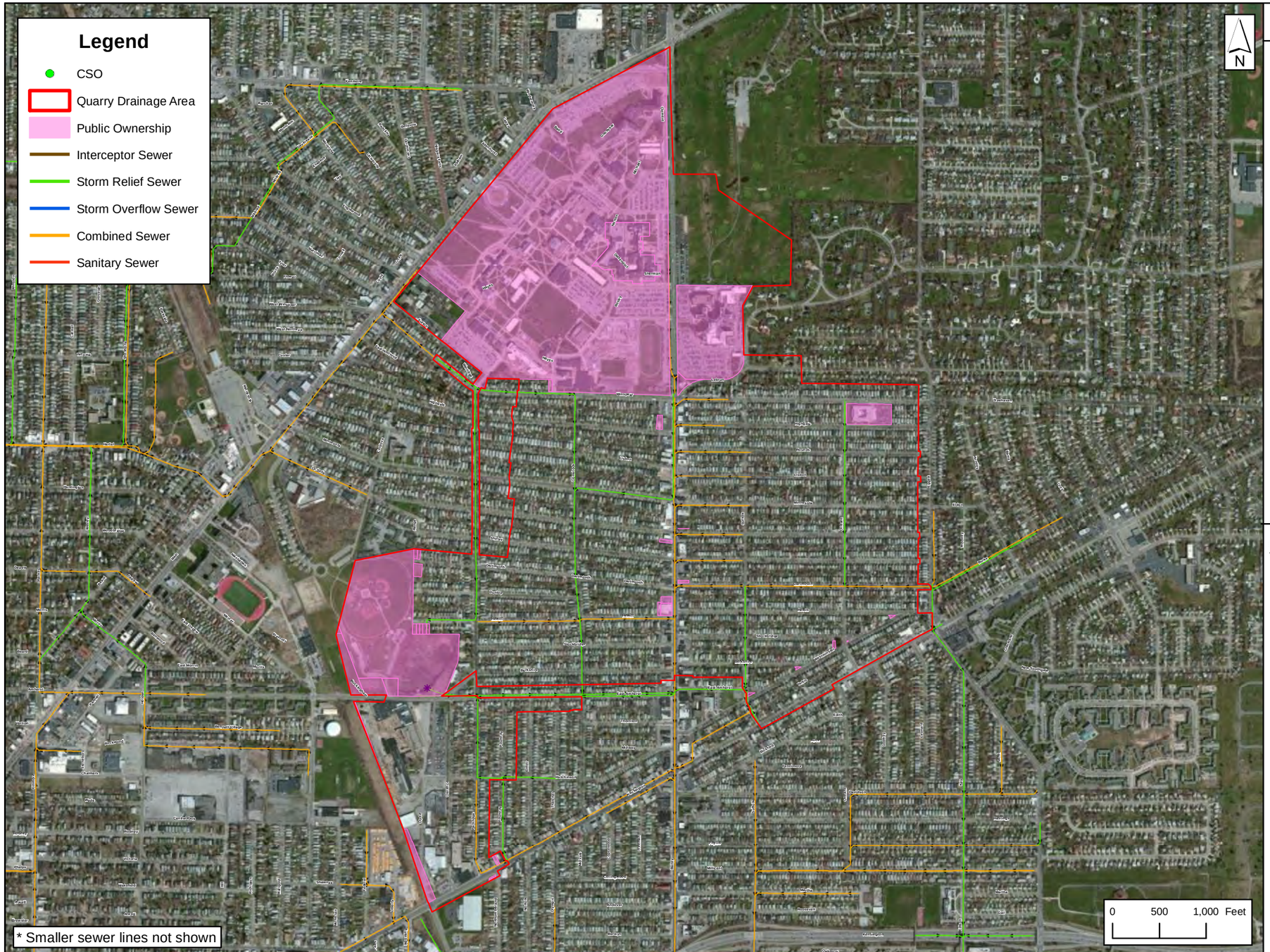
Green Infrastructure Opportunities Analysis

FIGURE 1
SOUTH CENTRAL DISTRICT
CSO-066



Quarry (659.9 acres)

Imperviousness: 55.2%

Total Impervious Area: 364.5 acres

Land Use:

Residential:	247.3 acres	37.8%
Community Service:	180.0 acres	27.5%
Transportation:	116.0 acres	17.7%
Vacant:	39.7 acres	6.1%
Conservation Areas / Parks:	26.0 acres	4.0%
Industrial:	22.3 acres	3.4%
Commercial:	16.6 acres	2.5%
Public Service:	4.3 acres	0.7%
Recreational:	2.0 acres	0.3%

