City of Akron

Long Term Control Plan Review and Disinfection Investigations

Prepared for
City of Akron

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May, 2005

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Background

In 1994, the Ohio Environmental Protection Agency (Ohio EPA) required that the City of Akron develop the Nine Minimum Controls document, revised Facilities Plan and a Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP). The City developed a detailed and comprehensive program to evaluate and address CSOs, and submitted a LTCP to the Ohio EPA in 1998. The CSO LTCP was subsequently updated and then summarized in a report issued April 7, 2000, and revised September 5, 2000. Notably, the LTCP stresses the need for flexibility so that new technologies and past improvements can be evaluated.

Since the LTCP was published, several developments have occurred, which may have an effect on the LTCP. Some of these developments include:

- Several technologies, which were not economically or technically feasible five years ago, are becoming feasible now. The City has already pilot tested ACTIFLO and DensaDeg treatment systems. These pilot studies are summarized in Section 4.
- The CSO elimination market continues to mature. Thus, the recent experiences of other communities may help Akron decide how to proceed.
- Costs have changed since the plan was prepared. For example, the last several years have witnessed a considerable increase in the price of energy (e.g., natural gas, gasoline, etc.), concrete and steel. The plan should be updated to accommodate these price increases.

For all these reasons, the City determined to review its existing CSO LTCP.

Scope and Organization of this Study

The objective of this study is to review the existing LTCP in a general way, and to make specific recommendations for a strategy on where to concentrate future initiatives. As such, this Study did not include a detailed review of each individual Rack. Rather, this study focused on the overall LTCP objectives and general goals.

To accomplish this, this study was partitioned into three major deliverables:

- A disinfection report, which reviews the current state-of-the-practice for disinfecting CSOs
- A memo of recommendation, which recommends how Akron should proceed with disinfecting CSOs, based on the results of the state-of-the-practice report.
- This report, which summarizes the LTCP, reviews the costs, and makes specific recommendations on how to proceed with future initiatives.

This report includes the following Appendices:

- Appendix A – The Disinfection Report
- Appendix B – The Disinfection Recommendation Memo
- Appendix C – Cost Summary Update
- Appendix D – Executive Summary of ACTIFLO Pilot Project

- Appendix E – Executive Summary of DensaDeg Pilot Project

Akron's CSO LTCP Synopsis

The City of Akron's LTCP is very detailed and thorough, and complies with the requirements of the Ohio EPA CSO policy. The approach is intentionally flexible, so that the City can adjust the plan to accommodate future industry drivers, technologies and economies.

The LTCP consists of the following general components:

- Characterization of the combined sewer system
- Identification of sensitive areas
- Alternative identification and evaluation
- Implementation schedule
- Public participation

If implemented as originally recommended, the LTCP will result in significant reductions in pollutant discharges to the environment, as well as reductions in total volume of discharge. The existing LTCP predicts an overall average annual reduction in discharges of carbonaceous biological oxygen demand (CBOD) by 50%. Likewise, the LTCP also predicts a total system-wide average annual reduction in CSO volume by 94%. However, while the implementation of the LTCP will result in these significant reductions, ambient background concentrations of pollutants and microorganisms upstream of Akron's discharges could still cause impairment of water quality standards.

Costs

Five overall CSO LTCP alternatives were developed as part of the Akron Facilities Plan '98 that ranged from system-wide sewer separation to combinations of CSO control technologies that included detention basins, tunnels and sewer separation. Wet weather treatment improvements at the Akron WPCS and non-traditional improvements such as stream restoration and natural habitat setback areas were also considered as part of the alternatives.

The LTCP recommends Integrated Alternative #2. The CSO control technologies for this alternative focus on the construction of 2 tunnels, 11 detention basins (storage or treatment), and 7 CSO areas for sewer separation. The 1998 capital and O&M costs for these CSO control technologies were updated to 2005 costs using a combination of economic indexes and industry experience. The largest variation to the methodologies used for estimating the 1998 costs is related to tunnel construction. An independent review of the OCI and NSI Tunnel construction costs suggests that the OCI Tunnel costs may be overestimated by as much as 30-percent.

Table ES-1 summarizes the 1998 and 2005 costs for the CSO control technologies in Integrated Alternative #2 for the detention basins, tunnels and sewer separation. Costs for plant improvements and stream enhancement projects are not included within Table ES-1.

Table ES-1*
Summary of 1998 and Update to 1998 (2005) Total Costs

CSO Control Technologies	Summary of 1998 Costs (in 1998 $)			Summary of Update to 1998 Costs (in 2005 $)		
	1998 Capital Cost	1998 Annual O&M Cost	20 Year Total PW (2018)	2005 Capital Cost	2005 Annual O&M Cost	20 Year Total PW (2025)
Detention Basins, Tunnels and Sewer Separation	$174,856,131	$1,365,955	$188,354,700	$201,259,151	$1,729,127	$214,480,700

*The Present Worth (PW) evaluation assumes all capital costs will be made in "year one".

Disinfection

The City of Akron's CSO LTCP recommended 11 detention basins as part of Integrated Alternative #2. Of these 11 basins, 5 were identified as treatment basins and 6 as storage basins. The CSO LTCP indicates that disinfection facilities were considered for the treatment basins, however they were not considered for the storage basins.

Currently, the City of Akron is considering the addition of disinfection at storage basins for the peak flow received at each respective storage basin under the typical year rainfall. Included with this Study, a CSO Disinfection Report was developed to examine disinfectant alternatives for CSOs. In summary, the following recommendations were made in the CSO Disinfection Report:

- Sodium hypochlorite, chlorine dioxide, bromine and UV are the most viable disinfection alternatives of those reviewed for CSO applications.
- Numerous studies and full-scale facilities have demonstrated that chemical disinfection of CSOs can be accomplished using high-rate disinfection. High-rate disinfection is defined as employing high-intensity mixing to accomplish disinfection within a short contact time, generally five minutes.
- High-rate disinfection with sodium hypochlorite followed by dechlorination is the most cost effective method to disinfect CSOs when considering total life-cycle costs.
- The data for chlorine dioxide shows that it is a more effective disinfectant than sodium hypochlorite. However, chlorine dioxide needs to be generated on site because it is too unstable even for short periods of time. Operating a chlorine dioxide generator at a remote satellite CSO facility for intermittent flows would be difficult given the currently available systems. In addition, chlorine dioxide, as with chlorine, can produce byproducts of concern. The advantage of using chlorine dioxide is that it is a rapid disinfectant with superior viricidal properties. Chlorine dioxide does not react with the ammonia and does not produce THMs. Several manufactures are currently working on new technologies to produce chlorine dioxide. Technologies may become available in the future that provides an easier and safer way to produce chlorine dioxide at a remote CSO locations.
- Bromine may also be a better disinfectant than sodium hypochlorite. However, at this time there is only one known CSO disinfection facility using bromine in the United States. Consequently, a pilot study should be considered to address effectiveness, byproduct formation, associated toxicity and operability at remote CSO locations before it is used for such an application.
- UV, another alternative to sodium hypochlorite for CSO disinfection, has been shown to be a more effective disinfectant than sodium hypochlorite. However it is significantly more expensive

than sodium hypochlorite and in addition would require more preliminary treatment. The other major advantage of UV is that it produces no residuals or disinfection byproducts.

Recommendations

This entire report makes the following specific recommendations:

1. To accommodate future changes in project drivers, technologies and economies, keep the CSO LTCP flexible in terms of preliminary engineering and site-specific installation details.

2. Evaluate LTCP every five years, and update it, if appropriate.

3. Proceed with implementing the LTCP, after Ohio EPA approval of the plan.

4. Re-evaluate each design of each rack at the preliminary design stage to make certain that the particular installation details comply with both the overall LTCP and site-specific constraints. Include in this evaluation, whether it is best to store, treat or convey the flows to the WPCS.

5. Continue to allocate funds to pilot new technologies, including the disinfection alternative for bromochlorodimethylhydantoin (BCDMH).

6. Before implementing solutions at any given rack, monitor the development and costs of other CSO technologies, including vortex separation, compressed media filters, ultraviolet disinfection, DensaDeg, ACTIFLO, etc.

7. Consider extending or expanding the tunnels to provide more storage and/or elimination of racks.

8. If disinfection is provided at storage facilities, include screening for removal of floatables at these storage facilities.

SECTION 1

LONG-TERM CONTROL PLAN SYNOPSIS

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LONG-TERM CONTROL PLAN SYNOPSIS

1.1 Background

The City of Akron, Ohio provides sewage to approximately 183 square miles of the metropolitan Akron area. This area serves about 350,000 people, and includes all or parts of five cities, four villages, and seven townships.

Sewage from about 94 square miles of this area is treated at the Akron Water Pollution Control Station (WPCS), which is located at 2460 Peninsula Road in Akron. The Akron WPCS is a single-stage nitrification, activated sludge treatment facility with an average design flow of approximately 90-milliongallons per day (mgd). The effluent is discharged to the Cuyahoga River south of Bath Road. Primary and waste activated sludges are individually thickened before they are blended and pumped to the Akron Composting Facility (ACF). The ACF is located opposite the Akron WPCS on the west bank of the Cuyahoga River.

Dry weather flows are treated at the wastewater treatment facilities. During wet weather events, excessive flows from the combined sewer system overflow to local waterways. The City of Akron is actively engaged in an ambitious and complex program to mitigate the effects of these Combined Sewer Overflows (CSOs). The City of Akron's CSO collection system includes approximately thirty-six locations where CSOs can discharge excessive flows during wet weather events. In Akron, most of these locations include a rack to screen or divert flow. Thus, most of these locations are known as "Racks."

1.2 The Combined Sewer Overflow Long-Term Control Plan

The Ohio EPA mandated that the City of Akron develop a plan to mitigate CSOs as part of the Director's Final Findings and Orders (DFFOs) for Ohio EPA Permit Number 3PF00000*FD, which became effective September 20, 1994 (specifically the 1994 DFFOs), require that Akron must prepare a revised Facilities Plan (Facilities Plan '98) and a CSO long-term control plan (Long Term Control Plan '98).

The City of Akron updated the 1980 Facilities Plan, and submitted the new Facilities Plan '98 to Ohio EPA for review. Likewise, the City of Akron submitted Long Term Control Plan '98 to Ohio EPA for review as well. The Long-Term Control Plan '98 has been adjusted since its original submission, to update costs and to re-evaluate newer technologies. The Long Term Control Plan '98 was developed as a comprehensive CSO control plan that recognizes the site-specific nature of CSOs and the impacts on receiving water bodies, and includes water quality based control measures that are technically feasible, affordable, and consistent with the USEPA CSO Control Policy.

The Long-Term Control Plan '98 was summarized in a document dated April 7, 2000, and revised September 5, 2000. That summary primarily addressed the following nine aspects of the LTCP:

- Characterization, monitoring, and modeling;
- Public participation;
- Consideration of sensitive areas;
- Evaluation of alternatives;
- Cost/performance considerations;

- Operational plan;
- Maximization of treatment at the water pollution control station;
- Implementation schedule; and
- Post-construction compliance monitoring program.

1.3 The CSO LTCP Data Collection and Models

The City of Akron hired a team of consultants to develop the CSO LTCP. This team provided detailed investigations of the City's sewer collection system, wastewater plants, and receiving waters. Further, extensive rainfall and flow data were gathered, organized, analyzed and modeled, to determine how the entire system performs hydraulically. The XP-SWMM model was used to model dry weather flow, infiltration, inflow and surface runoff. The USEPA WASP model was used for the receiving stream model. The hydrodynamic output from the XP-SWMM TRANSPORT module was directly linked to the USEPA WASP model, for water quality analyses. The results of these models were calibrated against field data.

Approximately forty years of precipitation data were analyzed statistically. The results indicated that 1994 represented a typical year for rainfall. Thus, the precipitation pattern from 1994 was used in subsequent model analyses for a "typical year."

The WASP model accounts for bacteria and the dissolved oxygen (DO) in response to multiple parameters. It predicted time-varying bacteria and DO in the Cuyahoga River, the Little Cuyahoga River and the Ohio Canal. The model was run for two events: for a significant single-event, and for the six-month recreational period of a typical year.

The WASP results of the single-event simulation, which corresponded to a 0.91-inch rainfall event over a 22-hour period (approximately equivalent to a one-month design storm), indicated the following:

- The Ohio Canal does not experience a local DO drop under this simulation.
- The Little Cuyahoga River downstream of the Ohio Canal is affected directly by the Ohio Canal CBOD5 load.
- The Cuyahoga River has a long continuous reach of relatively depressed DO from the confluence with the Little Cuyahoga River downstream to the Akron WPCS. The downstream portion of the Ohio Canal has fecal coliform levels elevated above ambient conditions for the longest periods of time in the system (System-wide, fecal coliform levels remained elevated above ambient conditions for at least 17 hours and up to 96 hours in all model reaches).
- All modeled reaches of the Cuyahoga River in the CSO area upstream of the confluence with the Little Cuyahoga River show fecal coliform concentrations remain elevated above ambient conditions for a relatively long period. The occurrence of the long-duration elevated concentrations extends upstream of the Northside Interceptor CSOs, thus implicating boundary conditions and non-point sources.

The WASP results of the six-month recreational period of a typical year indicated the following:

- Model-predicted DO is never below the 5.0 milligrams per liter water quality standard in any of the receiving waters. Although, it is noted that the model does not account for diurnal variations due to photosynthesis and respiration, which could depress the average DO values into a limited number of periods of noncompliance.

- Modeling of the Cuyahoga River within and downstream of the CSO area predicts difficulties in achieving compliance with the bacteriological standard for five to six months of the six-month recreational period simulated.
- Modeling of the Little Cuyahoga River within the CSO area predicts difficulties in achieving compliance with the bacteriological standard for five months of the six-month recreational period simulated.
- Modeling of the Ohio Canal within the CSO area predicts difficulties in achieving compliance with the bacteriological standard for six months of the six-month recreational period simulated.

The bacteria data collected suggest that consistently achieving compliance with bacteria standards in the receiving waters near the discharges from Akron's system may be impossible, due to background populations of bacteria from upstream sources. Table 1-2 summarizes these findings.

Table 1-1
Months of Non-Compliance for Bacteria Upstream of Akron CSOs,
Due to Excessive Background Bacteria Populations Pre-Existing in the Receiving Waters

Receiving Water	Location	Number of Months Out of the Six-Month Recreation Season Where Background Bacteria Populations Exceed Bacteria Standards
Cuyahoga River	Near Cuyahoga Falls Sheraton Suites	Six months out of six months
Little Cuyahoga River	Near Skelton Road	Three months out of six months
Ohio Canal	Near Ohio Department of Natural Resources Station	Five months out of six months

The LTCP analyzed the entire receiving water system, to determine which are considered sensitive areas, in compliance with the CSO Control Policy. The LTCP Summary (September 2000) identified the following receiving waters as sensitive areas:

- Portions of the Cuyahoga River
- Gorge and Cascade Valley Metropolitan Parks
- Cuyahoga Valley National Recreation Area
- Ohio and Erie Canal National Heritage Corridor
- Cuyahoga American Heritage River

1.4 Identification and Evaluation of LTCP Alternatives

Once the data were gathered and modeled, the City evaluated different approaches to their CSO LTCP. The CSO Control Policy allows for two approaches for CSO control: the presumptive approach and the demonstrative approach. The City's CSO LTCP is based upon "benefit effective" control levels that meet the presumptive approach. The background bacteria populations in the receiving waters seem too high to allow Akron to demonstrate consistent attainment of bacteria water quality standards.

A variety of collection system alternatives were analyzed. For the collection system, there are three fundamental alternatives for storage and treatment:

- Deep tunnels, to capture CSO discharges

- Storage basins, designed to store CSOs up to a selected design storm event
- Treatment basins, designed to treat CSOs up to a selected design storm event

The LTCP considered two floatable control alternatives for the collection system: vortex separators and netting systems.

The LTCP considered three collection system controls:

- Complete or partial separation of combined sewers
- Express sewers to convey primarily sanitary flows away from the CSO system
- Regulator modifications to improve performance

The LTCP also considered non-traditional alternatives, such as:

- Instituting mandatory setbacks from all receiving waters
- Stream restoration and channel repairs
- Re-aeration structures to improve DO in the receiving streams

To determine if storage or treatment was the preferred alternative, a knee-of-the-curve analysis was performed for every Rack. This knee-of-the-curve analysis is intended to select the most cost-effective method of addressing CSOs at each Rack. These are the steps taken for the knee-of-the-curve analysis for each Rack:

1. The hydraulic model was run under existing conditions for a variety of design storm events; for a one-month storm, a two-month storm, a three-month storm and a five-month storm. The results of these model runs were used to determine the respective CSO volumes to be captured or treated.

2. Given the CSO volumes determined under Step 1, storage and treatment basins were sized for each storm event and then incorporated into the model. Separate model runs were then conducted under the Typical Year rainfall and with the respective storage and treatment basins. These model runs predicted the effects of the respective storage and treatment basins under the Typical Year rainfall on three design parameters: the number of CSO events, the number of hours that the CSO would be activated, and the effect of Carbonaceous Biological Oxygen Demand (CBOD) on the receiving water.

3. The design storm was plotted on the abscissa (horizontal x-axis) and the results of the design parameter were plotted on the ordinate (vertical y-axis) for both storage and treatment alternatives. Three separate graphs for each rack were thus developed: one for Number of CSO activations, one for the duration of the CSO events, and one for CBOD. Each one of the three graphs had two curves: one curve for treatment and one curve for storage. See Figure 1-2 for an example used for the CBOD analysis for Rack 12. Note that Figure 1-2 in this document is the same as Figure 13.2 in the original LTCP.

4. For each graph, the inflection point for each of the two curves was identified. Since there are two curves per graph, there are two inflection points ("knee-of-curve" points). A horizontal line was drawn through each inflection point, and intersected with the ordinate (vertical y-axis). The value that corresponded to the intersection was the value for the minimum performance standard for that technology. One value represented the minimum performance standard for treatment, and the other value represented the minimum performance standard for storage. See Figure 1-3 for an example of

determining the minimum performance standards for Rack 12 for the CBOD design parameter. Note that Figure 1-3 of this document is the same as Figure 13.4 of the original LTCP.

5. The minimum performance standard for the treatment technology was compared against the minimum standard for the storage technology. Whichever of these two standards was less (i.e., resulted in a more stringent requirement) was chosen as the overall minimum performance standard. For an example, see Figure 1-4, which shows how the minimum performance standard was selected for Rack 12 for the design parameter of CBOD. Note that Figure 1-4 of this document is the same as Figure 13.5 of the original LTCP.

6. For each Rack, the minimum performance standard for each of the three design parameters (i.e., CBOD, number of activations, and hours of activation) was compared against treatment and storage

FIGURE 1-1
Rack 12 CBOD Level of Control Curve
(Based on System Model Simulations for Precipitation Year 1994.)

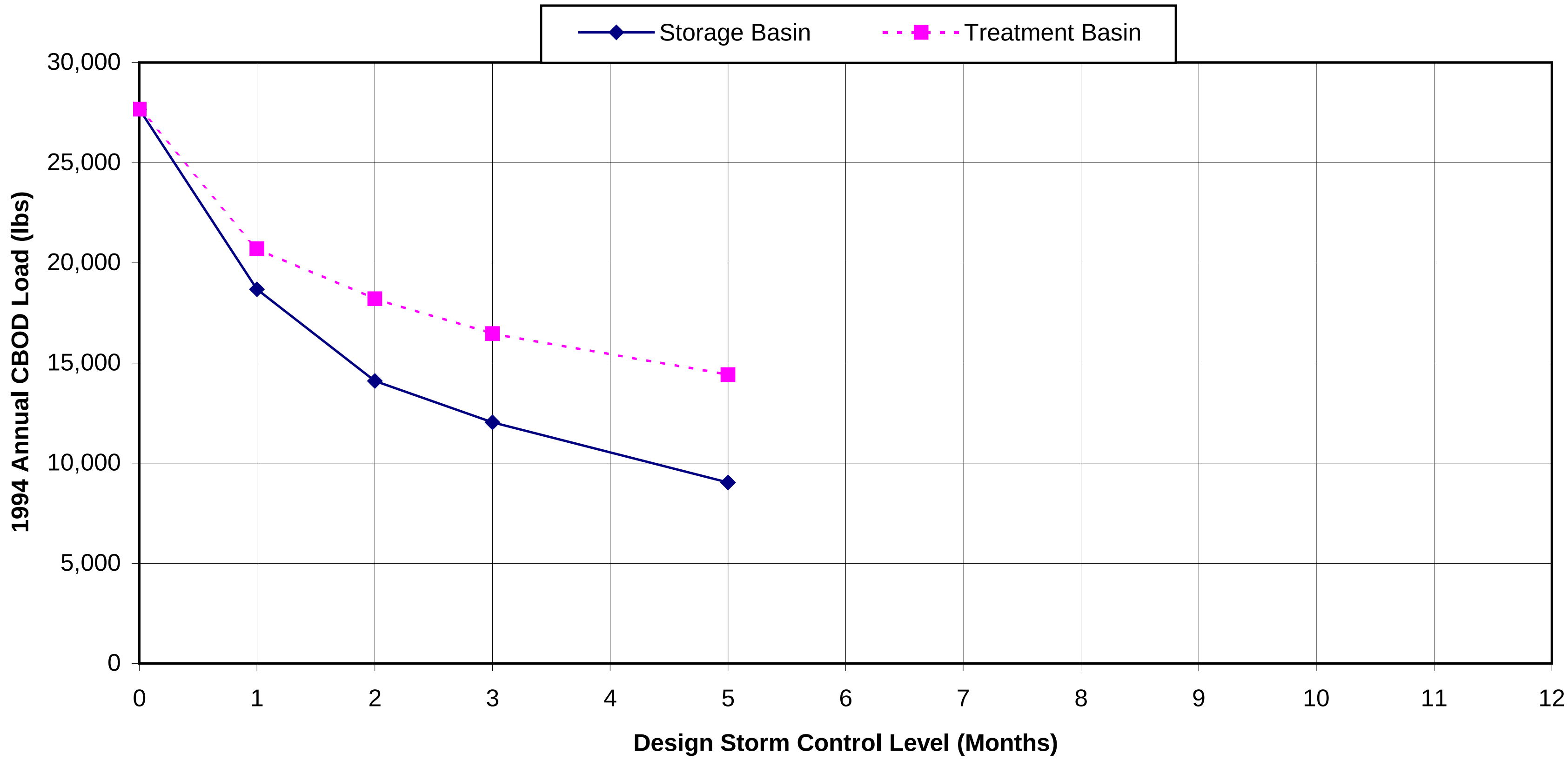


FIGURE 1-2
Identifying Knee-of-the-Curve for CBOD Reduction at Rack 12

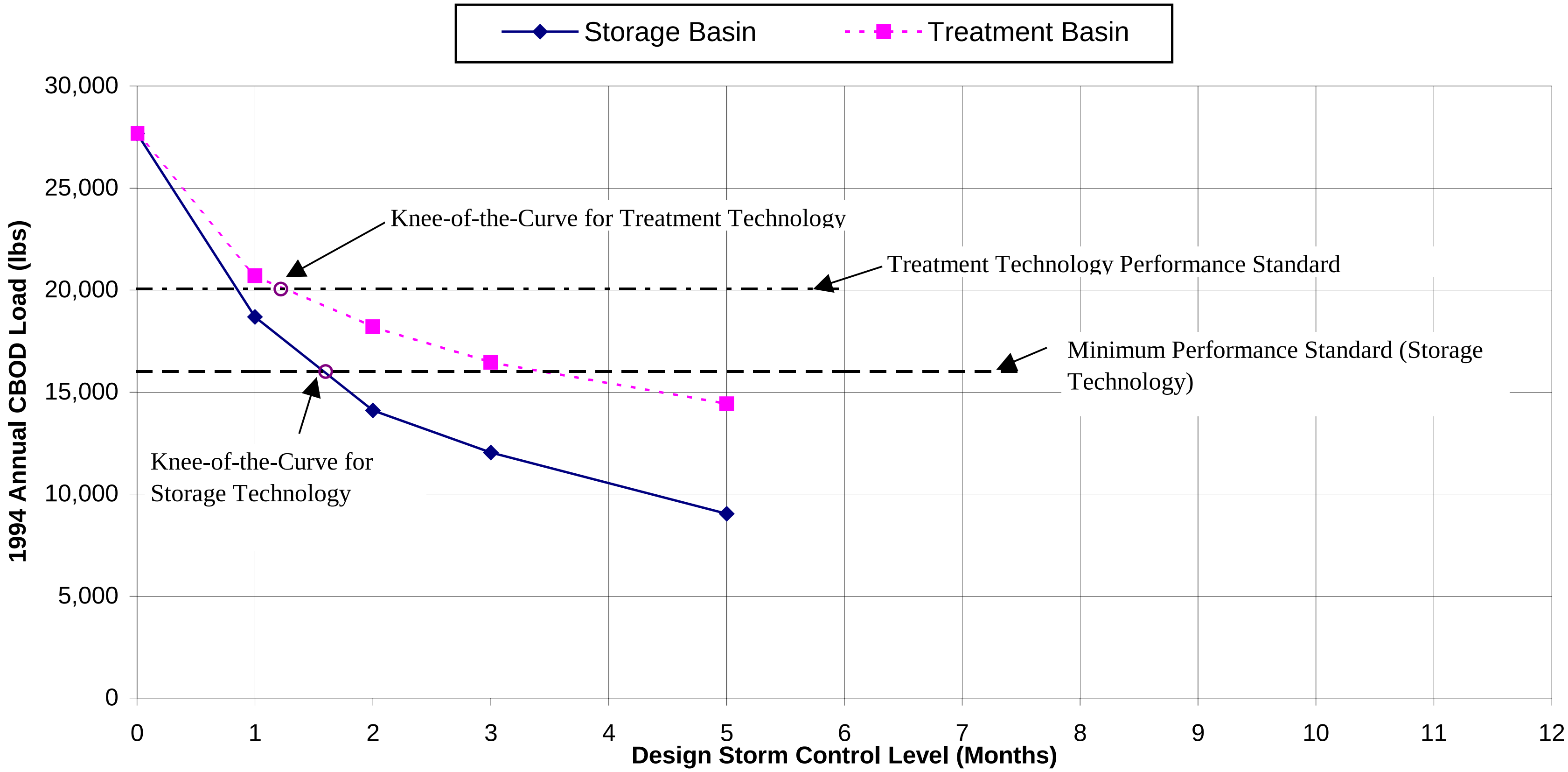
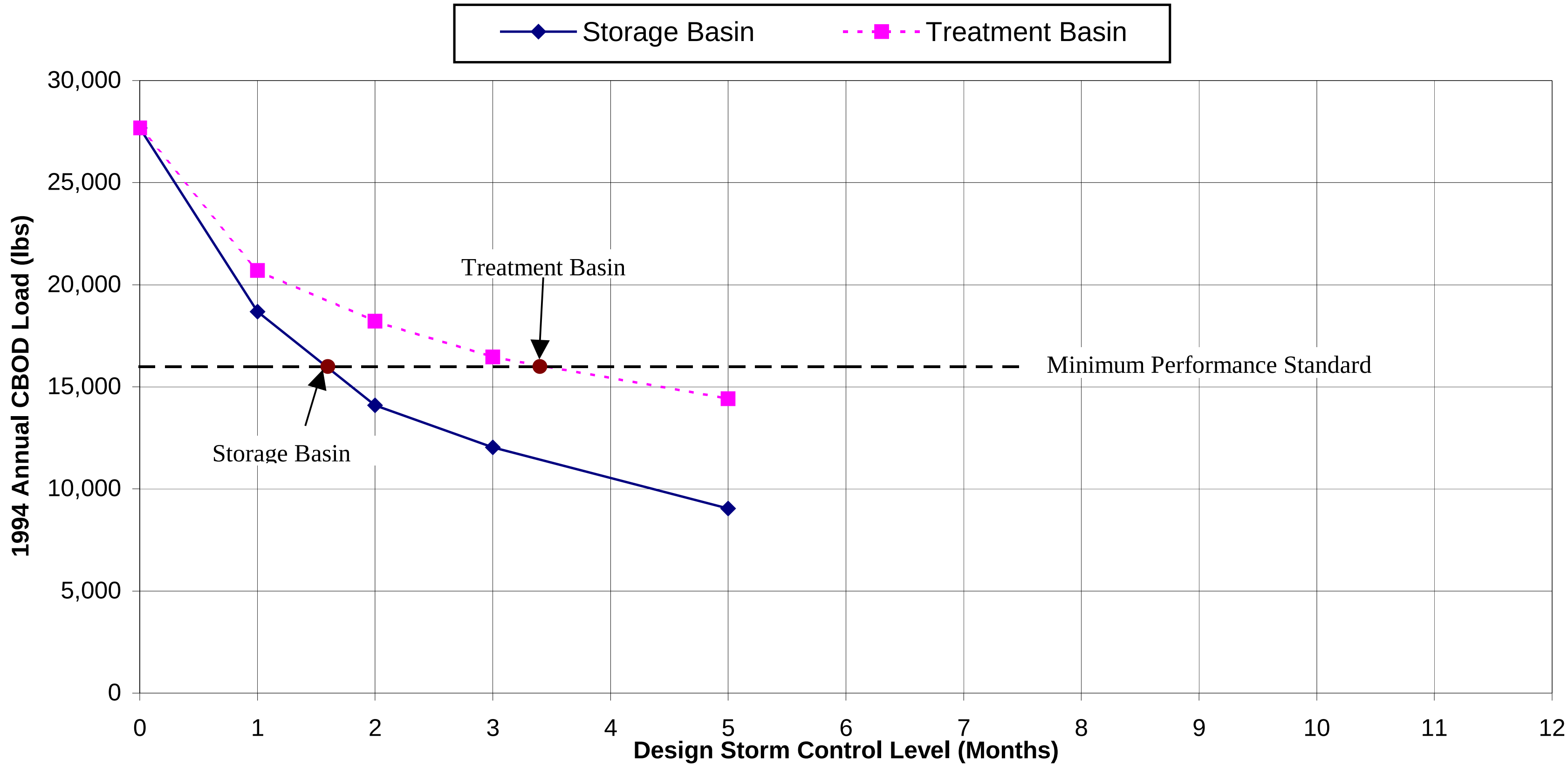


FIGURE 1-3
Rack 12 CBOD Level of Control Curve.
Options to Meet Minimum Performance Standard



technologies. For a given technology (i.e., either treatment or storage), the performance standard that resulted in the most overall restrictive standard was chosen for that Rack as being the option to be priced. For example, for Rack 12, the following Table 1-3 shows the minimum performance standard for all three design parameters, when compared to treatment and storage technologies. Note that Table 1-3 of this document is the same as Table 13.7 of the original LTCP.

Table 1-2
Six Potential Control Options at Rack 12

Design Parameter	Storage Technology to Meet Minimum Performance Standard (Design Storm Control Level)	Treatment Technology to Meet Minimum Performance Standard (Design Storm Control Level)
CBOD	1.5-month	**3.4-month**
Number of Events	2-month	3-month
Number of Hours	**5.2-month**	2-month

7. For each technology (i.e., treatment or storage), a cost estimate was developed. The alternative that provided the most restrictive performance standard and concurrently provided the lowest overall cost based on a 20-year present worth analysis was selected as the recommended alternative. For a given technology (i.e., treatment or storage), the costs of the alternative for the three design parameters (i.e., CBOD, number of activations, and hours of events) were compared. The highest cost for each given technology was selected. This resulted in two costs: one for the treatment alternative and one for the storage alternative. These two costs were compared against each other, and the lower cost was selected as the preferred alternative. Table 1-4 summarizes the results of this analysis.

Table 1-3
Summary of Original 1998 Cost Analyses for Akron Racks

Rack #	CBOD Present Worth ($)	EVENTS Present Worth ($)	HOURS Present Worth ($)	Technology Selection	Parameter Control	Design Storm (Months)	Present Worth ($)
3							
Storage	$ 2,019,200	$ 2,063,200	$ 2,975,700				
Treatment	$ 2,856,800	$ 2,969,800	$ 2,698,300	Treatment	EVENTS	3	$ 2,969,800
4							
Storage	$ 1,442,700	$ 1,471,400	$ 2,291,300				
Treatment	$ 2,069,600	$ 2,067,000	$ 2,019,700	Treatment	CBOD	2.6	$ 2,069,600
5+7							
Storage	$ 1,938,500	$ 1,941,200	$ 1,941,200	Storage	EVENTS/HOURS	2.4	$ 1,941,200
Treatment	$ 2,518,600	$ 2,647,900	$ 2,423,000				
10+11							
Storage	$ 3,828,700	$ 3,983,900	$ 5,436,800				
Treatment	$ 4,664,100	$ 4,990,800	$ 4,281,200	Treatment	EVENTS	3.7	$ 4,990,800
12							
Storage	$ 2,896,000	$ 3,368,000	$ 5,207,300				
Treatment	$ 5,074,700	$ 4,869,100	$ 4,265,400	Treatment	CBOD	3.4	$ 5,074,700
14							
Storage	$ 1,836,600	$ 1,953,700	$ 2,512,800	Storage	HOURS	3.4	$ 2,512,800
Treatment	$ 3,409,600	$ 2,556,000	$ 2,235,800				
15							
Storage	$ 1,646,200	$ 1,757,600	$ 2,090,800	Storage	HOURS	3	$ 2,090,800
Treatment	$ 2,944,900	$ 2,638,800	$ 2,218,900				
16+17							
Storage	$ 8,660,100	$ 10,305,200	$ 37,587,700				
Treatment	$ 14,934,500	$ 12,412,200	$ 8,892,000	Treatment	CBOD	8	$ 14,934,500
18+19							
Storage	$ 9,164,200	$ 11,348,900	$ 50,368,500				
Treatment	$ 16,344,300	$ 13,303,300	$ 8,280,100	Treatment	CBOD	8.3	$ 16,344,300
20							
Storage	$ 1,158,900	$ 1,170,000	$ 1,271,100	Storage	HOURS	3	$ 1,271,100
Treatment	$ 1,915,000	$ 1,719,100	$ 1,468,400				
22							
Storage	$ 1,413,200	$ 1,658,200	$ 1,742,000	Storage	HOURS	3	$ 1,742,000
Treatment	$ 2,073,000	$ 2,801,300	$ 3,416,800				
24							
Storage	$ 1,854,400	$ 1,931,100	$ 2,919,100	Storage	HOURS	5	$ 2,919,100
Treatment	$ 3,537,300	$ 2,966,600	$ 2,406,500				
26+28							
Storage	$ 2,837,200	$ 2,851,500					
Treatment	$ 4,532,800	$ 3,954,800	$ 3,368,900	Treatment	CBOD	9.6	$ 4,532,800
27+29							
Storage	$ 2,268,900	$ 2,243,400					
Treatment	$ 3,251,700	$ 3,057,500	$ 3,674,200	Treatment	HOURS	1.5	$ 3,674,200
32							
Storage	$ 2,098,000	$ 1,997,200	$ 2,722,800	Storage	HOURS	5	$ 2,722,800
Treatment	$ 3,581,300	$ 2,888,300	$ 2,580,500				
33							
Storage	$ 863,100	$ 935,700	$ 1,156,300	Storage	HOURS	8.6	$ 1,156,300
Treatment	$ 1,505,800	$ 1,182,000	$ 1,089,100				
34							
Storage	$ 1,191,700	$ 1,115,400	$ 1,400,900	Storage	HOURS	5	$ 1,400,900
Treatment	$ 1,837,100	$ 1,691,300	$ 1,423,500				
35							
Storage	$ 3,279,100	$ 3,482,700	$ 3,326,800	Storage	EVENTS	1.6	$ 3,482,700
Treatment	$ 5,704,600	$ 3,855,300	$ 3,935,200				
36							
Storage	$ 1,304,600	$ 1,193,800	$ 1,287,300	Storage	CBOD	2	$ 1,304,600
Treatment	$ 2,244,800	$ 1,892,700	$ 1,779,400				
40+31							
Storage	$ 13,471,200	$ 16,060,300		Storage	EVENTS	1.4	$ 16,060,300
Treatment		$ 11,488,600	$ 9,946,000				
							$ 93,195,300

Similarly, numerous WPCS improvement alternatives were analyzed. These included:

- Additional retention / storage at the WPCS
- Septage receiving station
- Tertiary treatment
- Effluent pumping
- Disinfection improvements
- Post aeration of the effluent

Improvements at the WPCS might reduce or eliminate collection system improvements. For example, providing more retention / storage at the WPCS might reduce the need to provide additional storage in the collection system. The ideal solution would be to combine the best WPCS and collection system improvements into one, ultimate, integrated plan. Also, the installation of tunnels would provide a cost-effective method of conveying the flows to the WPCS for treatment, as well as eliminate basins in difficult construction areas.. To do this, Akron developed five ultimate integrated plan alternatives. Each ultimate integrated plan alternative included different combinations of improvements to the WPCS and collection system. Akron then generated the capital cost for each ultimate integrated plan alternative. Capital costs for the five ultimate integrated plan alternatives varied between $1,072 M to $163 M.

However, the final decision was not based exclusively on the capital cost alone. Each ultimate integrated plan alternative was also evaluated on the following parameters:

- Storm water impacts
- Water quality improvements
- Operation and maintenance
- Costs
- Public acceptance
- Community improvements
- Construction issues

Using a computerized statistical method called Multiple Attribute Analysis Technique, all five ultimate integrated plan alternatives were evaluated on the above parameters. In addition to sewer system improvements, all five alternatives included WPCS disinfection improvements, WPCS post-aeration, Little Cuyahoga River stream restoration, and Cuyahoga River re-aeration. These five alternatives are summarized below:

- System-wide sewer separation
- Install the Ohio Canal Interceptor (OCI), the Northside Interceptor (NSI), and eleven detention basins, plus separate sewers in seven CSO areas
- Install the OCI, fifteen detention basins and separate seven CSO areas
- Install the NSI, eighteen detention basins, and separate nine CSO areas
- Install 22 detention basins and separate nine CSO areas

Integrated Alternative #2 was deemed to be the most acceptable overall. At the time this analysis was done (in year 1998), ultimate integrated alternative number 2 had the second highest capital cost. The capital cost for ultimate integrated plan number 2 was estimated to be $247.4 M. The major features of ultimate integrated plan number 2 are summarized in the following Table 1-5. Note that Table 1-5 of this document is the same as Table 4-1 of the September 2000 Long Term Control Plan Summary.

Table 1-4
Ultimate Integrated Plan No. 2 Major Components

Item	Description	Comments
Rack 2-N	N/A	No overflow in 1994 precipitation year*
Rack 2-S	N/A	No overflow in 1994 precipitation year*
Rack 3	Treatment Basin	
Rack 4	OCI Tunnel	
Rack 5	Storage Basin	Combined with Rack 7
Rack 6	N/A	No overflow in 1994 precipitation year*
Rack 7	Storage Basin	Combined with Rack 5
Rack 8	Separation	
Rack 9	Separation	
Rack 10	Treatment Basin	Combined with Rack 11
Rack 11	Treatment Basin	Combined with Rack 10
Rack 12	Treatment Basin	
Rack 13	Separation	
Rack 14	Storage Basin	
Rack 15	Storage Basin	
Rack 16	OCI Tunnel	
Div. Ch./Rack 17	OCI Tunnel	
Rack 18	OCI Tunnel	
Rack 19	OCI Tunnel	
Rack 20	OCI Tunnel	
Rack 21	Separation	Area along East Market Street to OCI Tunnel
Rack 22	Storage Basin	75 Acres to be Separated
Rack 23	OCI Tunnel	
Rack 24	OCI Tunnel	
Rack 25	Separation	
Rack 26	Treatment Basin	Combined with Rack 28
Rack 27	Treatment Basin	Combined with Rack 29
Rack 28	Treatment Basin	Combined with Rack 26
Rack 29	Treatment Basin	Combined with Rack 27
Rack 30	Separation	
Rack 31	Storage Basin	Combined with Rack 40
Rack 32	NSI Tunnel	
Rack 33	NSI Tunnel	
Rack 34	NSI Tunnel	
Rack 35	NSI Tunnel	
Rack 36	Storage Basin	
Rack 37	OCI Tunnel	
Rack 39	Separation	
Rack 40	Storage Basin	Combined with Rack 31
WPCS	Additional Retention	
WPCS	Disinfection Improvements	
WPCS	Post-Aeration Facilities	
Other	Non-Traditional	

1.5 Schedules for the Long Term Control Plan

The LTCP anticipated completing the work over a 35-year period. The $247.4 M program was arranged into seven groups of five years each. The LTCP anticipated beginning work in year 2000 and ending work in year 2035. The following table summarizes the costs and schedule for the improvements. Note that Table 1-6 in this document is the same as Table 5-1 in the 2000 LTCP.

Table 1-5
Program Schedule

Project Grouping	Capital Cost	Accumulative Capital Cost
2000-2005		
Separation 39	$300,000	
Separation 9	$210,900	$510,900
Rack 40/31 Storage	$13,421,300	$13,932,200
Rack 26/28 Treatment	$2,561,600	$16,493,800
Separation 21/22 (partial)		
2006-2010		
WPCS Storage Phase I (20 Mgal)	$25,450,000	$41,943,800
Misc. Separations	$200,000	$42,143,800
CR Re-Aeration Pilot Study	$750,000	$42,893,800
2011-2015		
Ohio Canal Tunnel	$93,446,100	$136,339,900
LCR Restoration	$8,103,600	$144,443,500
2016-2020		
WPCS Storage Phase II (20 Mgal)	$25,450,000	$169,893,500
WPCS Disinfection	$12,600,000	$182,493,500
Rack 14 Storage	$1,984,800	$184,478,300
Rack 15 Storage	$1,651,200	$186,129,500
Rack 3 Treatment	$1,700,100	$187,829,600
Rack 12 Treatment	$2,201,400	$190,031,000
2021-2025		
Northside Tunnel	$28,371,900	$218,402,900
2026-2030		
Rack 8 Separation	$2,326,400	$220,729,300
Rack 30 Separation	$7,574,000	$228,303,300
Rack 36 Storage	$992,800	$229,296,100
Rack 10/11 Treatment	$3,723,600	$233,019,700
2031-2035		
Rack 5/7 Storage	$1,672,800	$234,692,500
Rack 22 Storage	$1,283,000	$235,975,500
Rack 25 Separation	$2,974,500	$238,950,000
Rack 13 Separation	$4,328,200	$243,278,200
Rack 21 Separation	$2,199,500	$245,477,700
Rack 29/27 Treatment	$1,934,100	$247,411,800
Total Capital Cost	**$247,411,800**	

Note: Costs shown are the original 1998 costs.

1.6 Overall Reductions in CBOD and CSO Volumes

If implemented as originally recommended, the LTCP will result in significant reductions in pollutant discharges to the environment, as well as reductions in total volume of discharge. The existing LTCP predicts an overall average annual reduction in discharges of carbonaceous biological oxygen demand (CBOD) by 50%. Likewise, the LTCP also predicts a total system-wide average annual reduction in CSO volume by 94%. However, while the implementation of the LTCP will result in these significant reductions, ambient background concentrations of pollutants and microorganisms upstream of Akron's discharges could still cause impairment of water quality standards.

SECTION 2

UPDATE OF 1998 LTCP COSTS

SECTION 2
UPDATE OF 1998 LTCP COSTS

2.1 Summary of 1998 Plan Cost Development

Five alternatives were developed as part of the Akron Facilities Plan ’98 (’98 Plan) that ranged from system-wide sewer separation to combinations of technologies that included detention basins, tunnels and sewer separation. A set of CSO control technologies, Integrated Alternative #2, was recommended as part of the Akron Long-Term Control Plan and included 2 tunnels, 11 detention basins (storage or treatment), and 7 CSO areas for sewer separation. Additionally, WPCS improvements and non-traditional stream improvements were included in the selected alternative. A summary of the recommended CSO control technologies with the respective Rack number is presented in Table 2-1.

Table 2-1
Summary of Integrated Alternative #2 CSO Control Technologies

Rack Number	CSO Control Technology
3	Treatment Basin
4, 16, 17/DC, 18, 19, 20, 23, 24, 37	Ohio Canal Interceptor (OCI) Tunnel
5+7	Storage Basin
8	Separation
9	Separation
10+11	Treatment Basin
12	Treatment Basin
13	Separation
14	Storage Basin
15	Storage Basin
21	Separation
22	Storage Basin
25	Separation
26+28	Treatment Basin
27+29	Treatment Basin
30	Separation
31+40	Storage Basin
32, 33, 34, 35	Northside Interceptor (NSI) Tunnel
36	Storage Basin
39	Separation

The ’98 Plan and associated supporting documents describe the resources and methodologies by which capital, operation and maintenance, and present worth costs were developed for these CSO control technologies. The ’98 Plan indicates that during cost development a combination of historical and then current cost data were used for estimating, as well as applying contingencies where determined appropriate. A summary of these resources and methodologies are presented in Table 2-2.

Table 2-2
Summary of ’98 Plan Cost Development Methodologies

CSO Control Technology	Type of Cost	Estimating Methodology	Cost Resources / Assumptions
Treatment and Storage Basins	Capital	Updated cost resources using the ENR index.	• Disinfection (treatment basins): EPA/625/R-93/007; • Pumping costs: EPA/430/9-80-003; • Pumping costs (O&M): EPA/430/9-78-009; • Screens (treatment basins): EPA/625/R-93/007; • Odor Control Facilities: EPA/625/1-85/018; • Pumps sized to dewater basins in 24-hours.
		Local unit costs developed at time of estimate.	• Concrete tank itself estimated as \$2/gallon; • Excavation, backfill, exterior piping unit costs • Non-project costs of 30%, utility relocation of 10%, contingency of 20% added to unit costs. • Land acquisition at 4 x the tank size at \$30,000/acre. • Tie-down anchors at 15% of total tank capital cost. • Washdown system at 2.75% of total tank capital cost.
		Means construction cost Guide.	• Fencing (based on approximate tank perimeter), access road and control building costs with non-project costs of 30%, utility relocation of 10%, contingency of 20% added to unit costs.
	O&M	Updated Cost Resources using the ENR index	• Disinfection (treatment): EPA/625/R-93/007; • Pumping costs: EPA/430/9-78-009; • Screens: EPA/625/R-93/007; • Odor Control Facilities: EPA/625/1-85/018; • Pumps operate to dewater basins in 24-hours.
	Present Worth	Single Payment, Uniform Series and Gradient Series	• Equipment costs at 8% of the tank total capital cost; • 15-year equipment life, 50-year structure life; • Interest rate of 7.125% and inflation rate of 3%.
Tunnels	Capital	Local unit costs developed at time of estimate.	• Soft Ground Tunnel Construction Cost = $960(\text{dia.})^{0.56}$; • Rock Tunnel Construction Cost = $90(\text{dia.})^{1.1}$; • Construction shafts (entrance/exit) at \$6,000/foot; • Work shafts (i.e., connections to racks) at \$2,500/foot; • Microtunneling for outlet control structure (\$800 \$1,000/foot for 2' to 4' diameter); • Rack reconstruction (\$100,000 each); • Dry weather flow piping for pipe-in-pipe design; • Ventilation duct and fan (\$355,000 each); • Odor control facilities (\$500,000 each); • Outlet control structure (\$1,500,000 each); • Shaft connections (\$250,000 each); • Land acquisition (\$500,000 to \$1,000,000).
	O&M	Related to capital costs	• Annual O&M cost (\$1k) = $1.7031(\text{capital cost})^{0.4498}$;
	Present Worth	Single Payment, Uniform Series and Gradient Series	• Equipment costs at 8% of the tank total capital cost; • 15-year equipment life, 50-year structure life; • Interest rate of 7.125% and inflation rate of 3%.

Table 2-2
Summary of '98 Plan Cost Development Methodologies

CSO Control Technology	Type of Cost	Estimating Methodology	Cost Resources / Assumptions
Separation	Capital	Means construction cost guide and local unit costs.	• Storm sewers, laterals, catch basins, manholes, sheeting, traffic control, dewatering. • Non-project costs of 30%, utility relocation of 10%, contingency of 20% added to unit costs.
	O&M	Local costs developed at time of estimate.	• O&M costs were estimated to be $100/acre
	Present Worth	Single Payment, Uniform Series and Gradient Series	• 50-year structure life; • Interest rate of 7.125% and inflation rate of 3%.

2.2 Update CSO Control Technology Costs – Integrated Alternative #2

The selected CSO control technology costs described in the '98 Plan for Integrated Alternative #2 were updated to 2005 costs. The 1998 capital (unit and lump sum) and operation and maintenance (annual) costs were updated based on a combination of Engineering News-Record (ENR) cost indexes and industry experience. The present worth of the updated capital and operation and maintenance costs were developed based on standard single payment, uniform series and gradient series present worth factors and with historical interest and inflation rate trends. The estimated costs in the '98 Plan for WPCS and non-traditional improvements were not included in the cost update.

2.2.1 Methodology for Updating Capital and Operation & Maintenance Costs

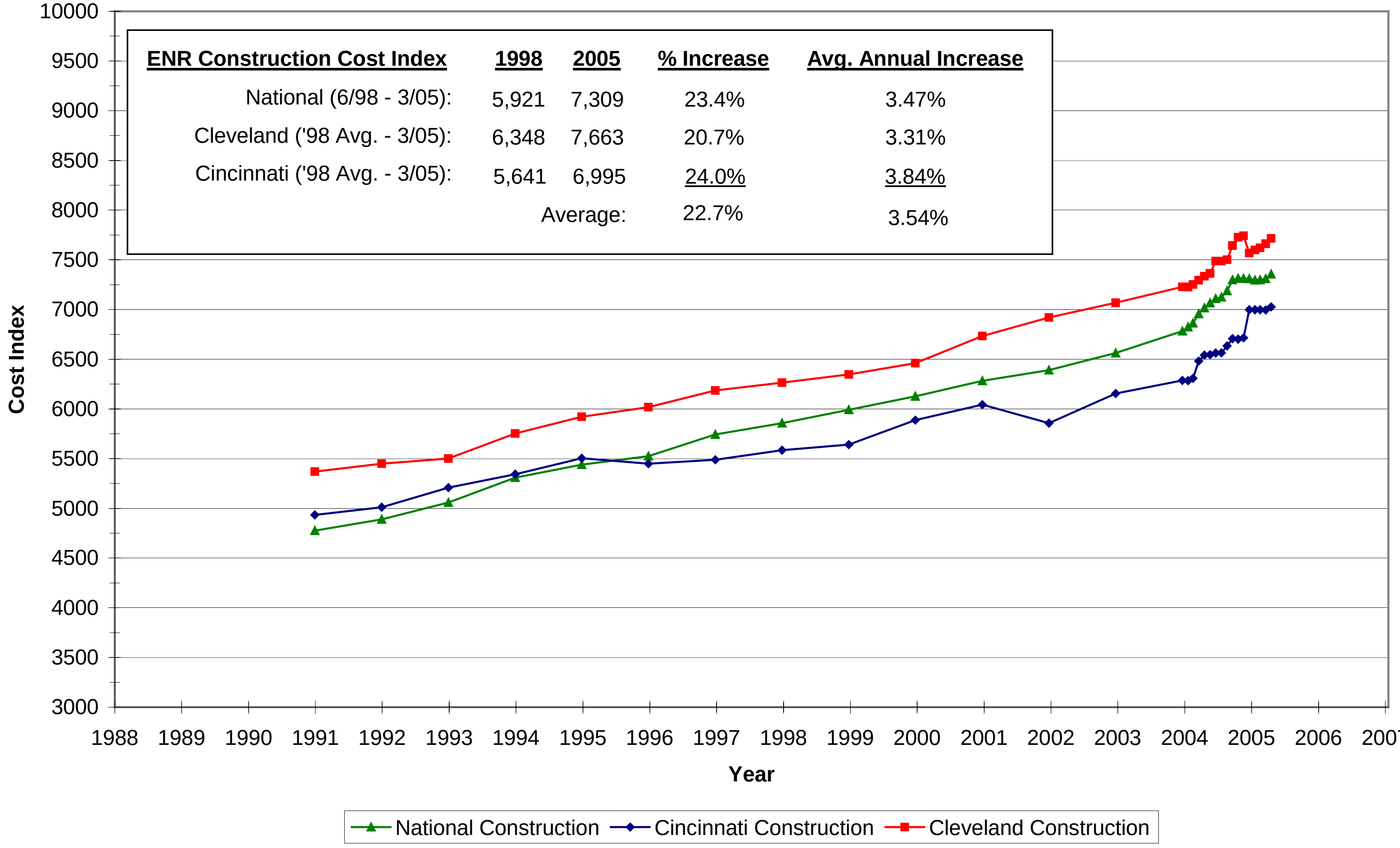
ENR cost indexes were reviewed to determine an appropriate inflation factor for updating the 1998 capital and operation and maintenance costs. For purposes of this Study, it was assumed that the 1998 costs represent June of 1998, and costs are updated to March of 2005 (6.75 years).