Target Green Infrastructure Control:

20% = 72.9 acres

Green Infrastructure Opportunities

Streets and Right of Way:	**116.0 acres**
Public Parcels:	**208.2 acres**
Residential Roof Surfaces:	**74.2 acres**
Public Parcels (Vacant):	**33.3 acres**

Potential Green Infrastructure Technologies:

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Long Term Control Plan Update
Green Infrastructure Opportunities Analysis

FIGURE 1
SCAJAQUADA DISTRICT
QUARRY

Appendix 11-9: Potential Facility Layouts for HRT and Storage

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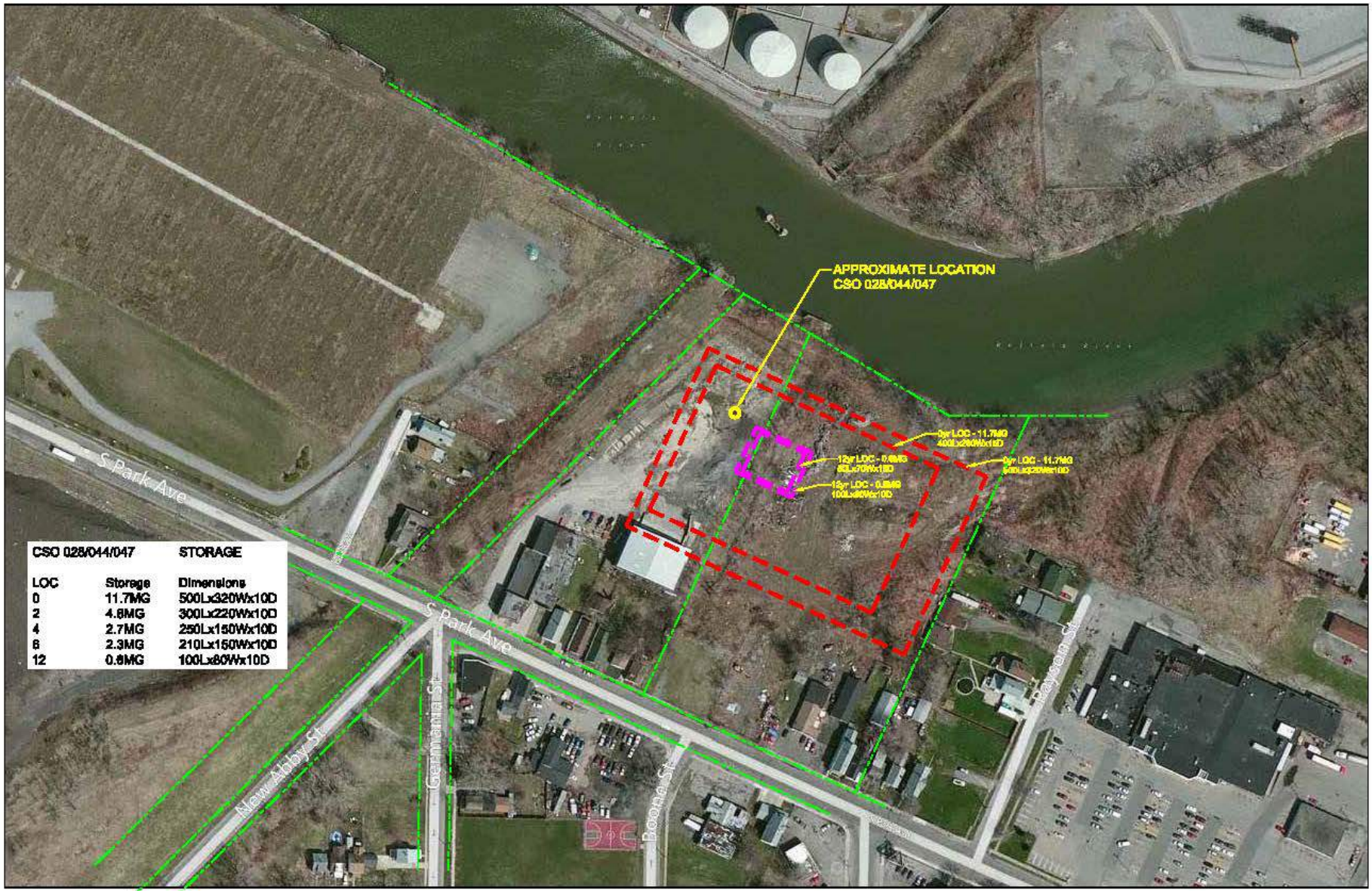