ENR construction cost indexes for Cleveland, Cincinnati and a 20-city national average (National) indicate that construction costs have increased approximately 22.7-percent on average since June 1998, or an average annual inflation rate of 3.54-percent. Figure 2-1 illustrates these cost indexes and trends.

The ENR material cost index for National indicates that material costs have increased approximately 11-percent since June 1998, or an average annual inflation rate of 1.6-percent. More recently, material costs have increase approximately 13-percent over the past year and dropped approximately 1.2-percent over the past six months. Figure 2-2 illustrates these cost indexes and trends.

The ENR skilled labor index for National indicates that skilled labor costs have increased approximately 27.8-percent since June 1998, or an average annual inflation rate of 4.1-percent. More recently, skilled labor costs have increase approximately 3.2-percent over the past year and approximately 0.7-percent over the past six months. Figure 2-3 illustrates these cost indexes and trends.

Figure 2-1. ENR Construction Cost Index Trends
National and Select Cities in Ohio



ENR Construction Cost Index	1998	2005	% Increase	Avg. Annual Increase
National (6/98 - 3/05):	5,921	7,309	23.4%	3.47%
Cleveland ('98 Avg. - 3/05):	6,348	7,663	20.7%	3.31%
Cincinnati ('98 Avg. - 3/05):	5,641	6,995	24.0%	3.84%
		Average:	22.7%	3.54%

Figure 2-2. ENR Material Cost Index Trends
National

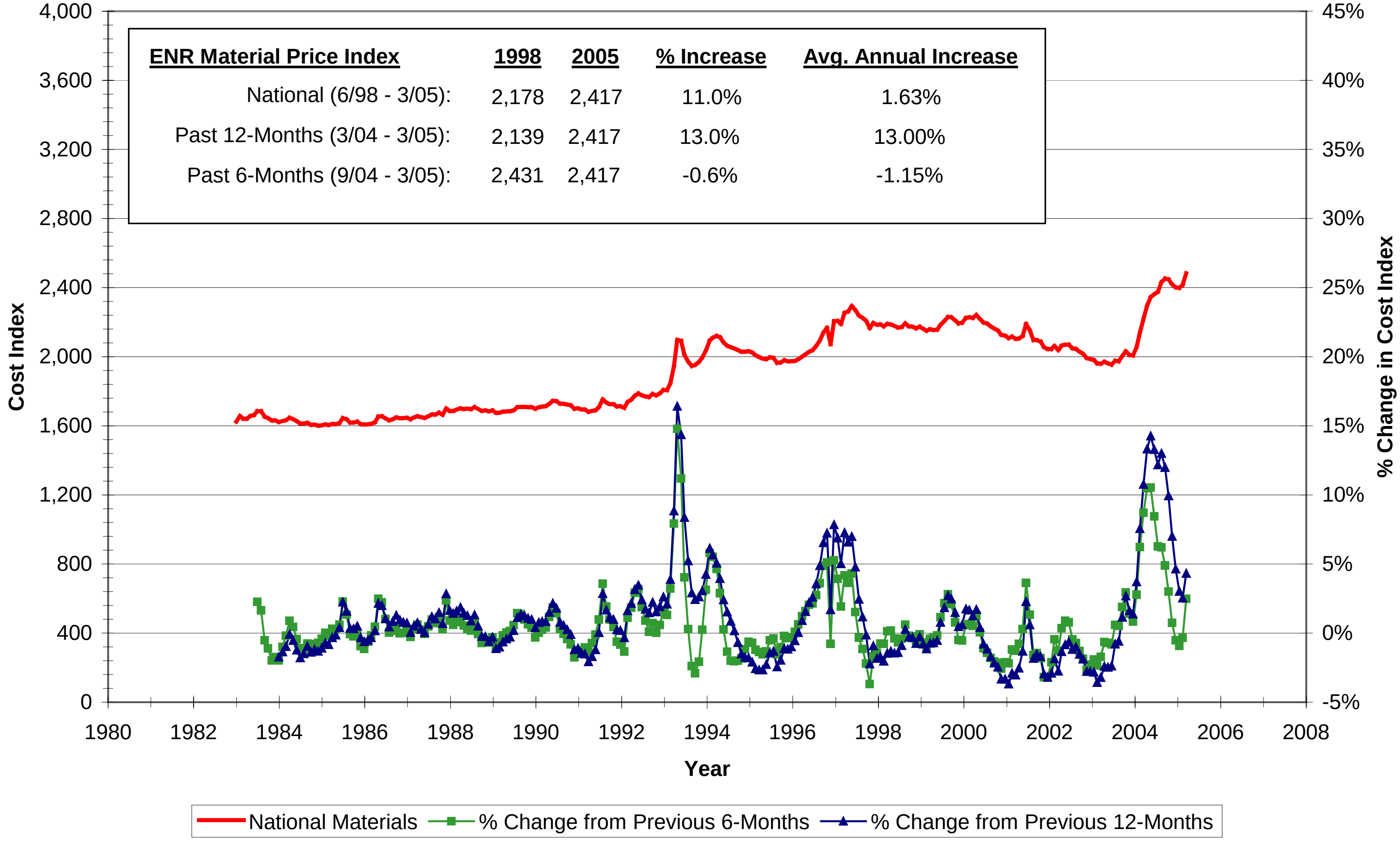
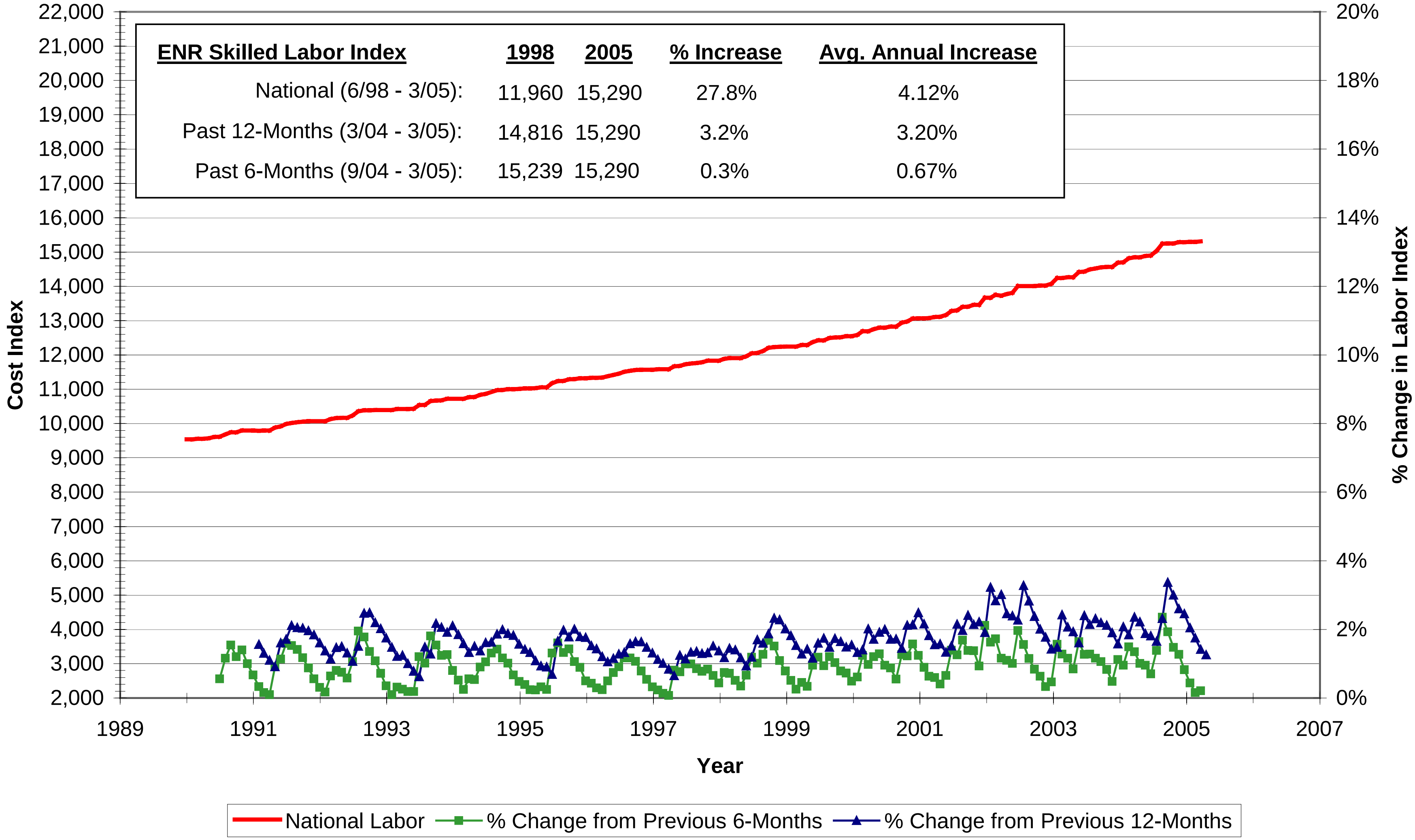


Figure 2-3. ENR Skilled Labor Index Trends
National



ENR Skilled Labor Index	1998	2005	% Increase	Avg. Annual Increase
National (6/98 - 3/05):	11,960	15,290	27.8%	4.12%
Past 12-Months (3/04 - 3/05):	14,816	15,290	3.2%	3.20%
Past 6-Months (9/04 - 3/05):	15,239	15,290	0.3%	0.67%

The ENR National construction cost index reflects a 20-city average including both material and skilled labor costs, therefore reflecting the slightly lower inflation in skilled labor costs and the more recent rapid increase in material costs. Because Cleveland and Cincinnati are included in the 20-city average, and that Figure 2-1 illustrates the National index as generally within the average of these two city indexes, an average of these three indexes is used for updating capital and operation and maintenance costs (3.54-percent average annual).

2.2.2 Comparison of 1998 Estimated Costs with Bid Results for Rack 40/31 Storage Basin

Basin cost assumptions made in the '98 Plan were compared to the November 2004 Rack 40/31 Storage Basin bid results where specific cost items could be delineated in the bid tabulation. The respective costs presented in the '98 Plan were updated to November 2004 costs for the comparison by use of the ENR construction cost index. Table 2-3 presents a comparison of these items.

Table 2-3
Comparison of Rack 40/31 Bid Results (November '04) with '98 Cost Assumptions

Item	Capital Cost Assumption [1]	'98 Cost Updated to 11-04 Cost	Bid Results
Odor Control	128,000*(Air Changes, cfm/9894)*(ENR/4146)	$392,000	$82,371
Concrete Tank [2]	$[18.303*(9.45\ MG)^2+342.54*(9.45\ MG)+383.35]*1000*(ENR/5921)$	$6,616,900	$5,494,592
Tie-Down Anchors	15% of Concrete Tank Cost	$992,600	$3,026,800
Total	**Sum of all cost items, including 30% contingencies**	**$16,904,200**	**$15,251,903**

Notes:
1. The ENR index for the '98 costs was 5921, and the ENR index in November 2004 was 7312.
2. Although the '98 Plan indicates a $2/gallon tank cost, this capital cost assumption was used in the calculations.

Based on the comparison of these cost items, the estimated mechanical equipment costs may be conservative (e.g., odor control system). The estimated concrete tank costs were approximately 20-percent above the bid results, however the bid cost shown above in Table 2-3 is related to concrete and reinforcement only. There may be miscellaneous concrete and tank related items elsewhere in the bid that are not reflected in this item comparison and might lessen this difference. The estimated cost for tie-down anchors was approximately 33-percent of the bid cost for this item.

The overall bid for the Rack 40/31 facility construction was approximately 11-percent below the '98 Plan estimate when updated to November 2004 costs. Considering that the estimated costs are at the planning level and a 30-percent contingency was included, it appears that the overall costs may be underestimated.

2.2.3 Comparison of Estimated Tunnel Costs with Industry Trends

The tunneling industry has made significant advances over the past decade in technologies and equipment that have generally lowered the cost of building tunnels. Additionally, the number of tunnel construction projects over the past decade has expanded the documentation from which reference cost data can be drawn from. This information wouldn't necessarily be reflected in a straight-line capital cost update based on ENR cost indexes. Therefore an independent review of the NSI and OCI Tunnel construction costs was made.

The original methodology used to estimate the costs for the Akron tunnels used cost curves based upon national averages and industry standards. The basic cost was generated using a cost curve, in which costs are an exponential function of diameter alone. To these basis costs, a few other fixed costs were added, for things like ventilation and outlet control structures. This approach produced reasonable accurate results for the NSI tunnel.

On this project, a similar approach was used. However, the costs were refined further. Thus, instead of using a cost curve for most of the costs, and then adding in a few other fixed costs, this project broke each tunnel aspect into more refined categories. This project priced items like mobilization, TBM setup, tunnel drives, TBM maintenance, TBM removal, tunnel cleanup, final liner, tunnel drive and demobilization as separate items. The original approach lumped many of these costs into the cost curve.

The result is that the costs of the NSI tunnel are reasonably close to the costs done in the original report. However, the costs for the OCI tunnel are significantly different enough to warrant further examination. Thus, our tunnel cost specialists checked the recent cost estimates. These specialists are industry experts in estimating the costs of tunnels, and this independent check confirmed the results.

One aspect that both the original and the recently revised costs estimates share is the lack of detailed, site-specific geotechnical data. Detailed geotechnical site investigations have not yet been performed. Without detailed, site-specific data, the costs may change considerably during detailed design. Table 2-4 compares the tunnel construction capital costs based on both the independent review and the updating of 1998 costs by use of the ENR cost index.

Table 2-4
Comparison of Estimated Tunnel Construction Costs with Industry Practice [1]

Tunnel	1998 Capital Cost (1998 $)	2005 Capital Cost (2005 $)	
		By Use of ENR Index	By Independent Review
NSI	$22,589,400	$28,568,325	$34,115,648
OCI	$88,413,600	$111,814,791	$86,380,542

Notes:
1. 2005 Capital Costs shown represent tunnel construction only. Mechanical equipment and land acquisition costs are not included.

The comparison of the cost update by independent review and ENR index indicates that the costs for the NSI Tunnel may be underestimated by approximately 15-percent when using the ENR index. However, the independent review suggests that the OCI Tunnel costs may be overestimated by approximately 30-percent. Considering the advances in construction technologies, combined with expanded reference cost data over the past decade, the tunnel capital costs estimated by independent review are assumed representative for purposes of this Study.

2.2.4 Methodology for Updating Present Worth Costs

National inflation and interest rate trends were reviewed to determine appropriate rates for determining the present worth of updated capital and operation and maintenance costs. Figure 2-4 illustrates that past 50, 20 and 6-year trends for these rates.

The past 20-year and 6-year average annual inflation rates are approximately 3.1-percent and 2.5-percent, respectively. Each of these rates is lower than the ENR annual inflation rate selected for cost updating (3.54-percent). Because the ENR indexes may better reflect the types of costs to be incurred over time for the constructed CSO control technologies (construction materials and skilled labor), the ENR derived inflation rate of 3.54-percent was used for present worth costs. This rate is higher than the 3.0-percent inflation rate used for present worth costs in the ’98 Plan.

The past 50, 20 and 6-year average annual prime interest rates are approximately 7.7, 8.0 and 6.2-percent, respectively. Interest rates have been less than 8-percent since 2001, and lower than 7-percent since 2002. However the rates have been increasing over the past two years and are expected to continue to rise. Because of uncertainty in how interest rates will change over the next 10 to 20-years, the past 20-year average of 8.0-percent is assumed for present worth costs. This rate is higher than the 7.125-percent interest rate used for present worth costs in the ’98 Plan.

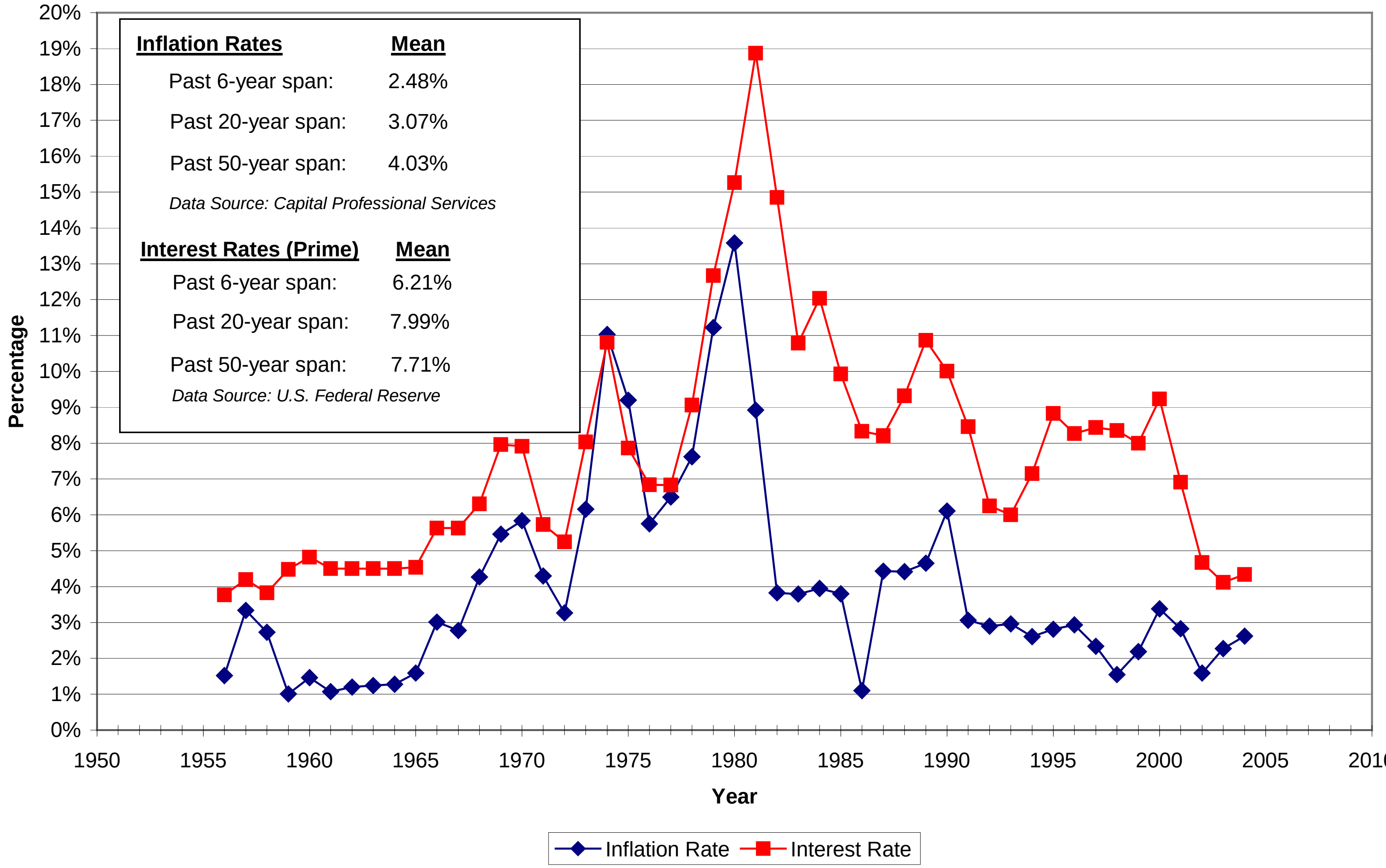
Present worth of the updated costs was developed for a typical 20-year analysis. The 20-year duration was chosen for consistency with the 20-year present worth used in the ’98 Plan. The present worth analysis consists of 5-primary cost components and described as follows:

$PW_{2005} = C_{2005} + M_{2005} + M_{PW} + CR_{PW} - S_{PW}$, *where*

PW_{2005} = *2005 Present Worth*
C_{2005} = *Estimated 2005 Capital Cost*
M_{2005} = *Estimated 2005 O&M Cost*
M_{PW} = *Present Worth of Estimated Annual O&M*
CR_{PW} = *Present Worth of Estimated Capital Replacement Costs*
S_{PW} = *Present Worth of Salvage Value*

The ’98 Plan calculation spreadsheets were used as a template, in part, for development of the present worth. During this process, an inaccuracy was found in the ’98 Plan calculation spreadsheets. The inaccuracy is related to how the present worth of incremental operation and maintenance costs were estimated. In short, the first year O&M present worth was included in the estimate of incremental increase in operation and maintenance over the present worth period. This inaccuracy resulted in a conservative estimate of operation and maintenance costs and was corrected for preparation of the updated present worth costs.

Figure 2-4. Historical Economic Trends



2.3 Summary of Updated Costs

Table 2-5 presents a summary of the ’98 Plan costs and the updated costs. The ’98 Plan capital costs for detention basins and sewer separation are updated based on a 3.54-percent average annual inflation rate. Operation and maintenance costs are updated based on a 3.54-percent average annual inflation rate.

Tunnel capital costs, less mechanical equipment and land acquisition, are based on an independent review (see Section 2.2.3). The mechanical and land acquisition costs are updated from the ’98 Plan capital costs using a 3.54-percent average annual inflation rate. Tunnel operation and maintenance costs are also updated from the ’98 Plan based on a 3.54-percent average annual inflation rate.

Table 2-5 also includes a summary of additional treatment and disinfection costs for the OCI Tunnel and Rack 31/40, and disinfection and screen costs for the remainder of Racks designated for storage basins. The additional treatment and disinfection costs for the OCI Tunnel and Rack 31/40 originated from the report titled Long Term Control Plan – Additional Evaluations, Proposed Integrated Alternative #2, May 2002. Costs developed for the remainder of storage basins is further described in Section 3. Updated costs for these facilities were developed similarly to the updating of costs from the ’98 Plan.

The present worth of the updated costs assume an average annual inflation rate of 3.54-percent and an interest rate of 8-percent. Based on the cost estimating criteria and methodologies described above, the 20-year present worth of updated costs for the CSO control technologies is estimated to be $325,879,000.

Table 2-5
Summary of Cost Update for Integrated Alternative #2 CSO Control Technologies

Rack Number	Technology	Control Parameter	Summary of 1998 Cost Estimate (in 1998 $)			Summary of Update to 1998 Cost Estimate (in 2005 $)		
			1998 Capital Cost	1998 Annual O&M Cost	20 Year Total PW (2018)	2005 Capital Cost	2005 Annual O&M Cost	20 Year Total PW (2025)
3	Detention Basin	Treatment/events	$1,700,088	$76,560	$2,969,800	$2,151,000	$97,000	$3,249,500
4, 16, 17/DC, 18, 19, 20, 23, 24, 37	OCI Tunnel	-	$93,446,078	$293,200	$90,587,300	$92,744,982	$370,804	$93,493,800
	Additional Treatment & Disinfection		-	-	-	$30,299,859	$1,316,747	$47,476,500
5+7	Detention Basin	Storage/event + hours	$1,672,788	$18,900	$1,941,200	$2,116,200	$24,000	$2,232,100
	Disinfection/Screen		-	-	-	$2,514,456	$125,065	$5,672,900
8	Separation	-	$2,326,353	$4,600	$2,052,900	$2,942,090	$5,818	$2,641,800
9	Separation	-	$210,926	$2,000	$215,300	$266,754	$2,529	$266,500
10+11	Detention Basin	Treatment/events	$3,723,641	$80,300	$4,990,800	$4,710,100	$101,800	$5,615,800
12	Detention Basin	Treatment/CBOD	$2,201,448	$169,950	$5,074,700	$2,785,200	$215,100	$5,408,800
13	Separation	-	$4,326,241	$7,200	$3,799,800	$5,471,305	$9,106	$4,889,700
14	Detention Basin	Storage/hours	$1,984,786	$34,500	$2,512,800	$2,510,900	$43,700	$2,857,100
	Disinfection/Screen		-	-	-	$3,312,299	$151,053	$7,339,900
15	Detention Basin	Storage/hours	$1,651,178	$28,590	$2,090,800	$2,088,900	$36,300	$2,376,600
	Disinfection/Screen		-	-	-	$2,931,896	$142,119	$6,543,400
21	Separation	-	$2,199,483	$10,400	$2,044,200	$2,781,640	$13,153	$2,600,800
22	Detention Basin	Storage/hours	$1,282,976	$29,190	$1,742,000	$1,623,200	$37,000	$1,963,900
	Disinfection/Screen		-	-	-	$4,792,434	$190,034	$10,101,900
25	Separation	-	$2,974,494	$8,300	$2,672,100	$3,761,780	$10,497	$3,419,000
26+28	Detention Basin	Treatment/CBOD	$2,561,620	$118,690	$4,532,800	$3,240,800	$150,300	$4,948,100
27+29	Detention Basin	Treatment/hours	$1,934,065	$104,005	$3,674,200	$2,446,900	$131,800	$3,982,200
30	Separation	-	$7,573,977	$6,900	$6,544,700	$9,578,646	$8,726	$8,463,200
31+40	Detention Basin	Storage/events	$13,421,279	$179,270	$16,060,300	$16,974,500	$226,800	$18,347,500
	Additional Treatment & Disinfection		-	-	-	$16,852,920	$681,878	$29,172,000
32, 33, 34, 35	NSI Tunnel	-	$28,371,900	$171,500	$33,254,700	$41,428,650	$216,892	$45,883,300
36	Detention Basin	Storage/CBOD	$992,811	$20,000	$1,304,600	$1,256,200	$25,400	$1,478,000
	Disinfection/Screen		-	-	-	$2,209,867	$115,320	$5,091,700
39	Separation	-	$300,000	$1,900	$289,700	$379,404	$2,403	$363,000
		Totals:	**$174,856,131**	**$1,365,955**	**$188,354,700**	**$264,172,882**	**$4,451,343**	**$325,879,000**

The costs in Table 2-5 are for detention basins, tunnels and sewer separation projects. Table 2-5 does not include cost of plant improvements and storm enhancements.

SECTION 3

CSO DISINFECTION

SECTION 3
CSO DISINFECTION

3.1 Background

The City of Akron's CSO LTCP recommended 11 detention basins as part of Integrated Alternative #2. Of these 11 basins, 5 were identified as treatment basins and 6 as storage basins. Based on discussions with the original authors of the CSO LTCP, it is our understanding that the design concept for the treatment basins includes disinfection facilities sized for a minimum of thirty minutes of detention time for the selected design event, and that sodium hypochlorite would be used as the disinfectant. The expectation is that the treatment basins would provide a 4-log kill for bacteria and an average CBOD removal of 15%.

Currently, the City of Akron is considering the addition of disinfection at storage basins for the peak flow received at each respective storage basin under the typical year rainfall. Included with this Study, a CSO Disinfection Report was developed to examine disinfectant alternatives for CSOs (see Appendix A). This Section summarizes the findings of the CSO Disinfection Report, and presents preliminary estimates of capital costs for adding disinfection to the storage basins.

3.2 Summary of CSO Disinfection Report

Chlorine has long been the disinfectant of choice for most wastewater disinfection systems. It offers reliable reduction of pathogenic microorganisms at reasonable operating costs. Alternatives to chlorine have been developed and evaluated for disinfection of wastewater discharges to small streams or sensitive water bodies, and are now being considered for treatment of CSOs and other episodic discharges. Such alternatives include:

- Sodium hypochlorite
- Calcium hypochlorite
- Chlorine dioxide
- Ozone
- Bromine
- Peracetic acid
- Ultraviolet radiation (UV)
- Electron beam irradiation (E-Beam).

Some of these alternatives are described in the EPA's CSO Technology Fact Sheet EPA 832-F-99-033, Alternative Disinfection Methods, which was partly based on the work performed in New York City at Spring Creek (CDM and M&A, 1997). More recent pilot studies for Water Environment Research Foundation (WERF), fully funded by the EPA, tested the effectiveness, disinfection by products and toxicity of the more promising technologies (WERF, 2005).

Based on a review of the literature as part of the WERF/EPA Disinfection Project (WERF, 2005) and Brown and Caldwell experience, a comparison of disinfection alternatives that have potential use for wet-weather flows are presented in Table 3-1.

Table 3-1 presents disinfection technologies and comparative rankings for specific criteria. The disinfection technologies are listed across the top of each column and the rankings are listed below for each criterion. The rankings are for comparative purposes only for each criterion.

The disinfection technologies presented in Table 3-1 represent candidate technologies for wet-weather flow disinfection. The major assumptions used in development of Table 3-1 are further described in CSO Disinfection Report (Appendix A).

Table 3-1
Comparison of Disinfection Technologies

Disinfection Technology / Criteria	Chlorine (NaOCl)	Chlorine Dioxide	Ultraviolet Radiation	Ozone	Bromine (BaBr)	Peracetic Acid
Effectiveness	High	Moderate	Moderate-High	Moderate	High	Moderate
Occupational Safety Requirements	Moderate	High	Low	Moderate-High	Moderate	High
Applicability to CSOs	High	Moderate	Moderate	Moderate	Moderate-High	High
Full Scale CSO Installations	High	None Known	Low	None Known	Low	Low
Ease of Operation	Simple	Simple-Moderate	Simple	Moderate-Complex	Simple-Moderate	Simple-Moderate
Generation Equipment Req'd	No	Yes	Yes	Yes	No	Yes
Persistent Residual	Yes	Yes	No	No	Yes	No
Power Requirement	Low	Low	Moderate-High	High	Low	Low
Present Worth Cost	Low	Low-Moderate	High	High	Moderate	Low

3.2.1 High Rate Disinfection

Effective bacteria kills may be achieved at lower contact times by using increased mixing intensity, increased disinfectant dose, alternate chemicals having a higher oxidation rate than chlorine or a combination thereof. High Rate Disinfection (HRD) essentially utilizes increased mixing and/or increased oxidation power as a substitute for an additional component of contact time that would otherwise be required.

Conventional disinfection is governed by the relationship:

Kill = c x t

Where c = concentration of disinfectant
t = time of contact (within a contained volume)
Required t is in the order of 15 minutes

HRD is governed by the relationship:

Kill = c x G x t
Where G = velocity gradient expressed as time-1 (a measure of mixing intensity).

When multiplied by t, Gt is a unitless quantity; the product has been related to log kill of bacteria in studies conducted in Syracuse and Rochester (U.S. EPA, 1979a; U.S. EPA, 1979b).

High rate mixing was the subject of a U.S. EPA Wet Weather Flow Environmental Technology Report that verified the effectiveness of HRD using high-rate induction mixers (NSF and U.S. EPA, 2002).

Currently, the City of Akron's CSO Long Term Control Plan provides for a minimum ten minutes of contact time assuming conventional chlorination for treatment basins. However, based on the cited literature (U.S. EPA, 1979a; U.S. EPA, 1979b; CDM and M&A 1997; CDM and M&A, 2001; M&A, 2000; WERF, 2005) and the direct experience of the project team, equivalent bacterial reductions can be achieved with five minutes of contact when using high-rate disinfection technology.

3.2.2 Conclusions of the CSO Disinfection Report

Sodium hypochlorite, chlorine dioxide, bromine and UV are the most viable disinfection alternatives of those reviewed for CSO applications.

Numerous studies and full-scale facilities have demonstrated that chemical disinfection of CSOs can be accomplished using high-rate disinfection. High-rate disinfection is defined as employing high-intensity mixing to accomplish disinfection within a short contact time, generally five minutes.

High-rate disinfection with sodium hypochlorite followed by dechlorination is the most cost effective method to disinfect CSOs when considering total life-cycle costs.

The data for chlorine dioxide shows that it is a more effective disinfectant than sodium hypochlorite. However, chlorine dioxide needs to be generated on site because it is too unstable even for short periods of time. Operating a chlorine dioxide generator at a remote satellite CSO facility for intermittent flows would be difficult given the currently available systems. In addition, chlorine dioxide, as with chlorine, can produce byproducts of concern. The advantage of using chlorine dioxide is that it is a rapid disinfectant with superior viricidal properties. Chlorine dioxide does not react with the ammonia and does not produce THMs. Several manufactures are currently working on new technologies to produce chlorine dioxide. Technologies may become available in the future that provides an easier and safer way to produce chlorine dioxide at a remote CSO locations.

Bromine may also be a better disinfectant than sodium hypochlorite. However, at this time there is only one known CSO disinfection facility using bromine in the United States. Consequently, this technology should be piloted in the City of Akron to address effectiveness, byproduct formation, associated toxicity and operability at remote CSO locations to confirm its application. BCDMH is a powdered form of Bromine being used for CSO disinfection in Japan but has not been implemented in the U.S.

UV, another alternative to sodium hypochlorite for CSO disinfection, has shown to be a more effective disinfectant than sodium hypochlorite. However it is significantly more expensive than sodium hypochlorite and in addition would require more preliminary treatment. The other major advantage of UV is that it produces no residuals or disinfection byproducts.

Full Scale Treatment Considerations: As concluded from the Columbus, GA project (see Section 3.2.3 in the CSO Disinfection Report, Appendix A), UV disinfection is related to light transmittance. It is well known that the size and nature of suspended solids contribute to transparency and consequently can act as an impediment to ultra violet disinfection. Color, as it affects transparency, and certain materials such as iron, can also serve as an impediment to UV effectiveness. Chemical disinfection can also be impaired by solids, particularly organics, but to a much lesser extent. Whereas solids can represent oxygen demanding components in addition to shielding and harboring organisms, chemicals penetrate solids more effectively than UV light. UV effectiveness is governed by UV Transmittance (UVT).

UVT is a measurement of the quantity of UV light that can pass through a sample of wastewater (UVT = 100% for pure water). Therefore, higher UVT values indicate more feasible and economical disinfection using UV. This is particularly true if low-intensity UV technology can be used as opposed to medium-pressure technology that was developed to disinfect poorer water quality.

Samples with UVT values above 35% to 40% are considered treatable using medium-pressure UV technology. However as the UVT decreases from 65% to 50%, the energy required for disinfection approximately doubles, thereby making UV more costly.

The minimum level of UVT for medium-pressure technology for effectiveness on the indicator bacteria has been shown to be 60%. Wastewater with lower UVT values would require preliminary treatment.

Technologies well suited to reduce highly-variable influent TSS to such levels are ACTIFLO and DensaDeg. Based on piloting of both technologies for Akron, OH, influent TSS of as high as 140 mg/l were reduced 97% to 5 mg/l using either the ACTIFLO or DensaDeg Process; these results were for the ACTIFLO and DensaDeg Pilots being run at rise rates of 30 and 40 gpm/S.F. respectively. Both Pilots used Alum and Ferric in combination with an anionic polymer ("Water Pollution Control Station Secondary Bypass Treatibility Study", Arcadis FPS, 3/2004;Water Pollution Control Station Secondary Bypass Treatibility Study Phase II", Arcadis FPS, 12/2004). Concentrations would need to be tailored for the wastewater in question.

The Table 3-2 representative of the ACTIFLO process and the resulting UVT. The UVT would be suitable for medium-pressure technology and possibly low-pressure technology but selection would need to be verified in accordance with NWRI Standards.

Table 3-2
UV Light Transmittance

Wastewater Type	Rise Rate (gpm/s.f.)	Coagulant Type	Coagulant Dose (mg/l)	Polymer Type	Polymer Dose (mg/l)	Average Unfiltered UVT (%)
Primary Effluent	60	Ferric	40	Dry Anionic	0.77	56
Primary Effluent	60	Ferric	85	Dry Anionic	0.77	60
Primary Effluent	60	Alum	50	Dry Anionic	0.77	66
Primary Effluent	60	Alum	100	Dry Anionic	0.77	69

Another technology that has proven effective as preliminary treatment to U.V. is Compressed Media Filtration, which is being used in Columbus, GA. This process is further described in the Disinfection Report.

3.3 Disinfection Retrofit Costs for Storage Basins

Based on the direct experience of the project team, planning level capital costs were estimated for adding disinfection to the CSO storage basins identified in the CSO LTCP for Integrated Alternative #2. These planning level costs are presented in Table 3-3 and are based on the use of sodium hypochlorite with high rate mixing. The planning level capital cost for adding disinfection at the storage basins is estimated at approximately $2.2 M, or about 1-percent of the updated overall capital cost estimate for Integrated Alternative #2 ($201.3 M in 2005 $). Several key assumptions were made in developing the disinfection costs, including:

- There is sufficient volume in the storage basins to accommodate high-rate disinfection (HRD) contact times in the basins as they are designed (300 seconds of chlorination contact time, 60 seconds of dechlorination contact time).
- The retrofit costs include only additional equipment needed by the HRD process. There are no provisions in the estimated costs for structural alterations that may be necessary to the currently planned tank design, which would require a more in-depth and detailed analysis.
- The estimated costs are for capital construction only and include a 30-percent contingency. The estimated costs do not include engineering, legal, administrative, or other project-related costs. The ENR CCI is equivalent to 7355.
- The flow rates used for estimating the costs and detention times are based on the typical year peak flow for each respective Rack as described in the '98 Facilities Plan, Section 12.

Table 3-3
Estimated Planning Level Capital Costs for Disinfection at Storage Basins

Item	Rack 5 & 7		Rack 14		Rack 15		Rack 22		Rack 31 & 40		Rack 36	
	Equipment	Structure	Equipment	Structure	Equipment	Structure	Equipment	Structure	Equipment	Structure	Equipment	Structure
Chemical Metering Pumps	$7,700	See Note 1	$11,500	See Note 1	$7,700	See Note 1	$11,500	See Note 1	See Note 4	See Note 4	$7,700	See Note 1
Induction Mixers	$121,700	See Note 1	$182,500	See Note 1	$121,700	See Note 1	$182,500	See Note 1	See Note 4	See Note 4	$121,700	See Note 1
Chemical Storage	$5,500	See Note 1	$16,000	See Note 1	$14,500	See Note 1	$26,000	See Note 1	See Note 4	See Note 4	$10,000	See Note 1
Piping Allowance	$13,500	See Note 1	$21,000	See Note 1	$14,400	See Note 1	$22,000	See Note 1	See Note 4	See Note 4	$13,900	See Note 1
Electrical Allowance	$20,200	See Note 1	$31,500	See Note 1	$21,600	See Note 1	$33,000	See Note 1	See Note 4	See Note 4	$20,900	See Note 1
Instrumentation	$6,700	See Note 1	$10,500	See Note 1	$7,200	See Note 1	$11,000	See Note 1	See Note 4	See Note 4	$7,000	See Note 1
Screens *(Note 2)*	$703,543	$1,055,314	$909,960	$1,364,939	$827,278	$1,240,917	$1,360,173	$2,040,260	See Note 4	See Note 4	$607,467	$911,200
Subtotal Capital Cost:	$878,843	$1,055,314	$1,182,960	$1,364,939	$1,014,378	$1,240,917	$1,646,173	$2,040,260	$1,144,358	$1,219,513	$788,667	$911,200
30% Contingency:	$263,700	$316,600	$354,900	$409,500	$304,300	$372,300	$493,900	$612,100	$343,300	$365,900	$236,600	$273,400
Total Capital Cost:	$1,142,543	$1,371,914	$1,537,860	$1,774,439	$1,318,678	$1,613,217	$2,140,073	$2,652,360	$1,487,658	$1,585,413	$1,025,267	$1,184,600
Annual O&M *(Note 3)*:		$125,065		$151,053		$142,119		$190,034		$681,989		$115,320
Total Cost by Rack:		**$2,639,500**		**$3,463,400**		**$3,074,000**		**$4,982,500**		**$3,755,100**		**$2,325,200**
Total Cost for all Racks:	**$ 20,239,700**											

Note 1. With exception to screens, disinfection costs include equipment only. Refer to assumptions described in Section 3.3 in the City of Akron Long Term Control Plan Review and Disinfection Investigations, Final Report, May 2005

Note 2. Screen costs are estimated based on EPA Combined Sewer Overflow Control Manual, EPA/625/R-93/007, September 1993, ENR = 4800. Costs include structure (assumed 60% total cost) and equipment (assumed 40% total cost), and are updated by ENR CCI to March 2005 (ENR = 7309).

Note 3. O&M costs are estimated based on EPA Combined Sewer Overflow Control Manual, EPA/625/R-93/007, September 1993, ENR = 4500, and are updated by ENR CCI to March 2005 (ENR = 7309).

Note 4. Disinfection and screen costs for this Rack are based on costs presented in the Long Term Control Plan - Additional Evaluations Report, May 2002. Costs are updated from May 2002 based on an average annual ENR inflation rate of 3.54%.

SECTION 4

ADVANCED WET-WEATHER TREATMENT TECHNOLOGIES

SECTION 4
ADVANCED WET-WEATHER TREATMENT TECHNOLOGIES

4.1 Summary of ACTIFLO and DensaDeg Pilot Studies

The City of Akron WPCS has successfully investigated numerous alternatives since the 1998 LTCP was released. In particular, the City pilot tested two wet weather alternative treatment technologies: Infilco Degremont's DensaDeg system and US Filter's ACTIFLO system.

Both DensaDeg and ACTIFLO are similar, in that they use a physical-chemical approach to treating wet weather flows. Both processes demonstrated their capacity to lower total suspended solids (TSS), phosphorous, fecal coliforms, and carbonaceous biological oxygen demand (CBOD).

The US Filter ACTIFLO system is a ballasted flocculation system. It was piloted at the Akron WPCS for three weeks from October 6, 2003 to October 24, 2003. After optimizing the system for proper alum, ferric chloride, and anionic polymer dosages, as well as the hydraulic optimization, this pilot project showed the following results:

Table 4-1
ACTIFLO Pilot Results

Parameter	Results
TSS Reduction	93%
Phosphorous Reduction	88%
CBOD Reduction	57%
Fecal Coliform Reduction	inconclusive results
Sludge Concentration Produced	0.2% solids

The Executive Summary of the ACTIFLO pilot work is included as Appendix E of this report. This summary indicated that ACTIFLO is a viable treatment technology for secondary bypasses at the Akron WPCS.
The Infilco Degremont DensaDeg system is a high-rate clarification system. It was piloted at the Akron WPCS for four weeks from September 13, 2004 to October 8, 2004. After optimizing the system for proper alum and ferric dosages, as well as the hydraulic optimization, this pilot scale project showed the following results:

Table 4-2
DensaDeg Pilot Results

Parameter	Results
TSS Reduction	83%
Phosphorous Reduction	91%
CBOD Reduction	55%
Fecal Coliform Reduction	95%
Sludge Concentration Produced	0.5% solids

The Executive Summary of the DensaDeg pilot work is included as Appendix F of this report. This summary indicated that DensaDeg is a viable treatment technology for secondary bypasses at the Akron WPCS.

SECTION 5

LONG-TERM CONTROL PLAN RECOMMENDATIONS

SECTION 5
LONG-TERM CONTROL PLAN RECOMMENDATIONS

5.1 Approach

The City of Akron, Ohio, developed the draft of the Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP) in 1998. At the time the plan was created, the regulations regarding CSOs and the federal guidelines for CSOs were relatively new. Since that time, many industry drivers, technologies, and economies have changed. We anticipate that these changes will continue to develop, as Akron implements their program. Thus, it is recommended that Akron maintain as flexible an approach to implementing their CSO LTCP as is reasonable, to accommodate changes in industry drivers, technologies and economies.

For example, the costs used to determine the most feasible alternative were based on costs current in 1998. Recently, there have been dramatic increases in the costs of concrete and steel, which could not have been anticipated in 1998. The result is that the plan's projected costs needed to be adjusted slightly. The LTCP should be sufficiently flexible to accommodate future changes in drivers, technologies and economies.

The LTCP evaluated five ultimate integrated plan alternatives, and the City chose the plan that was neither the least cost nor the greatest cost. The City's selection was based on numerous factors, including several non-cost factors, to arrive at a final recommended plan. As the CSO LTCP is implemented, the relative significance of these factors can change, which may result in a shift in LTCP emphasis. There may be opportunities to implement significant cost-effective alternatives in the future. It is recommended that the overall plan be evaluated and updated every five years, and updated, if appropriate, to make certain that the plan best accommodates changes in industry drivers, technologies and economies.

In addition to evaluating the plan every five years, the City should consider re-examining the design for each rack at the preliminary design phase, to make sure that the specific technology (e.g., storage, treatment, conveyance, etc.) is the best suited for that particular installation.

5.2 Drivers, Technologies and Economies

There have been several changes in technology, since the time the LTCP was published. The City of Akron should continue to evaluate the changes in technologies.

For disinfection, the LTCP implies that a chlorine-based disinfectant should be used. The results of this study agree with that recommendation, based on current data. However, at the time this report is being written, there are several other disinfection technologies that merit further investigation.

Bromochlorodimethylhydantoin (BCDMH) is a strong disinfectant that has been used commercially for years in the USA, primarily as a swimming pool disinfectant. Thus, our knowledge about BCDMH systems (e.g., chemical handling, chemical dosing, etc.) has been sufficiently developed in other industries, but has not yet been adapted well to the CSO market in the USA. Recently, BCDMH has been used to treat CSOs successfully in Japan. BCDMH has potential to be a viable CSO disinfectant. It is recommended that the City pilot this alternative, to determine its potential for CSO disinfection in Akron.

Ultraviolet (UV) irradiation has been used successfully for years in disinfecting water and wastewater. For UV to be effective, the wastewater must be sufficiently transparent, to allow the irradiation to inactivate microorganisms. Most CSO flows are not sufficiently transparent to make UV viable directly. However, the recent trends indicate that UV is effective with proper pretreatment. Also, there have been numerous advances in UV technologies, both in terms of reductions in cost and increases in effectiveness. It is recommended that the City continue to monitor the UV market carefully, to see if UV may be a viable alternative for future CSO improvements.

The ultimate integrated plan recommends the installation of two tunnels: the Ohio Canal Interceptor (OCI) and the Northside Interceptor (NSI). Since 1998, there have significant advances in tunnel technologies and equipment. This has yielded a significant reduction in price for tunnels, as well as a reduction in overall project risk. For example, the current estimated cost for the NSI is about 30% less in 2005 dollars than it was in 1998 dollars. Thus, it may be economical to consider extending or expanding the tunnels, to provide additional storage capacity and/or incorporate more racks.

The LTCP recommends the installation of large treatment basins at many of the racks. The size of these treatment basins, and thus the cost, may be reduced significantly through the installation of alternative treatment technologies. In particular, vortex separation units can be placed in a much smaller footprint than a conventional treatment basin. It is recommended that the City consider installing vortex separators for treatment basins.

Under this study, Akron examined a wet weather demonstration project in Columbus, Georgia. That facility included vortex separation units, as well as compressed media filters and UV treatment train. Data from this installation suggest that the compressed media filter and UV treatment alternative was effective in treating CSOs, using a significantly smaller footprint than the proposed treatment basins currently recommended in the LTCP. Akron may wish to consider compressed media filtration (or similar product) combined with UV for future installations.

Under previous work, the City pilot tested both DensaDeg and ACTIFLO units. While both provided improved effluent, Akron believes that both technologies do not seem well suited for remote, unmanned CSO installations. As this technology continues to develop, Akron may want to consider these or other similar physical-chemical treatment alternatives, for treating wet weather flows at the WPCS.

Compared to traditional wastewater treatment, CSO treatment is relatively new. The CSO market continues to evolve, and new CSO experiences continue to provide valuable data. While these data are valuable, pilot work data in Akron is far more indicative of what probably will, and what will probably not, work well in Akron. In general, the money spent in pilot work investigations is more than offset by the results they produce. Thus, it is recommended that Akron continue to allocate a portion of the annual budget for future pilot work investigations.

5.3 Disinfection at Storage Basins

As part of the negotiations with Ohio EPA regarding the City's CSO LTCP, the City conditionally agreed to add disinfection of discharges from the proposed storage basins up to the peak flow from either a 1-year design storm or the typical year. This suggestion blurs the distinction between treatment basins and storage basins. It is recommended that prior to beginning the design of each CSO rack improvement the selected improvement for that location should be further evaluated to determine if it is still the best choice.

For virtually any disinfection system to operate efficiently, the flows must receive some preliminary treatment. Thus, if disinfection is to be added at all the storage basins, it is recommended that coarse screening and floatable controls also be implemented at each storage basin where disinfection will be installed.

Disinfecting flows at storage basins was never fully defined. It is unreasonable and likely too costly to disinfect every drop of every wet weather event. The knee-of-the-curve analysis in the LTCP suggests that effective treatment occurs at events considerably less than either a one-year storm event or the peak flow from the typical year storm event. It is recommended that, if the City proceeds with disinfecting flows at storage basins, disinfection be limited to flows up to either a one-year storm event or the peak flow from the typical year event.

5.4 Additional Treatment

To address concerns raised by Ohio EPA regarding the impact on discharges from CSOs that have significant separate sanitary sewered areas tributary to them and from the Akron Water Pollution Control System secondary by-pass, the City conditionally agreed to add “additional treatment” to discharges from select locations. “Additional treatment” is currently being defined as an advanced primary treatment system such as enhanced high rate clarification, compressed media filtration or membrane technology. These are significant additions and appear to exceed the requirements of the current CSO policy. Also, with advances in technology happening so rapidly, it is recommended that the City do a thorough review of all available technologies prior to designing each of the “additional treatment” facilities.

APPENDIX A

CSO DISINFECTION REPORT

City of Akron

Long Term Control Plan Review and Disinfection Investigations

CSO DISINFECTION REPORT

Prepared for

City of Akron

Prepared by

Brown and Caldwell

As a Subconsultant to

Hatch Mott McDonald

February 17, 2005

Table of Contents

1. INTRODUCTION

Wet weather flows originate from a range of sources including diffuse overland flows, storm flows from industrial and municipal storm sewers, combined sewer overflows and sanitary sewer overflows. Wet weather flows can be characterized as highly variable in flow rate and pollutant content. Pollutants can include organic content, oil, grease, oxygen-demanding compounds chemicals, nutrients, heavy metals, bacteria and viruses. Disinfection of wet weather flows is often considered as treatment to minimize the impact associated with these occurrences. The disinfection process is arguably the most important stage of wet-weather flow treatment from the perspective of human health protection exposure to pathogens and the associated health concerns. The cost-effectiveness of disinfecting wet weather flows has been demonstrated numerous times over the past thirty years (U.S. EPA, 1979a; U.S. EPA, 1979b; Camp Dresser & McKee(CDM) and Moffa & Associates (M&A), 1997).