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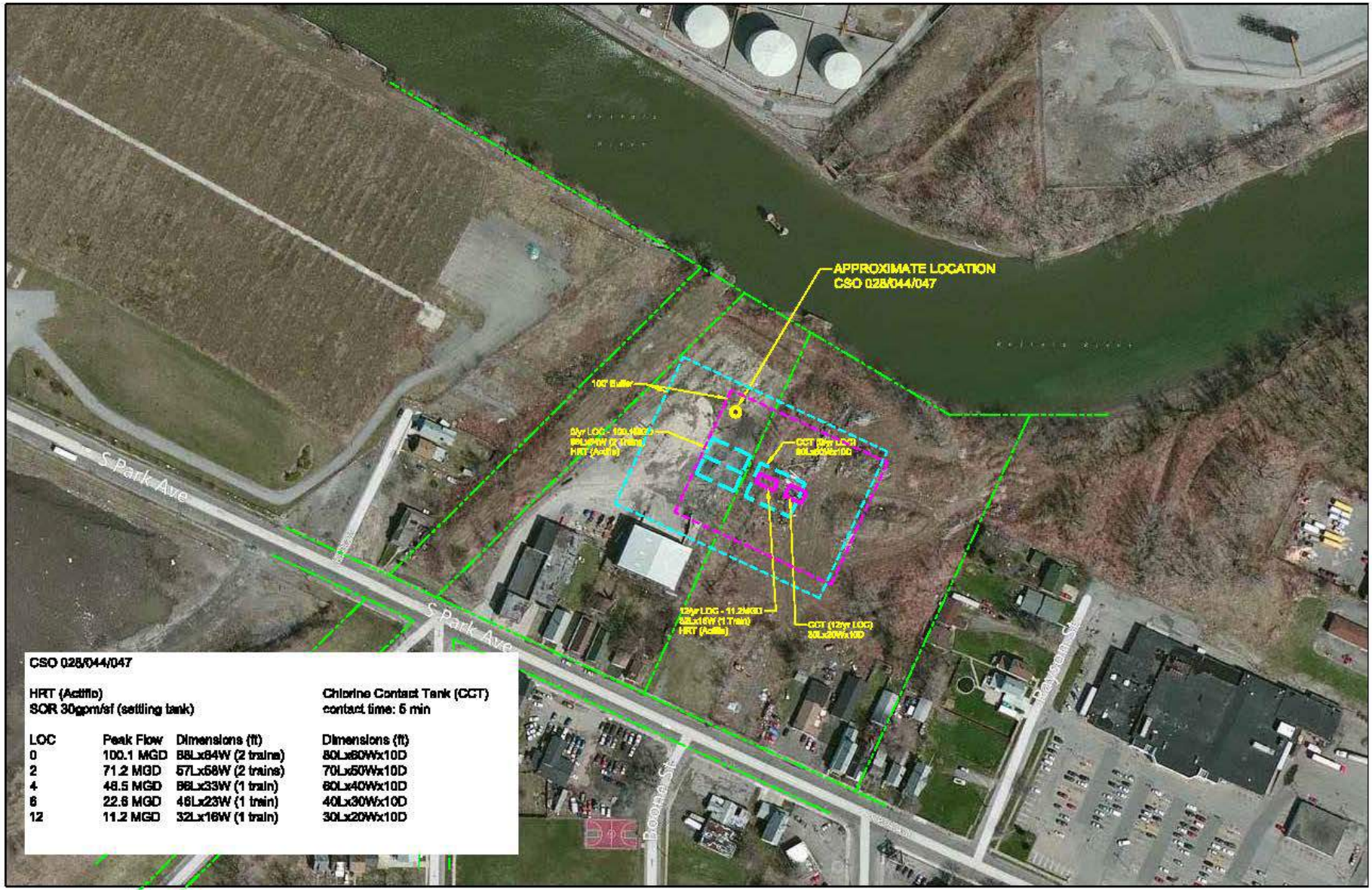
Long Term Control Plan Update

FIGURE 11-9A
POTENTIAL FACILITY FOOTPRINT
FOR STORAGE AT CSO 028/044/047



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Long Term Control Plan Update

FIGURE 11-9B
POTENTIAL FACILITY FOOTPRINT
FOR HRT AT CSO 028/044/047