Chlorine has long been the disinfectant of choice for most wastewater disinfection systems. It offers reliable reduction of pathogenic microorganisms at reasonable operating costs. See EPA's CSO Technology Fact Sheet EPA 832-F-99-034, Disinfection-Chlorination, in Appendix A for more information. Alternatives to chlorine have been developed and evaluated for disinfection of wastewater discharges to small streams or sensitive water bodies, and are now being considered for treatment of CSOs and other episodic discharges. Such alternatives include:

- sodium hypochlorite
- calcium hypochlorite
- chlorine dioxide
- ozone
- bromine
- peracetic acid
- ultraviolet radiation (UV)
- electron beam irradiation (E-Beam).

Some of these alternatives are described in the EPA's CSO Technology Fact Sheet EPA 832-F-99-033, Alternative Disinfection Methods, which was partly based on the work performed in New York City at Spring Creek (CDM and M&A, 1997). This fact sheet can be found in Appendix B. More recent pilot studies for Water Environment Research Foundation (WERF), fully funded by the EPA, tested the effectiveness, disinfection by products and toxicity of the more promising technologies (WERF, 2005).

The following sections identify methods and disinfectants developed and considered specifically for wet weather.

2. DESCRIPTION OF DISINFECTANTS

2.1 Definition of High Rate Disinfection (HRD)

The disinfection of wet weather flow discharges can present challenges because of their intermittent nature, variable flow rate, wide temperature variation, and variable water quality. Due to the challenges that are associated with CSOs, high-rate disinfection (HRD) treatment processes have been developed. HRD was first demonstrated in the early 1970’s through the EPA Research and Development Grants in Syracuse and Rochester (U.S. EPA, 1979a; U.S. EPA, 1979b). Later demonstrations were conducted in New York City in 1996 to 2000 (CDM and M&A 1997, CDM and M&A, 2001), Syracuse in 1999

(M&A, 2000), and for WERF/EPA in 2002 (WERF, 2005). These methods have been implemented full-scale at several locations throughout the country for wet and dry weather flows and generally apply to any chemical disinfectant as opposed to ultraviolet light disinfection.

Effective bacteria kills may be achieved at lower contact times by using increased mixing intensity, increased disinfectant dose, alternate chemicals having a higher oxidation rate than chlorine or a combination thereof. HRD essentially utilizes increased mixing and/or increased oxidation power as a substitute for an additional component of contact time that would otherwise be required.

Conventional disinfection is governed by the relationship:

Kill = c x t
Where c = concentration of disinfectant
t = time of contact (within a contained volume)

Required t is in the order of 15 minutes

HRD is governed by the relationship:

Kill = c x G x t
Where G = velocity gradient expressed as time-1 (a measure of mixing intensity).

When multiplied by t, Gt is a unitless quantity; the product has been related to log kill of bacteria in studies conducted in Syracuse and Rochester (U.S. EPA, 1979a; U.S. EPA, 1979b).

High rate mixing was the subject of a U.S. EPA Wet Weather Flow Environmental Technology Report which verified the effectiveness of HRD using high-rate induction mixers (NSF and U.S. EPA, 2002).

Currently, the City of Akron's CSO Long Term Control Plan provides for ten minutes of contact time assuming conventional chlorination. However, based on the cited literature (U.S. EPA, 1979a; U.S. EPA, 1979b; CDM and M&A 1997; CDM and M&A, 2001; M&A, 2000;WERF, 2005) and the direct experience of the project team, equivalent bacterial reductions can be achieved with five minutes of contact when using high-rate disinfection technology.

2.2 Summary of Potential Wet-Weather Flow Disinfection Technologies

Based on a review of the literature as part of the WERF/EPA Disinfection Project (WERF, 2005) and Brown and Caldwell experience, a comparison of disinfection alternatives that have potential use for wet-weather flows are presented in Table 1.

Table 1 presents disinfection technologies and comparative rankings for specific criteria. The disinfection technologies are listed across the top of each column and the rankings are listed below for each criteria. The rankings are for comparative purposes only for each criteria.

The disinfection technologies presented in Table 1 represent the most likely candidate technologies for wet-weather flow disinfection and the major assumptions are briefly identified below. More detailed descriptions of these technologies are presented later in this Section.

- Chlorine includes sodium hypochlorite and calcium chlorite. Gaseous chlorine is not recommended for wet-weather flow disinfection facilities that may be unmanned.
- Chlorine dioxide is generated onsite from gaseous chlorine. As noted for chlorine, gaseous chlorine is not recommended for wet-weather flow disinfection facilities; however the only commercially available chlorine dioxide generators use gaseous chlorine.
- Ultraviolet light includes the use of medium pressure, high intensity bulbs within a closed chamber or open channel.
- Ozone is generated on site using a corona type generator. Industrial grade oxygen can be generated on site or delivered to the site.
- Bromine includes sodium bromide. Other forms of bromine exists for disinfection such as pure bromine, bromine chloride and BCDMH; however none of these are in use in the United States for wet-weather flow disinfection.
- Peracetic Acid is generated on site by combining glacial acetic acid, hydrogen peroxide and water.
- Electron Beam Irradiation uses a reactor that creates a thin wastewater film that is scanned by an electron beam.

The disinfection technologies presented in Table 1 are compared to one another based on specific criteria. The criteria are described below.

- Effectiveness is the disinfectants ability to inactivate indicator organisms at dosages deemed by equipment suppliers and design engineers.
- Occupational Safety Requirements reflects the quantity and complexity of safety barriers required to maintain operator safety.
- Applicability to CSOs reflects how easily the disinfection technology can be adapted to wet-weather flow disinfection considering the intermittent nature, variable flow rate and variable water quality.
- Full Scale CSO Installations reflects the number of CSOs facility employ the technology.
- Generation Equipment Required denotes whether the disinfectant needs to be generated on site. Because UV bulbs and controls are significant pieces of equipment they are considered generators.
- Persistent Residuals is a measure of the disinfectant that remains as a residual after the disinfection process is complete. This also includes disinfection byproducts.
- Power Requirement reflects the amount of electric power required to operate the disinfection technology.
- Present Worth Cost includes capital and annual operational and maintenance costs.

Table 1. Comparison of Disinfection Technologies.

Disinfection Technology \ Criteria	Chlorine	Chlorine Dioxide	Ultraviolet Radiation	Ozone	Bromine	Peracetic Acid	Electron Beam Irradiation
	(NaOCl)				(NaBr)		
Effectiveness	High	Moderate	Moderate-High	Moderate	High	Moderate	High
Occupational Safety Requirements	Moderate	High	Low	Moderate-High	Moderate	High	High
Applicability to CSOs	High	Moderate	Moderate	Moderate	Moderate-High	High	Low
Full Scale CSO Installations	High	None Known	Low	None Known	Low	Low	None Known
Ease of Operation	Simple	Simple-Moderate	Simple	Moderate-Complex	Simple-Moderate	Simple-Moderate	Complex
Generation Equipment Required	No	Yes	Yes	Yes	No	Yes	Yes
Persistent Residuals	Yes	Yes	No	No	Yes	No	No
Power Requirement	Low	Low	Moderate-High	High	Low	Low	Moderate-High
Present Worth Cost	Low	Low-Moderate	High	High	Moderate	Low	High

2.3 Chlorination/Dechlorination

Chlorine has been the most widely used disinfectant for wastewater and potable water in the United States due to its low cost, reliable disinfection effectiveness, and adequate supply. Chlorine is available in many forms including chlorine gas and chlorine products such as sodium and calcium hypochlorite. Gaseous chlorine is not recommended for wet-weather flow disinfection facilities that may be unmanned due to safety concerns of chlorine gas leaks. This section and Table 1 only includes descriptions of liquid (sodium hypochlorite) and granular (calcium hypochlorite) forms of chlorine.

Sodium Hypochlorite (NaOCl): Liquid sodium hypochlorite has become widely used for wastewater disinfection due to its reliability and relative ease of handling. Sodium hypochlorite can be purchased in bulk forms of 10 to 15% available chlorine or can be manufactured on site. At this point in time, NaOCl is the predominate chlorine disinfectant employed for CSO-satellite treatment

Typical sodium hypochlorite has limited shelf life and is subject to loss of available chlorine content by decay. Decay may be caused by low pH, catalysts like metal salts and high temperatures. As discussed below some manufactures can produce a cleaner sodium hypochlorite product, which can extend the shelf life. Decay rates of typical 10% and 15% NaOCl solutions are presented in Table 2.

Table 2. Chlorine Strength vs. Days of Storage

Days of Storage	Strength at 15%	Strength at 10%
Day 0	15%	10%
Day 20	13%	9%
Day 60	10%	8%
Day 120	8%	7%

One way to minimize the effects of chlorine strength decay is to store smaller volume and have more frequent deliveries. The City of Akron is in the position to purchase sodium hypochlorite in the near future (2005) from a local manufacturer, BleachTech, which is located 30 - 40 minutes from Akron, thus making routine and frequent deliveries possible. An additional benefit of purchasing sodium hypochlorite from BleachTech is that they claim to manufacture the product in a manner that minimizes or eliminates contact with metal, thus reducing metal impurities that can cause degradation in strength.

Chlorination serves primarily to destroy or deactivate disease-producing microorganisms. Generally, bacteria are more susceptible to chlorination than viruses. The disinfection effectiveness is largely a function of the chemical form of the disinfecting species. Chlorine is applied to the waste stream in molecular (Cl_2) or hypochlorite (OCl^-) form. Chlorine initially undergoes hydrolysis to form "free" chlorine consisting of hypochlorous acid (HOCl) and hydrochloric acid (HCl):

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Hypochlorous acid can further dissociate depending upon pH and temperature to hypochlorite:

$$HOCl \rightarrow OCl^- + H^+$$

A combination of hypochlorous acid and hypochlorite ion (i.e., "free" chlorine) exists at a neutral pH. Both contribute to the disinfection process; however, hypochlorous acid is the more effective disinfectant given a limited contact time. Further reactions can occur if ammonia nitrogen is present in the wastewater to form compounds called chloramines. Formation of chloramines occurs under the following ordered processes:

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$ Monochloramine
$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$ Dichloramine
$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$ Trichloramine

These reactions are complex and the products can vary with time, ammonia present, and chlorine added. Additionally, chloramine formation is strongly influenced by pH. Under neutral and alkaline conditions, monochloramines dominate, while significant amounts of dichloramine are present under acidic conditions. Chloramines contribute to the disinfection process, but the disinfection process for chloramines is less rapid than for free chlorine. Collectively, chloramines are referred to as combined chlorine residual. The sum of free residual and combined residual chlorine is referred to as total residual chlorine (TRC) representing all forms of chlorine that contribute to the disinfection process and can represent toxicity to the receiving water.

Several studies and full-scale CSO disinfection facilities have demonstrated the effectiveness of using high-rate mixing to increase disinfection performance and reduce contact time. Some of these studies and full-scale facilities are presented in Table 3. Using high-rate mixing to increase disinfection performance and reduce contact time is possible due to two factors namely 1) immediately subjecting the organisms to molecular chlorine (White, 1999) before the chloromines form and 2) greater exposure by virtue of the increased velocity gradient or mixing intensity.

Table 3. CSO Disinfection Facilities and Pilots Using High-Rate Mixing

Project Name	Agency	Location	Range of flow (cfs)	Range of Cl2 dose (mg/l)	Range of log kill	Range of TSS (mg/l)
EPA-600/2-79-134	NA	Syracuse, NY	Bench	4-25	1-6	10-715
Bench-Scale CSO Disinfection Evaluation	NA	Erie, PA	Bench	7-32	4-7	48-88
Spring Creek, Phase I and Phase 2	NYC DEP	New York, NY	0.06-0.12	12-24	3-4	25-300
EPA-600/2-79-134	NA	Syracuse, NY	1.6-7.7	4-12	1-4	46-588
EPA-600/2-79-031b	NA	Rochester, NY	0.6-1.2	2-15	1-6	5-183
Conner Creek Pilot CSO Control Facility	Mich DNR	Detroit, MI	0.01	15-30	4	68-530
WERF Wet Weather Disinfection	US EPA	Syracuse, NY	0.025	12-28	3-4	50-200
Clinton RTF	NYS DEC	Syracuse, NY	700	12-20	2-3	500
Midland RTF	NYS DEC	Syracuse, NY	667	12-20	2-3	500
Conner Creek Pilot CSO Control Facility	Mich DNR	Detroit, MI	13,262	7-25	4	75-300
Leib/St. Alban (+others*)	Mich DNR	Detroit, MI	1500	7-25	4	75-300
"Washington DC Swirl Concentrators"	US EPA Rgn 3	Washington D.C.	up to 618	up to 12	up to 4	62-855
Bath, ME - WWTP	Maine DEP & US EPA Rgn 1	Bath, ME	11	15	3-4	>220
Augusta, ME - WWTP	Maine DEP & US EPA Rgn 1	Augusta, ME	26	15	3-4	>220
North Yonkers Pumping Station	NYS DEC	Yonkers, NY	up to 119	up to 25	4-6	20-150
Yonkers Joint Treatment Plant	NYS DEC	Yonkers, NY	37.128	5-20	4-6	20-150
Hiawatha Regional Treatment Facility	NYS DEC	Syracuse, NY	65	12	3-4	500
Rockland, ME - WWTP	Maine DEP & US EPA Rgn 1	Rockland, ME	35	25	3-4	147

Calcium Hypochlorite ($CaOCl_2$): Calcium hypochlorite is a relatively stable compound of chlorine in terms of maintaining product strength, and is commercially packaged either as a coarse powder or in tablet form or in wet form. The most commonly used calcium hypochlorites will yield 70 percent available chlorine by weight. In dry form, it maintains its strength longer than sodium hypochlorite, allowing long term storage. It loses 3 to 5 percent available chlorine every year. Like sodium hypochlorite, it loses its strength with exposure to air and should be stored properly to retain its strength. More importantly, proper storage can prevent the decomposition of calcium hypochlorite, which is exothermic and can occur very rapidly in the presence of heat and moisture. It can decompose so rapidly as to auto-combust or ignite packaging material.

Dechlorination: Free chlorine and combined chlorine residuals are toxic to aquatic life at certain concentrations. Intermittent discharges of total residual chlorine have been recommended not to exceed 0.2 milligrams per liter for a period of 2 hours per day where more resistant species of fish are known to live, or 0.04 milligrams per liter for a period of 2 hours per day for trout or salmon (Brungs, 1973). It is therefore sometime necessary to dechlorinate (i.e. reduce chlorine compounds) the chlorinated effluent before it is discharged into a receiving water.

Dechlorination may be accomplished through injection of any suitable reductant, such as a solution of sodium bisulfite ($NaHSO_3$) or sulfur dioxide (SO_2) into the process flow, following the chlorination process. The dechlorination process is nearly an instantaneous reaction. A potential problem with dechlorination is the possible depletion of dissolved oxygen by excess sulfite ion, thus requiring oxygenation prior to discharge.

<u>Advantages</u> of chlorination/dechlorination disinfection of CSO are:
- widely used and accepted for many areas of disinfection
- requires minimal operator attention
- relatively low cost

<u>Disadvantages</u> of chlorination/dechlorination disinfection of CSO are:
- produces disinfection byproducts
- reacts with ammonia to form chloramines
- corrosive nature of chlorine
- limited shelf-life of sodium hypochlorite
- disinfection effectiveness is pH dependent and is reduced at pH 8 or greater
- possible dissolved oxygen depletion of dechlorinated effluent
- safety considerations associated with chemical storage

2.4 Chlorine Dioxide

Chlorine dioxide (ClO_2) historically has proven its capabilities as an outstanding bactericide and viricide (White, 1999). ClO_2 is a yellowish gas at room temperature, but it is most often produced and used in an aqueous solution. ClO_2 is ten times more soluble in water than chlorine. Due to the highly reactive nature of ClO_2, it must be generated on-site on an as needed basis. In contrast to chlorine, ClO_2 does not react with ammonia and other nitrogenous compounds to form chlorinated organics as chlorine does and its disinfection efficiency is high over a wider pH range than chlorine. These can be the most important issues.

ClO_2 may be generated on-site by one of the following processes:

- Acid/ sodium chlorate generation,
- Acid/ sodium chlorite generation,
- Chlorine/sodium chlorite generation,
  a) solution generators
  b) gas-solid generators,
- UV radiation/sodium chlorite generation.

The acid/sodium chlorate process is only appropriate for large-scale production, such as in industrial paper bleaching operations. It is not cost effective for small-scale production, such as required by water and wastewater disinfection. The acid /sodium chlorite process is generally inefficient and is primarily used for generating ClO_2 on a laboratory scale. While this process has been used at some water treatment plants in Europe (White, 1999), it is generally not popular as the yield of ClO_2 is quite low (e.g., less than 50%). By far, the most prevalent method of ClO_2, generation for water and wastewater treatment is the chlorine/sodium chlorite process. The chlorine/sodium chlorite process can be further broken down into two types of generators, solution and gas-solid generators. The typical reaction of the chlorine/sodium chlorite solution generation is as follows:

$$Cl_2\text{(gas)}+\text{Sodium Chlorite(solution)} \rightarrow ClO_2\text{(solution)}+\text{Sodium Chlorite + Chlorate Ion}$$

There are two important points to note in this reaction. The first is that the reaction is carried out in the presence of excess chlorine in order to achieve high conversion (82-90 percent) of chlorite to ClO_2. However, excess chlorine favors chemical reactions that result in the formation of the chlorate ion in the final ClO_2 product. The second is that unreacted sodium chlorite remains as a byproduct of the reaction. Chlorine dioxide, chlorite and chlorate ions can be are toxic to aquatic life at certain concentrations. However, when chlorine gas is allowed to react directly with an excess of moist solid sodium chlorite, chlorine dioxide gas that is free of chlorine, chlorate ion, and chlorite ion are produced (CDG Technology Inc., 1995). This is the gas-solid generator as described by following equation:

$$Cl_2\text{(gas)} + 2NaClO_2\text{(solid)} \rightarrow 2\ ClO_2\text{(gas)} + 2NaCl\text{ (solid)}$$

Using an excess of sodium chlorite favors the production of ClO_2 over chlorate ion and minimizes the possibility of chlorine impurities in the ClO_2 product. Since the CIO_2, produced is in the gas phase, neither chlorate ion nor chlorite ion are present. The gas-solid generator provides an actual ClO_2 yield of 95 to 98 % (A.R. Pitochelli, 1995). The one disadvantage to this ClO_2 generation process is that it employs chlorine gas as a feedstock. Restrictions on the transportation and use of chlorine gas limit the application of this generation process. As an alternative, the chlorine gas used in this generation process could be produced on-site either electrolytically or by the reaction of acid with sodium hypochlorite.

A new process that uses the acid/sodium chlorate chemistry is the Ben Franklin™ process, manufactured by CDG Technology. The Ben Franklin™ process uses the chemical reaction of hydrochloric acid with sodium chlorate to generate chlorine dioxide, a technique common for pulp bleaching. However, in contrast to generation plants used in the pulp industry, the Ben Franklin™ process produces a mixture of chlorine and chlorine dioxide, both in the gas phase. These gases, as produced by the Ben Franklin™ generator, may be applied directly to water as a combination, or they may be separated and applied at different points in the water treatment process. In its most direct application, the mixed chlorine/chlorine dioxide product can be injected into the water to be treated. The result is a mixed disinfectant containing chlorine dioxide and chlorine. The chlorine dioxide acts as a very rapid disinfectant/oxidant while the chlorine persists longer. This can be an advantage in the water systems where a residual is desired but a disadvantage in the receiving water where TRC is a concern.

Chlorine dioxide disinfection of wet-weather flows has been studied recently in two separate projects, New York City Spring Creek (CDM and M&A, 2001) and WERF/EPA (WERF, 2005). In the Spring Creek project reductions in indicator bacteria and virus were measured in addition to effluent toxicity. In the WERF/EPA project reductions in indicator bacteria and effluent toxicity were measured. In both these projects chlorine dioxide was applied with an induction mixer and five minutes of contact.

In the Spring Creek project a dose of between 6 and 9 mg/L of chlorine dioxide was required to achieve a 4-log reduction in *Escherichia coli* (E. coli). In comparison it required between 20-28 mg/L sodium hypochlorite to achieve the same E. coli reductions. Virus reductions were also measured; however the concentration of naturally occurring viruses were too low to detect. Therefore, bacteria phage, including T4, f2, MS2 and X174 were seeded into the chlorine dioxide influent. A 10 mg/L chlorine dioxide dose resulted in nondectable levels of virus. Toxicity was also measured at Spring Creek during several distinct events; when the chlorine dioxide dose was 10 mg/L or less and the chlorite concentration in the effluent sample was less than 5.8 mg/L, no toxicity was observed in the test organisms (opossum shrimp and sheepshead minnow). These data are discussed in more detail in Section 3.

In the WERF/EPA project a dose of 9 mg/L was required to reach an effluent concentration of 1,000 cfu/100ml of E. coli. In comparison it required 22 mg/L sodium hypochlorite to achieve the same E. coli effluent concentrations. It should be pointed out that for this small-scale pilot chlorine dioxide was produced by acidifying sodium chlorite, which resulted in higher residual chlorite in the product than in the Spring Creek project. As described in this section, other methods of chlorine dioxide generation do not produce chlorite as a residual to generation. Therefore by using these methods of generation aquatic toxicity could be avoided without the addition of reducing agents. Additionally, the effluent samples collected for the WERF/EPA project were based on the whole effluent sample and do not account for potential receiving water dilutions. Effluent toxicity was measured using the WET and Microtox™ tests. For the chlorine dioxide effluent process, aquatic toxicity corresponded to residual chlorine dioxide and chlorite concentrations. Seven of the nine events had 100 percent mortality for the aquatic test organisms; the mortality rate decreased in the last two events, both of which had non-detected concentrations of residual chlorine dioxide and low chlorite concentrations (<1 mg/L). The correlation between residual chlorine dioxide and chlorite and the Microtox™ EC_{50} was strong (R2 value of > 0.83) and demonstrates that aquatic toxicity increases with increases in chlorine dioxide and chlorite. Aquatic toxicity decreased in events when ferrous sulfate was used to reduce the chlorine dioxide and chlorite residuals, which indicates that toxicity problems can be avoided with proper control prior to discharge. These data are discussed in more detail in Section 3.

A recent advance involving a process of ultraviolet radiation of a single chemical, sodium chlorite ($NaClO_2$), has emerged as a new and innovative technology for ClO_2 generation. ClO_2 is produced by this method through the disassociation of chlorite, a process that requires very little energy in the generation process. Under proper control and intensity, UV radiation of aqueous sodium chlorite can generate ClO_2, by the following reactions (UVD Inc., 1996):

$$NaClO_2 + \text{UV radiation} \rightarrow Na^+ + ClO_2$$

$$Na^+ + H_2O \rightarrow NaOH$$

The primary benefit of this generation method compared to conventional ClO_2 generation methods is that chlorine gas is not used in the generation process. This technology was developed in several bench-scale facilities. The first full-scale pilot of the UV-ClO_2 generation process was operated at the Meadowbrook-Limestone POTW, Onondaga County, NY. This system was also operated as part of an alternative disinfection study for the Onondaga County Department of Drainage and Sanitation in 1999.
The role of ClO_2 as an oxidizing agent in water involves three steps:

1. ClO_2 gains one electron to form chlorite (ClO_2^-):
   $ClO_2 + 1e^- = ClO_2^-$

2. Chlorite gains four electrons to form chloride (Cl^-):
   $ClO_2^- + 2H_20 + 4e^- = Cl^- + 4OH$

3. Under alkaline conditions, ClO_2 can more readily degrade to form chlorate (ClO_3^-) and chlorite (ClO_2^-):
   $2\ ClO_2 + 2OH^- = H_2O + ClO_2^- + ClO_3^-$

The first step to form chlorite can usually occur in a pH range normally found in wastewater. The second step does not occur as readily; hence, the overall five-electron transfer for complete reaction through the first two steps is not often available. The third step does not occur to an appreciable extent at a pH less than 8; however, the rate of degradation is influenced by the ClO_2 concentration. Higher rates of degradation occur at higher concentrations of ClO_2.

Advantages of high-rate ClO_2 disinfection of CSO include:
- 10 times greater aqueous solubility than chlorine
- effective over a broader pH range than chlorine
- does not react with ammonia
- more effective bactericide and viricide than chlorine at comparable doses
- requires less contact time than chlorine
- no production of trihalomethanes (THMs)

Disadvantages of ClO_2 disinfection of CSO are:
- requires on-site generation
- conventional method of generation requires use of gaseous chlorine
- corrosive nature of ClO_2
- safety considerations associated with ClO_2 disinfection systems
- ClO_2 strength degrades readily unless refrigerated
- ClO_2 is an innovative technology for CSO treatment, with no full-scale CSO application data

2.5 Ultraviolet radiation (UV)

The use of UV for disinfection of secondary effluent is an established technology with over 1,000 systems in operation throughout the United States and Canada. These systems range from 20,000 gpd to 300 MGD; however, only 30 units have been installed at wastewater treatment plants with flows in excess of 50 MGD, which all provide filtration prior to disinfection with UV with the exception of the Sand Island WWTP. Furthermore there are only two full-scale UV facilities for CSO treatment , namely Columbus, GA and Bremerton, WA. Additionally, there is one full-scale UV disinfection facility that is proceeded by primary clarification at the Sand Island WWTP; primary clarified wastewater can be similar to preliminarily treated CSO. However several various scale pilots have been conducted to show its effectiveness in poor water quality of 40 to greater than 100 mg/l of TSS as discussed later in this section.

The Sand Island WWTP provides primary clarification for dry weather flows up to 86 mgd. The primary effluent is then disinfected with high intensity medium pressure UV technology before it is discharged to the receiving water. The target fecal coliform log reduction in is 2.5. There are 1,334 total UV lamps installed in six channels with 4 banks each.

In Columbus GA, the CSO facility includes vortex separation, compressed media filtration and UV disinfection up to 15 MGD. Medium pressure high intensity bulbs are applied to the compressed media filter effluent with a typical contact time of 2 seconds with light transmittance levels of 30% to 40%. UV disinfection is accomplished for the majority of the CSOs, typically the small events. The larger events are disinfected with sodium hypochlorite. This facility is described in more details in both the pilot- and full-scale case studies (Sections 3 and 4).

In the Bremerton WA, the CSO facility includes ballasted flocculation followed by UV disinfection. CSO flows are physically and chemically treated using an ACTIFLOW process and then treated with low-pressure, high-output UV disinfection before it is discharged into Puget Sound.

Ultraviolet light irradiation is a physical process offering short detention times, typically 5 to 7 seconds, that does not involve the addition of chemicals. UV disinfection does not produce known toxic residuals or byproducts that are a risk to humans or aquatic systems. Some concerns have been raised regarding the development of organism mutations, but no conclusive data exists. UV technology works on the principle that all microorganisms that contain nucleic acids are susceptible to damage through the absorption of radiation in the UV energy range. The extent of damage, mutation, or death will depend upon the organism's resistance to radiation penetration. This depends on several factors, including cell-wall composition and thickness. UV disinfection is accomplished by electromagnetic radiation at specific wavelengths ranging from 100 to 400 nanometers (nm). Optimum disinfection is achieved at a wavelength of 253.7 nm.

The intensity of UV light produced is described in terms of energy per unit area with the most common units of milliwatts per square centimeter (mW/cm^2). UV dose is computed by multiplying this intensity by the exposure time and is represented in units of $mW\text{-}sec/cm^2$. UV-dosage requirements depend upon several parameters, including the frequency and intensity of the UV radiation, the number and configuration of the UV lamps, the distance between the lamp surface and the waste stream, the chamber turbulence, and the wastewater's absorption coefficient and exposure times. UV disinfection systems also vary by lamp technologies.

Lamp technologies are categorized as follows:

Lamp Type	Operating Pressure (torr)
• Low-pressure, low-intensity	10^{-3} to 10^{-2}
• Low-pressure, high-intensity	10^{-1} to 10^{-2}
• Medium-pressure, high-intensity	10^{2} to 10^{4}

Low-pressure lamps result in 85% of their output being monochromatic at a wavelength of 253.7 nm. UV disinfection facilities have historically been designed using low-pressure, low-intensity UV lamps. The low output of these systems limited their use to drinking water and wastewater following secondary treatment. Due to the lower intensity of these lamps as compared to higher intensity systems, low-pressure, low-intensity systems have not been considered feasible for CSO wastewater.

Medium-pressure, high-intensity lamps differ substantially in terms of the output spectrum of the lamps. The radiation from these lamps is emitted over a large fraction of the UV spectrum. Only a small fraction of the UV output is in the germicidal wavelength of 254 nm. However, the higher UV light intensity produced by these lamps, provides a higher intensity within the reactor with fewer lamps as compared to low-pressure, low-intensity systems. The advent of medium-pressure, high-intensity lamp has redefined the suitability of UV disinfection in the wastewater arena. Medium-pressure, high-intensity lamp systems are a promising technology for disinfection of the high wastewater strength normally found in CSO discharges. CSO discharges are characterized by low UV transmissivity and relatively high TSS and require higher intensity radiation to provide the penetration necessary for disinfection. A significant amount of the lamp input energy for medium-pressure lamps is lost as thermal energy to the surrounding water. As a result, power consumption is significantly greater than for low-pressure technology. Low-pressure, high-intensity UV lamps are a recent development in lamp technology. Manufacturers of these systems claim that they can achieve the high intensities of medium pressure lamps at the higher energy efficiency of low-pressure lamps. This technology promises high disinfection efficiency while offering reduced operational costs. At the present, there are only a few manufacturers offering this technology and there is limited data on the performance of these systems.

UV disinfection systems vary in reactor geometry, lamp type, orientation and arrangement, and lamp power. These factors dictate how the electromagnetic energy is delivered to the wastewater. When UV systems are used for disinfection of wastewater of poor quality, an operational concern arises over the potential for lamp fouling. The medium-pressure, high-intensity lamps are operated at high temperature to provide the necessary energy required for disinfection. The high temperature can result in fouling of the lamps with a glaze-like film. This film acts to reduce the energy transferred from the lamps to the wastewater. To alleviate this problem, elaborate systems have been devised to provide a mechanism for cleaning the quartz lamp sleeves. These consist of mechanical and mechanical/chemical-wiping systems, sonic cleaning and chemical baths for removal of accumulated material on the quartz sleeves.

UV disinfection of wet-weather flows has been studied recently in two separate projects, New York City Spring Creek (CDM and M&A, 2001) and WERF/EPA (WERF, 2005). In the Spring Creek project, reductions in indicator bacteria and virus were measured in addition to effluent toxicity. In the WERF/EPA project reductions in indicator bacteria and effluent toxicity were measured. In both these projects the UV lamp technology was medium pressure, high intensity.

In the Spring Creek project an applied UV dose of between 75 and 160 mWsec/cm^2 was required to achieve a 4-log reduction in E. coli. In comparison it required between 20-28 mWsec/cm^2 sodium hypochlorite to achieve the same E. coli reductions. Virus reductions were also measured; however the concentration of naturally occurring viruses were too low to detect. Therefore, bacteria phage, including T4, f2, MS2 and X174 were seeded into the UV influent. With the exception of T4, UV disinfection at 145 mWsec/cm^2 resulted in nondectable levels of virus. Toxicity was also measured at Spring Creek during several distinct events. No toxicity to opossum shrimp and sheepshead minnow was measured in the UV effluent, a clear benefit to UV disinfection. These data are discussed in more detail in Section 3.

In the WERF/EPA project a dose of 129 mWsec/cm^2 was required to reach an effluent concentration of 1,000 cfu/100ml of E. coli. In comparison it required 22 mg/L sodium hypochlorite to achieve the same E. coli effluent concentrations. Effluent toxicity was also measured. No toxicity to water fleas and fathead minnow was measured in the UV effluent, a clear benefit to UV disinfection. These data are discussed in more detail in Section 3.

Advantages of UV disinfection of CSO include:

- no disinfectant chemicals are required
- no byproducts
- short contact time
- ability to deactivate wide range of pathogens
- more effective protozoan deactivation than chlorine
- potential for simple control (on-off), especially with respect to intermittent operation

Disadvantages of UV disinfection of CSO are:

- sensitivity to high solids concentrations and transmissivity to achieve comparable bacteria reductions as chemical disinfectants
- fouling of UV lamps by CSO wastewater and associated operation and maintenance costs
- UV is an innovative technology for CSO treatment, with limited full-scale CSO application data
- high energy demand

2.6 Bromine

Bromine disinfection has the advantage of providing a more reactive disinfectant species namely, hypobromous acid than the chlorine counterpart, hypochlorous acid. However, there have been conflicting reports on the toxicity of organobromines relative to organochloramines. Most studies of bromine have been performed on drinking water and therefore organobromines have not been a major issue. Studies by Hohfeld, et al of Dow Chemical reported that reaction products of bromine chloride are less toxic to fish than those produced from chlorine. This is attributed to the rapid breakdown of bromamines. However, certain organobromines are more toxic than organochloramines.(White,1999) Some organobromines may be more toxic than organochloramines, but they are generally found in lower concentrations due to the lower dosage of bromine than chlorine that is required as a bactericide. This may explain the conflicting results of these studies.

Many forms of bromine are available for disinfection, such as, pure bromine, bromine chloride, sodium bromide and BCDMH. Pure bromine and bromine chloride are liquids at normal atmospheric conditions, but are highly volatile. These forms of bromine are stored in sealed containers and generally introduced into the wastewater as a vapor using the similar equipment as used for gaseous chlorine. Sodium bromide is a liquid form at normal atmospheric conditions, but is not as volatile as pure bromine and bromine chloride. Owing to the inert nature of the sodium bromide, sodium hypochlorite is used to react with the sodium bromide to form hypobromous acid. Bromochlorodimethylhydantoin (BCDMH) was developed to be in solid state at normal atmospheric conditions to facilitate storage and handling. Sodium bromide is the only form of bromine in use as a disinfectant for CSO in the USA and has had only limited use in CSO disinfection to date. The only known CSO application in the USA is Burlington, Vermont.

Recent developments in Japan by Ebara Corporation have shown that full-scale facilities up to 1,900 MGD can be effectively operated using a powered form bromochlorodimethylhydantoin (BCDMH) at one-half the equivalent Cl_2 dose and less than half the toxicity using Microtox^{TM}. This process will be discussed further under a separate cover if it is decided to proceed with piloting.

Advantages of sodium bromine for CSO disinfection include the following:

- more reactive disinfectant than chlorine
- three times more soluble than chlorine
- residuals are less persistent than chlorine

Disadvantages of sodium bromine disinfection of CSO are:

- limited availability of sodium bromine
- limited full-scale application experience for CSO
- corrosive nature of bromine
- produces disinfection byproducts
- safety considerations associated with chemical storage

2.7 Ozone

Ozone is a chemical oxidizing agent that has been widely used for disinfection of drinking water systems and bleaching in the pulp and paper industry. Ozone gas is an extremely strong oxidant and is well established for its powerful antibacterial and antiviral properties. Ozone is a rapid disinfectant, requiring substantially less contact time than conventional chlorination disinfection systems to achieve the similar inactivation of bacteria at comparable doses. Based upon research performed by the U.S. Environmental Protection Agency (EPA) in the 1970s and early 1980s, ozone was considered to be one of the most feasible disinfection alternatives to chlorination. However, there presently are few operating facilities using ozone for disinfection of municipal wastewater. This may be attributable to the relatively high initial capital costs associated with ozone generation equipment and the poor operating records of previous generations of ozone generators. Also, when compared to Cl_2 and ClO_2 in the Spring Creek (CDM and M&A, 1997) projects utilizing high rate disinfection (five minute contact) it required 10-15 minutes of contact time resulting in higher projected costs. The longer contact time required in the Spring Creek project is contrary to other findings and this difference is attributed to the difference in contact chamber design. Ozone readily gaseous out off solution and contactor efficiency is therefore very important (White, 1999).

Since ozone is unstable, it must be generated on site. The corona discharge process is the most commonly used method of ozone generation. Ozone is produced when oxygen is subjected to a high-voltage electrical current. The voltages used in this process range from 7,500 to 30,000 volts. Passing air or oxygen through this high voltage electrical field produces ozone. Air preparation is required if oxygen is not used as the feed source. Oxygen may be purchased as liquid oxygen or generated on-site using pressure swing adsorption, vacuum-assisted pressure swing adsorption, or cryogenic air separation technology. Commercial ozone generators can produce 1 to 4 % ozone using air as the feed gas and 6-14% ozone, by weight using oxygen as the feed gas. In present day ozone generators, only approximately 10 percent of the applied energy goes toward the generation of ozone (White, 1999). Most of this energy is dissipated as heat.

The major components of an ozone generator include:

- feed gas preparation,
- electrical power supply,
- high voltage and ground electrodes with dielectric material forming the discharge gap,
- cooling system to remove heat generated.

Gaseous ozone is dissolved in the wastewater by injecting the ozone gas into the process stream in an ozone reactor or contactor. The most common ozone dissolution systems include fine bubble diffusers and injectors. A baffled retention tank is commonly used to allow residual ozone to continue to react with the process water. Ozone is relatively volatile and is easily stripped from water. Dissolved ozone residual is reasonably stable in clean water. However, in the presence of oxidizable organic and inorganic matter, any residual ozone is rapidly consumed. A benefit of ozone disinfection is that dissolved oxygen is formed from the decomposition of ozone which can elevate oxygen levels in treated water. If insufficient detention time is provided or if ozone dose exceeds demand and decay, chemical quenching of excess ozone residual may be needed to remove any residual ozone. Quenching agents include hydrogen peroxide, sodium bisulfite, sodium metabisulfite, and sulfur dioxide.

Byproducts from the reaction of ozone with wastewater have been identified. In general, the reaction of organic molecules with ozone leads to destruction of the original molecule, often forming a more biodegradable product; however, more research relating to the byproducts of wastewater ozonation is needed. Ozone byproducts include bromate, aldehydes, ketones, acids, and other rapidly biodegradable organic compounds.

Ozone is a toxic and corrosive gas requiring proper safety precautions in design and operation. The major issues that must address during design are:

- Need for watertight, gas-tight contactor (ozone reactor).
- Need for collection of off-gas and ozone destruction (typically using thermal/ catalytic off-gas destruction) prior to atmospheric discharge.
- Monitoring, alarm, and ventilation systems.
- Corrosion resistant construction materials.

<u>Advantages</u> of ozone disinfection of CSO are:

- high oxidation potential and more reactive disinfectant than chlorine
- more effective bactericide and viricide than chlorine at comparable doses
- residuals are far less persistent than chlorine
- fewer disinfection byproduct concerns than chlorine

<u>Disadvantages</u> of ozone disinfection of CSO are:

- high capital costs
- high operation and maintenance costs
- corrosive nature of ozone
- safety considerations associated with ozone disinfection systems
- high ozone consumption due to reaction with organic material in wastewater
- ozone is an innovative technology for CSO treatment, with no full-scale CSO application data

2.8 Peracetic acid

Peracetic acid (CH3COOOH) (PAA), also known as ethaneperoxoic acid, peroxyacetic acid, or actyl hydroxide, is a strong oxidant. Based on limited demonstration data for disinfection of secondary treatment plant effluent, peracetic acid appears to be an effective disinfectant and should be evaluated further for treating CSOs. The equilibrium mixture of hydrogen peroxide and acetic acid that produces PAA is too unstable and explosive to transport, and so PAA must be produced on site. The decomposition of PAA results in acetic acid, hydrogen peroxide and oxygen.

The Oxymaster technology, as manufactured by Interox Chemicals, Ltd, has been applied for disinfection of stormwater discharges. Oxymaster is a disinfectant consisting of peracetic acid, water, hydrogen peroxide, and acetic acid, of which peracetic acid (PAA) is the active ingredient.

Interox claims the principal advantages of Oxymaster are:
- fast acting disinfection
- non-tainting to wastewater
- it produces safe, innocuous decomposition products that are non-polluting.

Disadvantages of the Oxymaster are:
- need to mix two chemicals which requires stoichiometric control onsite
- reduced effectiveness at higher suspended solids concentrations
- highly corrosive
- byproducts can exert an oxygen demand
- no full-scale demonstration of the Oxymaster process has been conducted to date

2.9 Electron Beam irradiation (E-Beam)

In the E-Beam process, a stream of high energy electrons is directed into a thin film of water or sludge. The electrons break apart water molecules and produce a large number of highly reactive chemical species. The reactive species formed are the oxidizing hydroxyl radical (OH), the reducing aqueous electron and hydrogen atom. Reactions of these intermediates with contaminants (bacterial, viral, hazardous organics, etc) occur at diffusion limited rates, and the treatment is complete in less than one-tenth of a second. The E-Beam process, an innovative treatment system initially developed for the disinfection of sludge from municipal wastewater treatment plants and the destruction of hazardous organic compounds, was developed by High Voltage Environmental Applications, Inc. (HVEA).

The accelerator produces high voltage by a three phase transformer with multiple secondary windings that are energized by insulated core segments in an iron core. The resulting voltage and current are transferred to an accelerator tube and tungsten wire filament, respectively. The electrons generated by the tungsten filament are then accelerated by means of a 500 kV voltage differential. The beam current is continuously variable from 0 to 40 milliamperes. Once the accelerated electrons pass through the accelerator tube, they are deflected magnetically (scanned) to sweep a larger irradiation filed. The scanned electron beam then impacts the flowing process stream producing highly reactive species.
Currently there is insufficient information on the E-Beam process to make a full determination of its usefulness for CSO disinfection, but a pilot study performed for the New York City Department of Environmental Protection (NYCDEP) determined the advantages and disadvantages of the E-Beam system.

Advantages of the E-Beam technology for CSO disinfection include the following:
- no disinfection chemicals are required
- no byproducts are known to be produced
- very short contact time required
- potential to deactivate a wide range of pathogens
- potential to penetrate waste streams with high solids concentrations

Disadvantages of E-Beam disinfection of CSO are:

- thin process flow stream which is impractical at high flows
- excessive pre-treatment, straining of influent is required for this delivery system
- safety considerations with high voltage technology and the generation of X-ray radiation
- no full scale application experience for CSO
- high capital costs
- high operation and maintenance costs

3. DESCRIPTION OF FULL-SCALE AND PILOT SCALE DEMONSTRATIONS

Three case studies of recent wet weather flow disinfections projects are presented in this section. These projects are:

1. New York City Department of Environmental Protection - Spring Creek AWPCP Upgrades (CDM and M&A, 1997 and CDM and M&A, 2001).
2. Columbus, Georgia Advanced Demonstration Facility for Wet Weather Treatment Technologies. Wet Weather Demonstration Projects (WWETCO, 2001).
3. Identifying Technologies And Communicating The Benefits And Risks Of Disinfecting Wet Weather Flows (WERF, 2005)

The purpose of presenting the results of these demonstrations is to provide data collected from actual field testing of the disinfection technologies presented in Section 2. It is important to note that these results are site-specific to the demonstration study area. Disinfection effectiveness is related to site-specific water quality and to a lesser degree facility design/layout. The results presented from these demonstrations can be used to provide a indication of doses, residuals and disinfection byproducts and costs for other study areas.

3.1 Spring Creek New York City Auxiliary Wastewater Pollution Control Plant Upgrades

3.1.1 Background

The primary objective of the disinfection pilot study was to evaluate the relative performance of four disinfection technologies for the treatment of CSO wastewater. Flow rates tested for each technology were as follows:

Chlorination/Dechlorination	30-50 gpm
Chlorine Dioxide	30-50 gpm
Ozone	6-10 gpm
UV	58-240 gpm

The results of the pilot study were intended to provide a basis for possible selection of an alternative disinfection technology for use at the Spring Creek Auxiliary Wastewater Pollution Control Plant (AWPCP) and to develop full-scale design criteria for application at the Spring Creek AWPCP. Figure 1 illustrates the pilot system flow schematic.

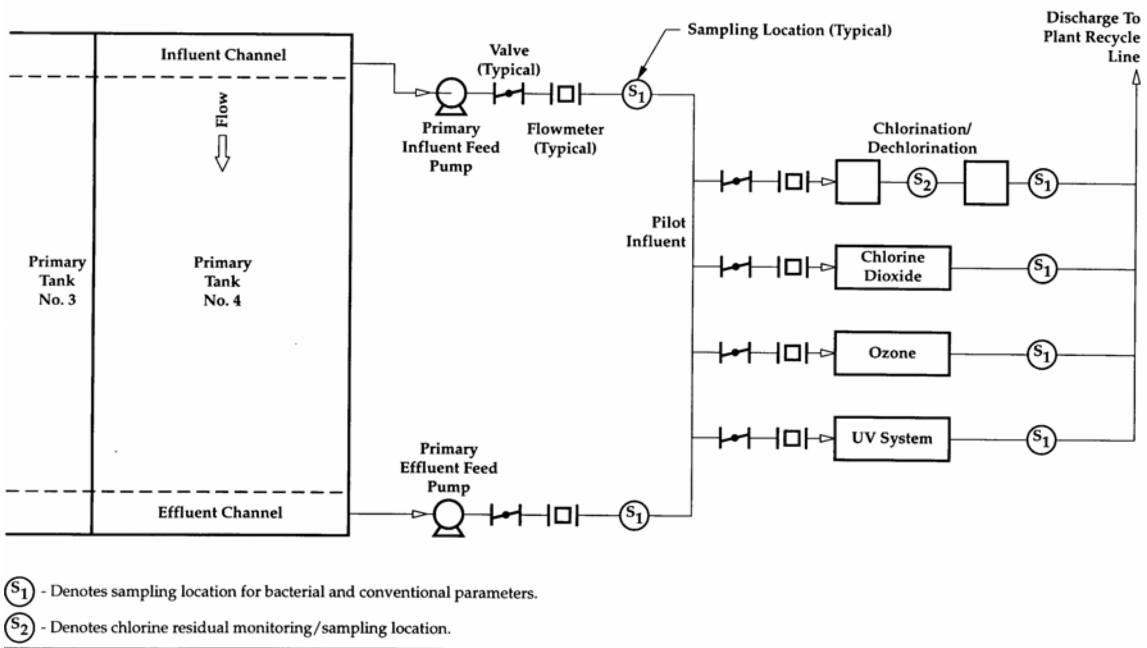


Figure 1. Spring Creek AWPCP Pilot System Flow Schematic

The four disinfection technologies demonstrated in this pilot study were ultraviolet light, ozone, chlorine dioxide, and chlorination/dechlorination. The following is a description of the disinfection equipment tested during the pilot study:

<u>UV Pilot Equipment</u>: The UV pilot disinfection system was provided by Aquionics, Inc., of Erlanger, Kentucky. The unit was a medium pressure, high intensity UV unit.

<u>Ozone Pilot Equipment</u>: The ozone unit was a trailer mounted system manufactured by Aquifine Wedeco Environmental Systems, Inc. (AWES), of Valencia, California. Ozone was generated on-site and on-demand using 90 percent pure oxygen and a corona discharge type ozone generator.

<u>Chlorine Dioxide Pilot Equipment</u>: Two chlorine dioxide generators were used in this project. The first was a UV radiation/sodium chlorite generator provided by UVD Inc. of Syracuse, New York. The second was the chlorine/sodium chlorite gas-solid generator provided by CDG Technology of New York City.

<u>Chlorination/Dechlorination Pilot Equipment</u>: The chlorination/dechlorination pilot unit was a skid mounted system consisting of chlorination and dechlorination contact tanks with mixers, chemical day tanks with solenoid metering pumps, and residual instrumentation. UVD Inc. provided the pilot system.

These technologies were operated in parallel over a total of 16 test runs. This allowed comparison of disinfection efficiency of each technology on identical wastewater. Samples of the common pilot influent and the treated pilot effluents were collected and tested for the following water quality parameters.

TSS	VSS	Settleable Solids	Soluble BOD	
BOD	TKN	COD	TOC	
Iron	F. Coliform	T. Coliform	E. Coli	
Entercocci	Virus	Chlorite	Chlorate	UV Transmissivity
pH	Temperature	DO	Disinfection Residuals	Toxicity

3.1.2 Dose-Response Relationships Results and Virus Results

Dose versus log reduction and effluent bacteria density relationships were developed for each bacteria group for each disinfection technology. These relationships were developed to identify the dose required to achieve a range of bacterial log reductions and effluent concentrations. Bacterial log reductions increased as dose increased for each disinfection technology.

The Figures 2 through 5 depict the results of these analyses for the fecal coliform bacterial group for each disinfection technology. It is important to note that the doses plotted for these graphs are based on average doses. In general, these graphs demonstrate that as dose increase, bacterial log reductions increase and the effluent concentrations decrease. The graphs do not always depict consistently increasing or decreasing log reductions or concentrations as dose increases due to statistical differences between the ranges of doses. The inconsistencies are possibly a result of limited data and highly variable influent bacterial concentrations. Projected dose-response relationships have been shown at the higher doses where inconsistencies were observed.

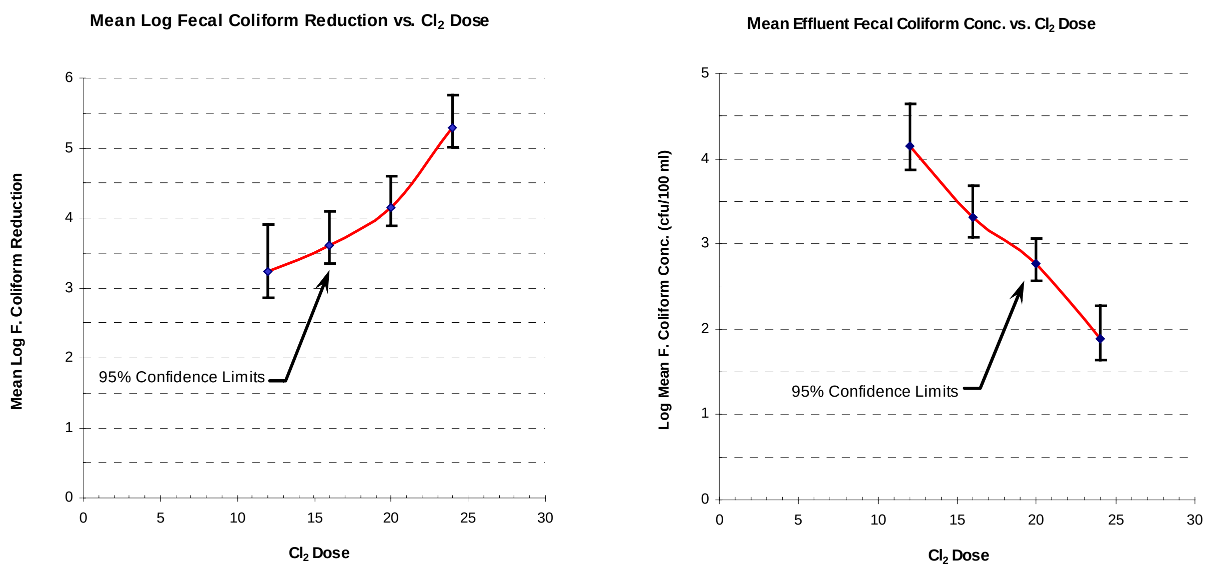


Figure 2. Chlorine Dose vs. Fecal Coliform Reductions and Effluent Concentrations

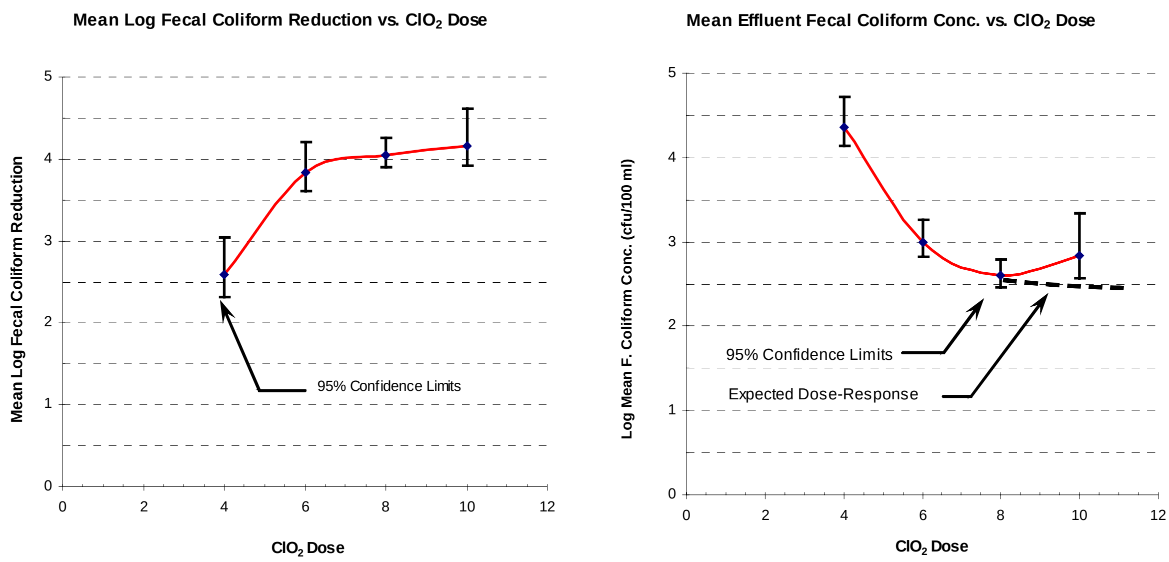


Figure 3. Chlorine Dioxide Dose vs. Fecal Coliform Reductions and Effluent Concentrations

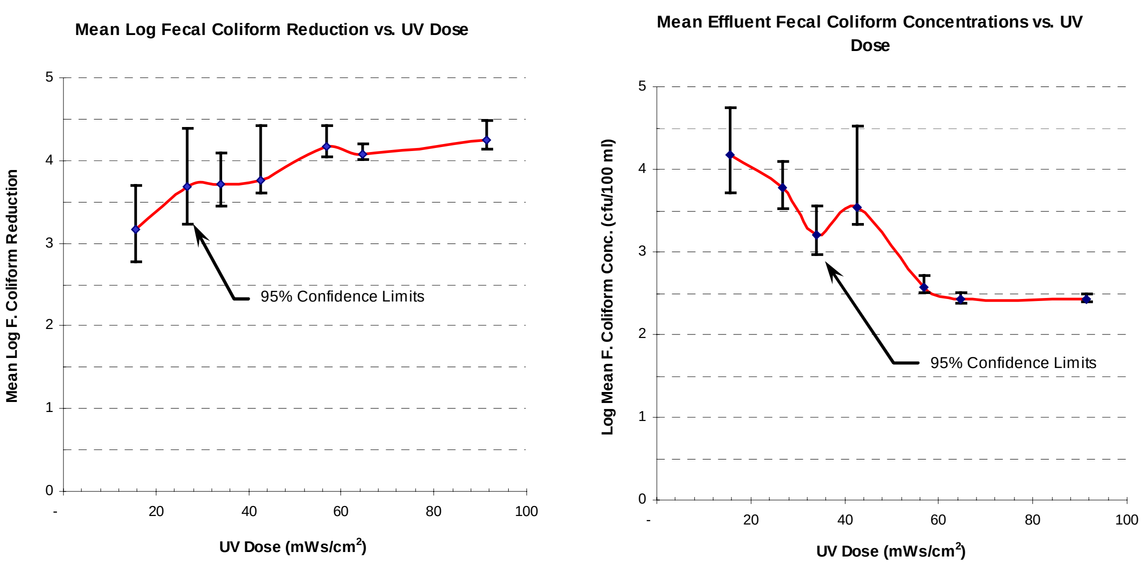
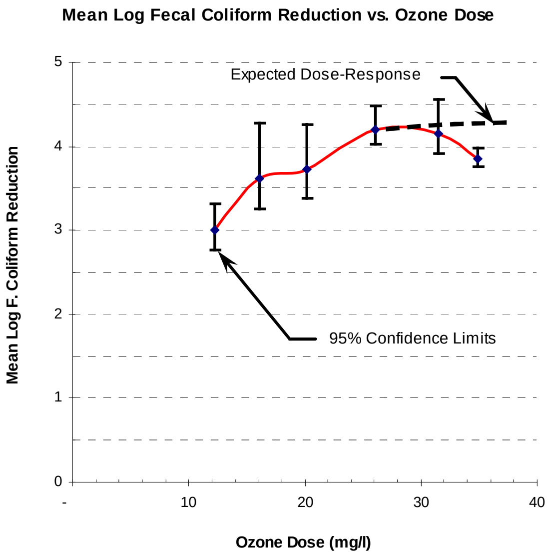


Figure 4. UV Dose vs. Fecal Coliform Reductions and Effluent Concentrations



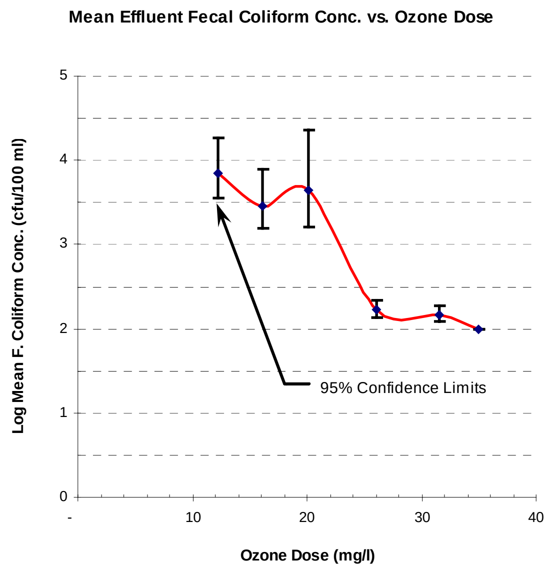


Figure 5. Ozone Dose vs. Fecal Coliform Reductions and Effluent Concentrations

Table 4 summarizes the estimated range of doses required for each disinfection technology to achieve corresponding bacterial concentrations of 1,000 cfu / 100 ml, 3-log and 4-log bacterial reductions.

Table 4. Disinfection Criteria and Doses Required to Achieve Criteria, Spring Creek 2001

Parameter	*Disinfection Criteria*	*Required Disinfection Dose*			
		UV Dose (mWs/cm2)	*Ozone Dose (mg/l)*	*Chlorine Dioxide Dose (mg/l)*	*Chlorination/ Dechlorination Dose (mg/l)*
Total Coliform	1,000 cfu/100 ml	>100	37 (e)	>8	>30
	3-log reduction	30	15	>6	25
	4-log reduction	100	40 (e)	N/A	>30
Fecal Coliform	1,000 cfu/100 ml	50	24	5	18
	3-log reduction	20	12	6	10
	4-log reduction	55	40 (e)	8	20
Escherichia Coli	1,000 cfu/100 ml	35	23	5.5	17
	3-log reduction	15	8 (e)	4	8
	4-log reduction	40	40 (e)	6	18
Enterococcus	1,000 cfu/100 ml	35	12 (e)	5.5	22
	3-log reduction	25	16 (e)	5.5	22
	4-log reduction	50	>40	9	26 (e)

Notes:
1. Disinfection criteria indicate either effluent bacterial density or reduction in influent density.
2. (e) denotes that value is extrapolated
3. N/A denotes level of disinfection was not observed for that technology and could not be extrapolated from the data.

In addition to the indicator bacteria reductions, virus reductions were also measured. Concentrations of naturally occurring viruses were too low to detect. Therefore, bacteria phage, including T4, f2, MS2 and X174 were seeded into the chlorine dioxide and UV influent. With the exception of T4 and f2 in the UV effluent after disinfection at 145 mWsec/cm2, the highest doses (10 mg/L ClO2 and 75 to 145 mWsec/cm2) resulted in nondectable levels of virus. Table 5 presents the log reduction.

Table 5. Disinfection Dose vs. Viral Reductions, Spring Creek 2001

Viral Reductions					
	Chlorine Dioxide Dose (mg/L)		**UV Dose (mWsec/cm2)**		
	8	**10**	**43**	**75**	**145**
T4 and f2 Influent	$1.8x10^5$	$3.7x10^5$	$1.9x10^5$	500	$3.5x10^5$
T4 and f2 Effluent	$5x10^3$	0	8	0	60
Log Reduction	1.6	5.6	4.4	2.7	3.6
MS2 and X174 Influent	$5.1x10^5$	$7x10^5$	$3.6x10^5$	$2x10^4$	$1.1x10^6$
MS2 and X174 Effluent	$1.5x10^3$	0	75	0	0
Log Reduction	2.5	5.8	3.7	4.3	6.0

3.1.3 Bacterial Group Sensitivities Results

The pilot test results demonstrated differing sensitivities of bacterial groups to the four technologies. The following observations might one day add to the discussion of alternate indicator bacteria:

- In the case of UV, enterococci showed a greater susceptibility than did fecal coliform and there was less variability in concentration.
- In the case of ozone, there were only minor differences between fecal coliform and enterococci.
- In the case of chlorine dioxide, enterococci showed a greater susceptibility and less variability in enterococci concentrations between 6 and 10 mg/l than did fecal coliform.
- In the case of chlorine, enterococci showed a greater susceptibility to chlorine between doses of 16 and 24 mg/l than did fecal coliform.

3.1.4 Disinfection Byproducts Results and Toxicity

Disinfectant residuals and the generation of disinfection byproducts have become a concern for oxidizing type disinfectants. UV has the distinct advantage of little or no byproduct generation that causes concerns for toxicity.

Residuals from chlorination and chlorine dioxide were monitored. The only disinfection byproducts measured were chlorite (ClO_2^-) and chlorate (ClO_3^-). In the case of chlorination, dechlorination by sodium bisulfite removed essentially all chlorine residuals. Increased chlorate and chlorite concentrations correlated to chlorine dose. Chlorite concentrations in the chlorination/dechlorination never exceeded 5 mg/L, however chlorate concentrations were as high as 18 mg/L. In the case of ClO_2, residuals were found to occur at ClO_2 doses of 6 mg/l and above. During the highest ClO_2 doses tested in the pilot study using the CDG Technology gas-solid process, the total of ClO_2^- and ClO_3^- did not exceed 5 mg/l.

Toxicity was also measured at Spring Creek during several distinct events for chlorination/dechlorination, chlorine dioxide and UV only. Toxicity was also measured in the influent as a control or reference point. When the chlorine dioxide dose was 10 mg/L or less and the chlorite concentration in the effluent sample was less than 5.8 mg/L, no increase in toxicity was observed in the test organisms (opossum shrimp and sheepshead minnow). In the case of both chlorination/dechlorination and UV, no increase in toxicity to opossum shrimp and sheepshead minnow was observed.

3.1.5 Cost Comparison Results

Conceptual level cost projections were prepared for each disinfection technology for comparison purposes, with the goal of recommending a technology for implementation at the Spring Creek AWPCP. To streamline the cost analysis, costs for each disinfection technology were prepared on a common flow basis and were prepared for a range of flow rates experienced at Spring Creek. This approach shows the sensitivity of cost to flow rate and allows independent comparison of technology costs at flow rates representative of different application points.

Equipment capital costs were developed for the following peak design flow conditions for a duration of 4 hours.

- 1,250 cfs (800 mgd),
- 2,500 cfs (1,600 mgd),
- 5,000 cfs (3,200 mgd).

The 5,000 cfs flow rate represents approximately the maximum facility inflow for the 5-year storm. The lower flow conditions were selected at reasonable fractions of the 5-year condition. Operating costs were developed based on an estimate of approximately 40 events/year producing inflow to the Spring Creek AWPCP, at a volume of 15 million gallons (MG) treated per event. As shown in Table 6, chlorination/dechlorination and chlorine dioxide are significantly less costly than either UV or ozone. It is important to note that for other CSO facilities, the cost for construction of disinfection contact tanks for the chlorination/dechlorination and chlorine dioxide alternatives would need to be considered and may make UV a somewhat more attractive option.

Table 6. Capital and O&M Costs vs. Facility Flow Rate, Spring Creek 2001

Technology	Chlorination/Dechlorination			Chlorine Dioxide			UV			Ozone		
Design Flow condition	**1,250 cfs**	**2,500 cfs**	**5,000 cfs**	**1,250 cfs**	**2,500 cfs**	**5,000 cfs**	**1,250 cfs**	**2,500 cfs**	**5,000 cfs**	**1,250 cfs**	**2,500 cfs**	**5,000 cfs**
Capital Costs	$854,000	$979,000	$1,142,000	$651,000	$1,085,000	$1,808,000	$45,000,000	$63,000,000	$88,200,000	$18,000,000	$23,000,000	$28,600,000
Annual Capital Costs	$87,000	$100,000	$116,000	$66,000	$111,000	$184,000	$4,583,000	$6,417,000	$8,983,000	$1,833,000	$2,343,000	$2,913,000
Annual O&M Costs	$239,000	$239,000	$239,000	$275,000	$275,000	$275,000	$232,000	$465,000	$929,000	$500,000	$550,000	$615,000
Total Annual Costs	**$326,000**	**$339,000**	**$355,000**	**$341,000**	**$386,000**	**$459,000**	**$4,815,000**	**$6,882,000**	**$9,912,000**	**$2,330,000**	**$2,893,000**	**$3,528,000**

Notes:

1. Costs are present worth in 1997 dollars.
2. Capital costs are based upon sizing to meet peak design flow and 4-log reduction in fecal coliform
3. Capital costs are for installation at Spring Creek and are for process equipment only. Costs do not include additional contact tankage (if required) or support facilities.
4. Annual operating costs are based upon an assumed typical 40 CSO events/year at a volume treated of 15 million gallons per event.
5. Annualized costs are based upon a period of 20 years at an interest rate of 8%.
6. UV equipment includes: medium-pressure, high-intensity lamps.
7. Ozone equipment includes: oxygen feed ozonation with eductor or side stream venturi type mass transfer configuration.
8. Chloride Dioxide equipment includes: High-rate mixing, Generation of Cl02 using the chlorine (gas) /sodium chlorite (solid) process, with onsite generation of chlorine gas via the acidification of NAOCl with HCl, Use of emergency gas scrubber for potential chlorine gas release, 5 minute contact time.
9. Chlorination/dechlorination equipment includes: High-rate mixing, Use of 15% sodium hypochlorite and 38% sodium bisulfite, 5 minute contact time.

It should be noted that these flow rates and associated costs are scalable for approximating costs of other size facilities. A subsequent study in San Clemente, CA used lower flow rates.

3.1.6 Conclusion

Generally all four technologies were able to provide 3 to 4 log bacterial reductions or effluent concentrations of fecal coliform less than 1,000 cfu/100mL. Chlorination/dechlorination, chlorine dioxide, and ozone were able to provide these levels of disinfection over the full range of wastewater quality tested. UV, however, showed lower effectiveness at total suspended concentrations above approximately 150 mg/l.

Chlorination/dechlorination and chlorine dioxide are significantly less costly than either UV or ozone. Generally, less capital intensive projects with slightly higher annual O&M costs are favored over high capital cost technologies with lower annual O&M costs.

3.2 Columbus, Georgia Advanced Demonstration Facility for Wet Weather Treatment Technologies. Wet Weather Demonstration Projects

3.2.1 Background

The purpose of the Columbus, Georgia, CSO technology demonstration program was to study solids removal and disinfection technologies based on the full-scale facilities designed to handle up to 90 mgd. The CSO technology-testing program included an array of side-by-side full-scale processes for solids separation and disinfection. Solids separation processes included screening, vortex separation, grit separation, and compressed media filtration. Disinfection alternatives included sodium hypochlorite, chlorine dioxide, peracetic acid and UV processes. The British vortex separators were used as gravity and chemically assisted settling basins, as air flotation basins and as contact chambers for three types of chemical disinfection – chlorine with dechlorination, chlorine dioxide and peracetic acid. A compressed media filter and UV disinfection was evaluated at various pre-treatment levels prior to UV disinfection. The Figure 6 presents the pilot layout.

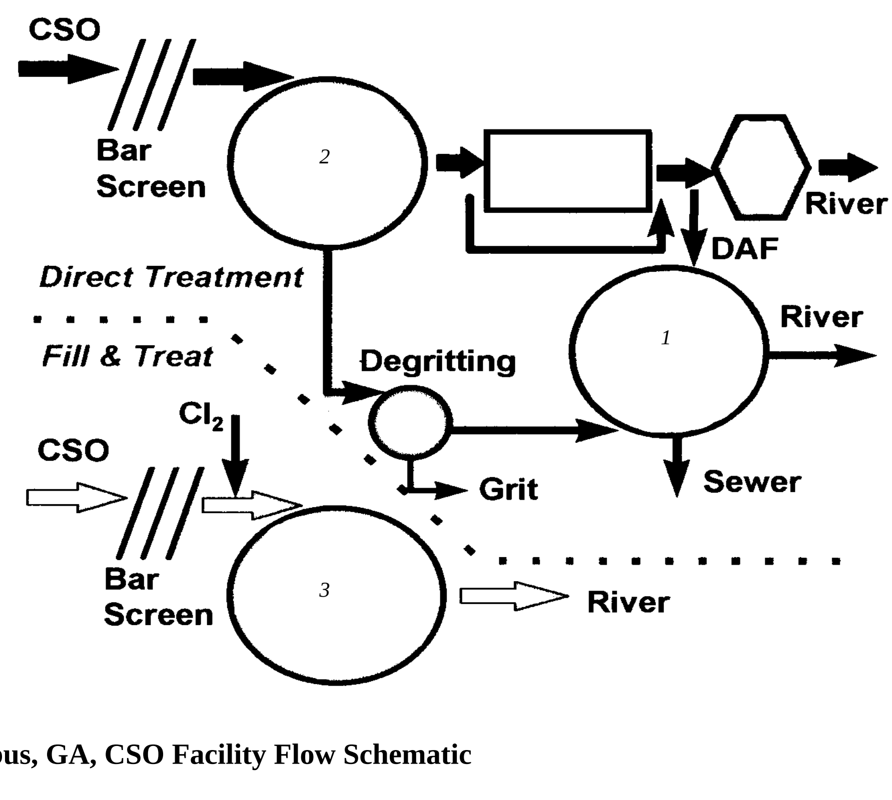


Figure 6. Columbus, GA, CSO Facility Flow Schematic

3.2.2 Disinfection Results

Performance of alternative disinfections was compared for similar water quality. An example dose response curve for different disinfectants on the same quality CSO is shown in Figure 7.

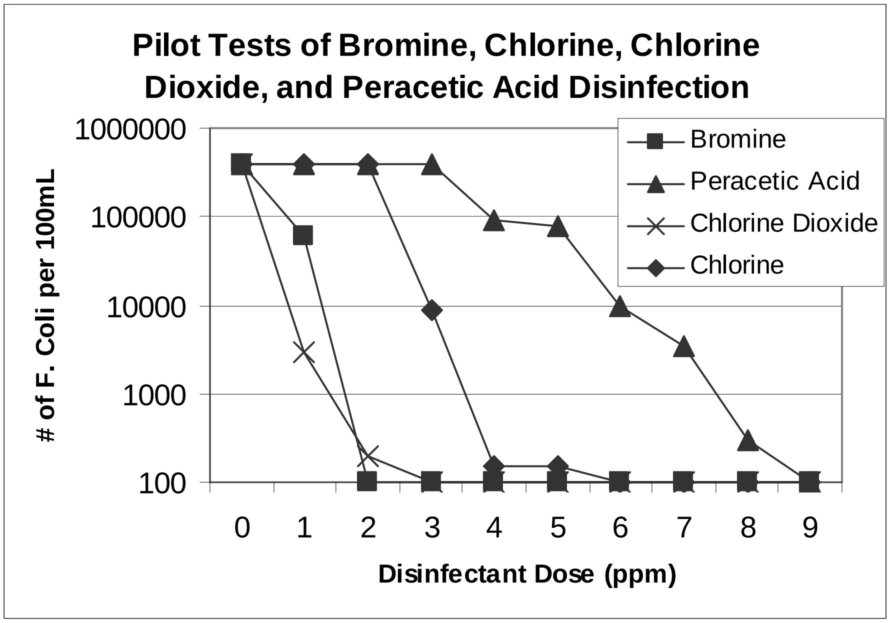


Figure 7. Disinfectant Dose versus Effluent Fecal Coliform

Another significant finding was the correlation between the performance of the chemical disinfection ainfluent water quality (as measured by ammonia and COD) and disinfectant dose. Contact time did not improve the correlation with disinfection parameters. This indicates that the germicidal performance is more dependant on satisfying the oxidant demands as opposed to the length of contact time.

Chemical dose normalized by influent ammonia, COD removed and temperature showed degrees of correlation with effluent bacteria. Examples of disinfection performance for sodium hypochlorite, peracetic acid and chlorine dioxide normalized by influent quality parameters are shown in Figures 8 through 10.

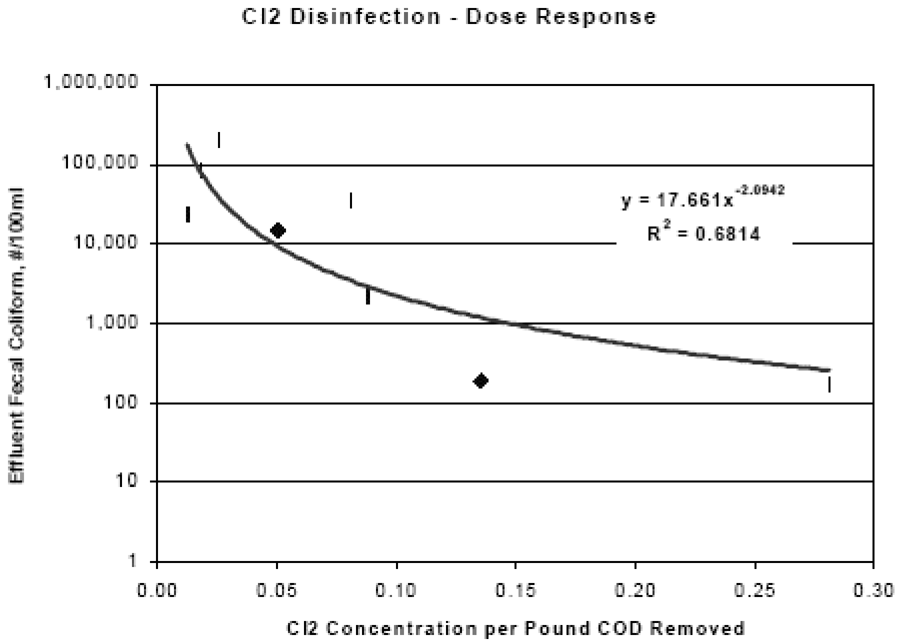


Figure 8. Chlorine Dose Normalized by COD Removal versus Effluent Fecal Coliform

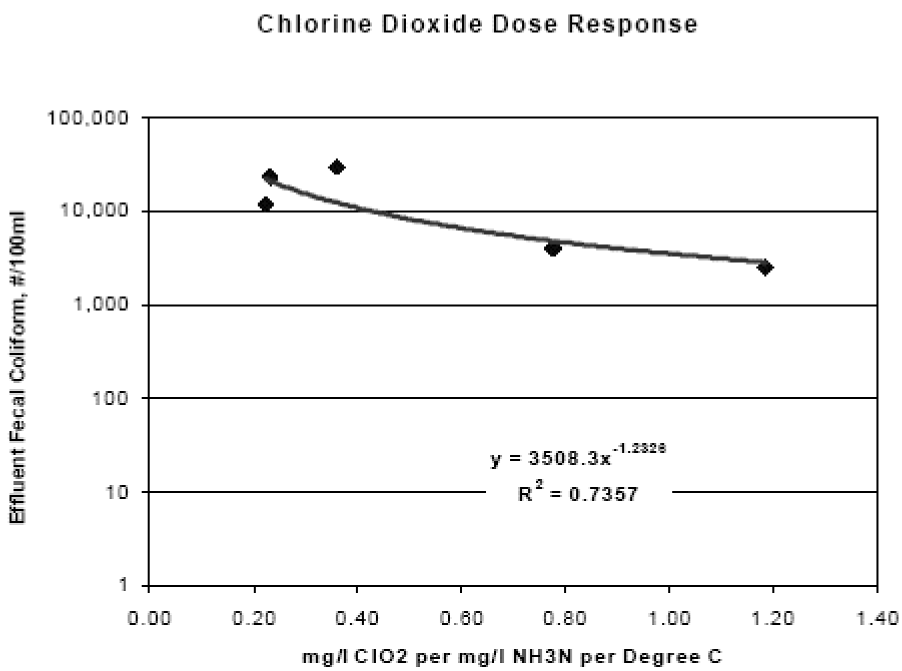


Figure 9. Chlorine Dioxide Dose Normalized by Influent Ammonia versus Effluent Fecal Coliform

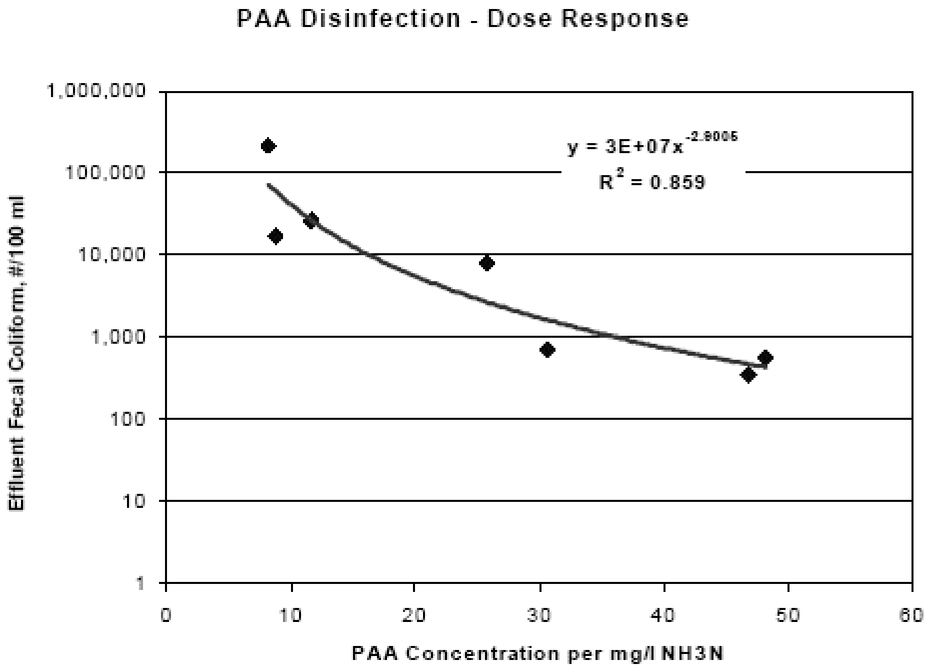


Figure 10. PAA Dose Normalized by Influent Ammonia versus Effluent Fecal Coliform

Influent quality varies with time or accumulative volume typically having high concentrations at the beginning of the CSO (flush effect). Other antecedent weather, sewer system use and hydrologic conditions can vary the flush effect. Operation of chemical disinfection for CSO treatment requires a history of chemical demand constituents versus time or accumulative volume.

Performance correlations can be developed from bench scale tests of different quality CSO's. An example dose response curve for different disinfectants on the same quality CSO is shown in the following figure. Histogram data coupled with performance correlations provides the necessary algorithm to control the disinfection process. Chlorine disinfectant residuals were typically controlled in the 1-mg/l range. Dechlorination controls should be designed and operated to provide overdosing of potential residual chlorine concentrations.

UV disinfection was found to be a function of lamp intensity (measured as the applied power), contact time and light transmissivity through the pretreated CSO. UV performance was generally correlated to other water quality parameters such as TSS, ammonia, COD and temperature. The compressed media filter provided the pretreatment for UV disinfection. UV disinfection of E. coli bacteria during winter temperature rain is shown in Figure 11 as a function of dose (product of intensity and time) and light transmittance. Unfiltered light transmittance would generally be decreased to 20% to 60% after compressed media filtration. UV disinfection of fecal coliform resulted in effluent fecal coliform concentrations generally in the hundreds at transmissivity levels above 40% and an order of magnitude higher at levels below 40%.

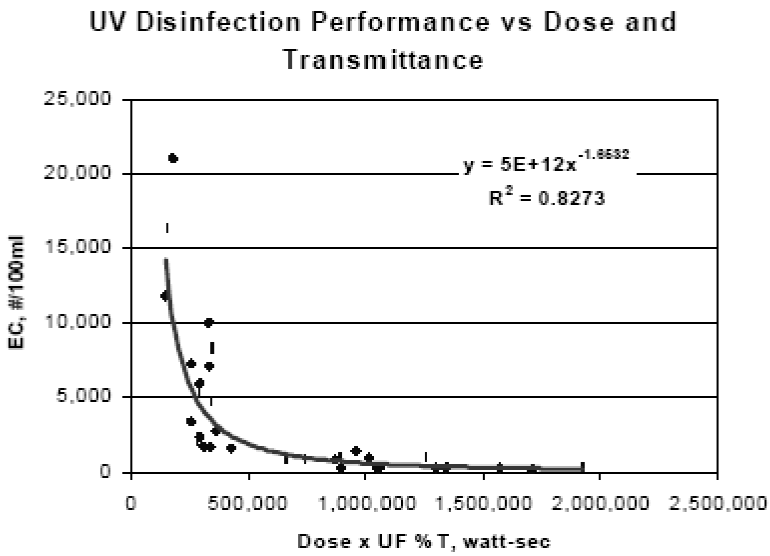


Figure 11. UV Dose Normalized by Transmissivity versus Effluent E. coli

3.2.3 Conclusion

The primary conclusions that may be drawn from the Columbus Water Quality Programs include the following:

- Cost-effective CSO controls can be achieved by using direct treatment processes such as the vortex separator with chemical disinfection or vortex followed by compressed media filtration and UV disinfection.

- High rate CSO disinfection is achievable through alternative chemical and nonchemical methods. Performance is dependent upon total and temporal CSO quality. Chemical disinfection requires satisfying the variable chemical demand throughout the wet weather hydrograph leading to a chemical feed control that replicates the oxidant demands (breakpoint chlorination). Combined chlorine disinfection practices are not practical or reliable for these applications. Breakpoint control results in the maximum chemical dosage for complete oxidation of ammonia and other chemical demands. This will provide added benefits of BOD reduction, oil and grease removal, improved clarity and odor control.

- UV disinfection performance is related to light transmittance that is also a function of the pretreated CSO quality. UV Disinfection performance was also correlated to quality parameters such as ammonia and COD that might be representative of pretreatment quality or water clarity.

3.3 Water Environment Research Foundation's "The Benefits And Risks of Disinfecting Wet Weather Flows"

3.3.1 Background

The primary objective of the Water Environment Research Foundation project was to identify and communicate the benefits and risks of disinfecting wet weather flows with chlorine and alternative disinfectants, including chlorine dioxide, ozonation and ultraviolet light (UV). The benefits of disinfection include the reduction of pathogens discharged to receiving waters that may be used for recreation or municipal drinking water supplies. The risks of disinfection include an increase in disinfection residuals and disinfection by-products (DBPs) to these waters.

3.3.2 Disinfection Demonstration Approach

Chlorination, chlorine dioxide, ozonation and UV were deemed to be the most appropriate technologies for disinfection of wet weather flows and therefore they were piloted for this disinfection demonstration. Peracetic acid and E-Beam were not evaluated due to lack of full-scale experience. In the case of peracetic acid, on-site generation using two chemicals is needed and this technology has not been implemented in a full-scale wet-weather flow application. In the case of E-Beam pretreatment requirements make it inappropriate for wet-weather flow disinfection. Bromine was not evaluated separately from chlorine since bromination has similar disinfection residual and DBP concerns as chlorination. However more recent developments using a powered form of bromine may warrant independent piloting of this technology (EBARA Corporation, 2004).

The disinfection demonstration was a large bench-scale pilot test; each disinfection technology was sized to treat approximately 50-100 gallons of flow volume. The disinfection technologies were considered "high-rate" meaning the contact time for chlorination and chlorine dioxide was approximately five minutes, the contact time for ozonation was approximately three minutes and the contact time for UV was approximately five seconds. The pilots were operated such that disinfectant dose was varied for each demonstration event so that disinfectant dose versus bacterial reductions (dose-response) curves could be developed. The chlorination pilot included dechlorination with sodium bisulfite for the purpose of reducing residual chlorine. After the first four events ferrous sulfate was added as a reducing agent to the chlorine dioxide pilot. The addition this reducing agent was for the purpose of reducing chlorite concentrations in the pilot effluent, which were the result of chlorite contamination of the chlorine dioxide product.

3.3.3 Effluent Bacterial Reductions

Effluent samples were collected from each of the disinfection technologies and compared to the influent samples for the purpose of developing disinfectant dose versus bacterial reduction (dose-response) curves. In addition to dose-response curves, disinfection residual and DBP production curves were developed for each of the disinfection technologies. These sets of curves were used to compare the bacterial reductions (i.e. benefits) and risks of the disinfection technologies, respectively.

The dose-response curves were originally developed using the applied doses and the resulting bacterial reductions, but the correlation between the doses and bacterial reductions was marginal. However, when the dose was normalized by water quality parameters such as temperature, COD, TSS and TKN the correlation improved markedly. pH did not vary and therefore was not considered as a normalization parameter. The best correlations occurred when the applied doses were normalized by COD and temperature. The addition of other parameters such as TSS and TKN did not improve this relationship measurably and therefore the data analysis was performed with the COD/temperature normalized curves.

Using the normalized dose-response curves, the performance of the technologies was evaluated based on their ability to achieve the bacterial criteria presented in Table 7. The table also presents the disinfectant doses that were required to achieve the bacterial criteria for a water quality characterized by a COD of 200 mg/L and a temperature of 20ºC.

Table 7. Disinfection Criteria and Doses Required to Achieve Criteria, WERF 2005

Parameter	Bacteria Criteria	Chlorination	Chlorine Dioxide	Ozone	UV
Fecal coliform	4,274cfu/100mL	18 mg/L	6.3 mg/L	25 mg/L	110 mWsec/cm^2
E. coli	2,507cfu/100mL	18 mg/L	6.6 mg/L	23 mg/L	100 mWsec/cm2
Enterococcus spp.	656 cfu/100mL	22 mg/L	8.6 mg/L	20 mg/L	140 mWsec/cm2

The chlorine dose to meet the criteria for fecal coliform and *E. coli* was approximately the same but increased markedly to meet the *Enterococcus* spp criterion. A similar trend was observed for chorine dioxide and UV. For chlorination, chlorine dioxide and UV, between 20% to 36% higher doses were required to achieve the *Enterococcus* spp. criterion as compared to the fecal coliform, *E. coli* criteria. In contrast, ozonation was most effective at achieving the *Enterococcus* spp. criteria, requiring 22% less ozone as compared to the fecal coliform criteria.

On the order of one third the dose of chlorine dioxide was required to achieve the same bacterial reductions as chlorination. In general, chlorine dioxide in water is 10 times more soluble, a broader bactericide and an effective viricide (White, 1999). In contrast, it required a higher ozone dose to achieve the same bacterial reductions as chlorination, which is contrary to the literature regarding ozonation (Morris, 1975). Research by J.C. Morris illustrates that ozone is a more powerful germicide against all classes of organisms by a factor of 10-100 times. This contrast may be the result of a combination of ozone demand and difficulties in general with measuring ozone residuals.

3.3.4 Effluent Disinfection Residuals, DBPs and Toxicity

Equally important as measuring and evaluating the performance of the disinfection technologies to inactivate bacteria was the development of disinfection residual and by-product curves for each of the disinfection technologies. In summary chemical disinfection of wet weather flows with chlorine and chlorine dioxide resulted in disinfectant residuals and by-products. Ozonation and UV disinfection did not produce residuals and DBPs.

Chlorine and chlorine dioxide residuals were generally found to correlate to the applied dose before the addition of a reducing agent. When applying 18 mg/L of chlorine and 6.6 mg/L of chlorine dioxide the resulting residuals were 4.3 mg/L of chlorine and 0.14 mg/L of chlorine dioxide.

DBPs measured included chlorates and chlorites. The U.S. EPA Microbial and Disinfection By-Products Rule limits ambient concentrations for chlorite to 0.8 mg/L. There is no current limit for chlorate or studies indicating toxicity effects for this substance, but the U.S. EPA has suggested limitation of its production without specifying a limit.

The production of chlorate was found to be proportional to the applied dose in both chlorination and chlorine dioxide pilots. When applying 18 mg/L of chlorine and 6.6 mg/L of chlorine dioxide, chlorate production was estimated as 3.0 mg/L and 3.3 mg/L for chlorination and chlorine dioxide disinfection, respectively. For the same applied doses, chlorite production was estimated as zero and 18 mg/L for chlorination and chlorine dioxide, respectively. These chlorate and chlorite values are before the addition of the reducing agents. The chlorite concentration (18 mg/L) in the chlorine dioxide effluent exceeded the applied dose (6.6 mg/L) because there was residual chlorite in the chlorine dioxide product as a result of the generation method employed for this demonstration. Full-scale applications would employ generation processes that produce a chlorite-free product.

In most instances the residual chlorine from the chlorination process was successfully reduced with sodium bisulfite. However, there were four events when an insufficient quantity of sodium bisulfite was added and residual chlorine remained present in the effluent. During one of the four events additional sodium bisulfite was added to ensure the residual chlorine was below the detection limit. Ferrous sulfate was successful at reducing both chlorine dioxide residuals and chlorite concentrations during events when the reducing agent was added in sufficient quantities. Chlorate concentrations in both the chlorination and chlorine dioxide effluents were unaffected by either of the reducing agents.

Trihalomethanes (THMs), most notably chloroform, were produced in the chlorination disinfection process. THM production was proportional to the applied dose. When applying 18 mg/L of chlorine, the resulting chloroform production was 4.0 µg/L. The chlorine dioxide disinfection process did not produce THMs. The Safe Drinking Water Act's maximum concentration level (MCL) for THMs is 80 µg/L.

Both the chlorination and chlorine dioxide disinfection processes produced haloacetic acids (HAAs). When applying 18 mg/L of chlorine and 6.6 mg/L of chlorine dioxide, the resulting total HAAs production was 13µg/L and 36 µg/L for chlorination and chlorine dioxide, respectively. The Safe Drinking Water Act's MCL for HAAs is 60 µg/L.

For the chlorination disinfection process effluent, all events with total residual chlorine (TRC) less than the detection limit after dechlorination had little or no aquatic toxicity. Events with measurable TRC after dechlorination had significant aquatic toxicity. The data indicate that aquatic toxicity problems can be avoided with proper dechlorination prior to discharge.

For the chlorine dioxide process, aquatic toxicity corresponded to residual chlorine dioxide and chlorite concentrations. Seven of the nine events had 100 percent mortality for the aquatic test organisms; the mortality rate decreased in the last two events, both of which had non-detected concentrations of residual chlorine dioxide and low chlorite concentrations. The correlation between residual chlorine dioxide and chlorite and the Microtox™ EC_{50} is strong (R^2 value of > 0.83) and demonstrates that aquatic toxicity increases with increases in chlorine dioxide and chlorite. Aquatic toxicity decreased in events when ferrous sulfate was used to reduce the chlorine dioxide and chlorite residuals, which indicates that toxicity problems can be avoided with proper control prior to discharge. It should be pointed out that for this small-scale pilot chlorine dioxide was produced by acidifying sodium chlorite, which can result in residual chlorite in the product. Certain methods of chlorine dioxide generation do not produce chlorite as a residual to generation, therefore by using these methods of generation; aquatic toxicity could be avoided without the addition of reducing agents.

For the ozone and UV pilots, no significant aquatic toxicity was measured.

3.3.5 Conclusion

- Chlorination, chlorine dioxide, ozonation and UV technologies used for disinfection of wet-weather flow discharges can all achieve the U.S. EPA guideline criteria for bacteria (U.S. EPA 2002).

- Normalizing dose by water quality constituents provides a reliable base for developing dose-response relationships.
- Chlorination (18 mg/L) and chlorine dioxide (7mg/L) doses produce disinfection residuals and DBPs.
- Ozonation (23 mg/L) and UV (100 mwattsec/cm2) doses do not produce disinfections residuals and DBPs.
- Chlorination produce TRC, chlorate THMs and HAAs.
- Using the acid/ chlorite method to generate chlorine dioxide produces TRC, chlorate, chlorite and HAAs.
- Reducing agents can control TRC in the chlorination process and TRC and chlorite in the chlorine dioxide.

4. CASE STUDIES OF FULL-SCALE INSTALLATIONS

Several communities that have installed full-scale CSO disinfection facilities are highlighted in this Report in Appendix C. The case studies include a background information and descriptions of the communities and their CSO and treatment systems. The case studies also highlight at least one of the CSO disinfection facilities constructed by each community. The communities are:

- Syracuse, NY
- Columbus, GA
- Atlanta, GA
- Augusta, ME
- Burlington, VT

5. CONCLUSIONS

Sodium hypochlorite, chlorine dioxide, bromine and UV are the most viable disinfection alternatives of those reviewed for CSO applications.

Numerous studies and full-scale facilities have demonstrated that chemical disinfection of CSOs can be accomplished using high-rate disinfection. High-rate disinfection is defined as employing high-intensity mixing to accomplish disinfection within a short contact time, generally five minutes.

High-rate disinfection with sodium hypochlorite followed by dechlorination is the most cost effective method to disinfect CSOs when considering total life-cycle costs.

The data for chlorine dioxide shows that it is a more effective disinfectant than sodium hypochlorite. However, chlorine dioxide needs to be generated on site because it is too unstable even for short periods of time. Operating a chlorine dioxide generator at a remote satellite CSO facility for intermittent flows would be difficult given the currently-available systems. In addition, chlorine dioxide, as with chlorine, can produce byproducts of concern. The advantage of using chlorine dioxide is that it is a rapid disinfectant with superior viricidal properties. Chlorine dioxide does not react with the ammonia and does not produce THMs. Several manufactures are currently working on new technologies to produce chlorine dioxide. Technologies may become available in the future that provide an easier and safer way to produce chlorine dioxide at a remote CSO locations.

Bromine may also be a better disinfectant than sodium hypochlorite. However, at this time there is only one known CSO disinfection facility using bromine in the United States. Consequently, a pilot study should be considered to address effectiveness, byproduct formation, associated toxicity and operability at remote CSO locations before it is used for such an application.

UV, another alternative to sodium hypochlorite for CSO disinfection, has shown to be a more effective disinfectant than sodium hypochlorite. However it is significantly more expensive than sodium hypochlorite and in addition would require more preliminary treatment. The other major advantage of UV is that it produces no residuals or disinfection byproducts.

Full Scale Treatment Considerations

As concluded from the Columbus, GA project (See 3.2.3), UV disinfection is related to light transmittance. It is well known that the size and nature of suspended solids contribute to transparency and consequently can act as an impediment to ultra violet disinfection. Color, as it affects transparency, and certain materials such as iron, can also serve as an impediment to UV effectiveness. Chemical disinfection can also be impaired by solids, particularly organics, but to a much lesser extent. Whereas solids can represent oxygen demanding components in addition to shielding and harboring organisms, chemicals penetrate solids more effectively than UV light. UV effectiveness is governed by UV Transmittance (UVT).

UVT is a measurement of the quantity of UV light that can pass through a sample of wastewater (UVT = 100% for pure water). Therefore, higher UVT values indicate more feasible and economical disinfection using UV. This is particularly true if low-intensity UV technology can be used as opposed to medium-pressure technology which was developed to disinfect poorer water quality.

Samples with UVT values above 35% to 40% are considered treatable using medium-pressure UV technology. However as the UVT decreases from 65% to 50%, the energy required for disinfection approximately doubles, thereby making UV more costly. Values lower requires that much more energy.

The minimum level of UVT for medium-pressure technology for effectiveness on the indicator bacteria has been shown to be 60%. Wastewater with lower UVT values would require preliminary treatment.

Technologies well suited to reduce highly-variable influent TSS to such levels are Actiflo and DensaDeg. Based on piloting of both technologies for Akron, OH, influent TSS of as high as 140 mg/l were reduced 97% to 5 mg/l using either the Actiflo or DensaDeg Process; these results were for the Actiflo and DensaDeg Pilots being run at rise rates of 30 and 40 gpm/S.F. respectively. Both Pilots used Alum and Ferric in combination with an anionic polymer ("Water Pollution Control Station Secondary Bypass Treatibility Study", Arcadis FPS, 3/2004;Water Pollution Control Station Secondary Bypass Treatibility Study Phase II", Arcadis FPS, 12/2004). Concentrations would need to be tailored for the wastewater in question.

The Table 8 is representative of the Actiflo process and the resulting UVT. The UVT would be suitable for medium-pressure technology and possibly low-pressure technology but selection would need to be verified in accordance with NWRI Standards.

Table 8. UV Light transmittance

Table 4-5 ACTIFLO UV Transmittance (UVT)						
Wastewater Type	Rise Rate (gpm/s.f.)	Coagulant Type	Coagulant Dose (mg/l)	Polymer Type	Polymer Dose (mg/l)	Average Unfiltered UVT (%)
Primary Effluent	60	Ferric	40	Dry Anionic	0.77	56
Primary Effluent	60	Ferric	85	Dry Anionic	0.77	60
Primary Effluent	60	Alum	50	Dry Anionic	0.77	66
Primary Effluent	60	Alum	100	Dry Anionic	0.77	69

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APPENDIX B

DISINFECTION RECOMMENDATION MEMO

1. CONCLUSIONS

Sodium hypochlorite, chlorine dioxide, bromine and UV are the most viable disinfection alternatives for CSO applications.

Numerous studies and full scale facilities have demonstrated that chemical disinfection of CSOs can be accomplished using high rate disinfection. High rate disinfection is defined as employing high intensity mixing to accomplish disinfection in a short contact time, generally five minutes.

High-rate disinfection with sodium hypochlorite followed by dechlorination is the most cost effective method to disinfect CSOs when considering capital costs and operational and maintenance costs.

The data for chlorine dioxide shows that it is a more effective disinfectant than sodium hypochlorite. However, chlorine dioxide needs to be generated on site because it is too unstable to store for any length of time and operating a chlorine dioxide generator at a remote satellite CSO facility for intermittent flows would be difficult given the currently manufactured systems. In addition, chlorine dioxide, as with chlorine, can produce byproducts of concern. The advantage of using chlorine dioxide is that it is a rapid disinfectant with superior viricidal properties. Chlorine dioxide does not react with the ammonia and does not produce THMs. Several manufactures are currently working on new technologies to produce chlorine dioxide. Technologies may become available in the future that provides an easier and safer way to produce chlorine dioxide at a remote CSO. In the near future, chlorine dioxide may become an attractive alternative to sodium hypochlorite.

Bromine may also be a better disinfectant than sodium hypochlorite. However, at this time there is only one known CSO disinfection facility using bromine in the United States. Consequently, a pilot study should be considered to address effectiveness, byproduct formation, associated toxicity and operability at remote CSO locations before it is used for such an application.

UV, another alternative to sodium hypochlorite for CSO disinfection, has proved to be equally effective. However it is significantly more expensive than sodium hypochlorite. The major advantage of UV is that it produces no residuals or disinfection byproducts.

2. RECOMMENDATIONS

- The City of Akron should design CSO disinfection facilities with high rate disinfection with sodium hypochlorite.
- The CSO disinfection facilities should be designed with enough building space to allow for conversion to an alternative chemical disinfectant like chlorine dioxide or bromine.
- For chlorination, consideration needs to be given to dechlorination requirements based upon potential byproduct formation and site-specific receiving water toxicity issues.
- Piloting should be considered in order to develop chlorine dose versus bacterial reduction curves.

APPENDIX C

COST SUMMARY UPDATE

City of Akron CSO LTCP
Cost Update - Summary of Alternative 2 Costs

Rack Number	Technology	Control Parameter	Summary of 1998 Cost Estimate (in 1998 $)			Summary of Update to 1998 Cost Estimate (in 2005 $)		
			1998 Capital Cost	1998 Annual O&M Cost	20 Year Total Present Worth (2018)	2005 Capital Cost	2005 Annaul O&M Cost	20 Year Total Present Worth (2025)
3	Detention Basin	Treatment/events	$ 1,700,088	$ 76,560	$ 2,969,800	$ 2,151,000	$ 97,000	$ 3,249,500
4, 16, 17/DC, 18, 19, 20, 23, 24, 37	OCI Tunnel	-	$ 93,446,078	$ 293,200	$ 90,587,300	$ 92,744,982	$ 370,804	$ 93,493,800
	Additional Treatment & Disinfection		$ -	$ -	$ -	$ 30,299,859	$ 1,316,747	$ 47,476,500
5+7	Detention Basin	Storage/event + hours	$ 1,672,788	$ 18,900	$ 1,941,200	$ 2,116,200	$ 24,000	$ 2,232,100
	Disinfection/Screen		$ -	$ -	$ -	$ 2,514,456	$ 125,065	$ 5,672,900
8	Separation	-	$ 2,326,353	$ 4,600	$ 2,052,900	$ 2,942,090	$ 5,818	$ 2,641,800
9	Separation	-	$ 210,926	$ 2,000	$ 215,300	$ 266,754	$ 2,529	$ 266,500
10+11	Detention Basin	Treatment/events	$ 3,723,641	$ 80,300	$ 4,990,800	$ 4,710,100	$ 101,800	$ 5,615,800
12	Detention Basin	Treatment/CBOD	$ 2,201,448	$ 169,950	$ 5,074,700	$ 2,785,200	$ 215,100	$ 5,408,800
13	Separation	-	$ 4,326,241	$ 7,200	$ 3,799,800	$ 5,471,305	$ 9,106	$ 4,889,700
14	Detention Basin	Storage/hours	$ 1,984,786	$ 34,500	$ 2,512,800	$ 2,510,900	$ 43,700	$ 2,857,100
	Disinfection/Screen		$ -	$ -	$ -	$ 3,312,299	$ 151,053	$ 7,339,900
15	Detention Basin	Storage/hours	$ 1,651,178	$ 28,590	$ 2,090,800	$ 2,088,900	$ 36,300	$ 2,376,600
	Disinfection/Screen		$ -	$ -	$ -	$ 2,931,896	$ 142,119	$ 6,543,400
21	Separation	-	$ 2,199,483	$ 10,400	$ 2,044,200	$ 2,781,640	$ 13,153	$ 2,600,800
22	Detention Basin	Storage/hours	$ 1,282,976	$ 29,190	$ 1,742,000	$ 1,623,200	$ 37,000	$ 1,963,900
	Disinfection/Screen		$ -	$ -	$ -	$ 4,792,434	$ 190,034	$ 10,101,900
25	Separation	-	$ 2,974,494	$ 8,300	$ 2,672,100	$ 3,761,780	$ 10,497	$ 3,419,000
26+28	Detention Basin	Treatment/CBOD	$ 2,561,620	$ 118,690	$ 4,532,800	$ 3,240,800	$ 150,300	$ 4,948,100
27+29	Detention Basin	Treatment/hours	$ 1,934,065	$ 104,005	$ 3,674,200	$ 2,446,900	$ 131,800	$ 3,982,200
30	Separation	-	$ 7,573,977	$ 6,900	$ 6,544,700	$ 9,578,646	$ 8,726	$ 8,463,200
31+40	Detention Basin	Storage/events	$ 13,421,279	$ 179,270	$ 16,060,300	$ 16,974,500	$ 226,800	$ 18,347,500
	Additional Treatment & Disinfection		$ -	$ -	$ -	$ 16,852,920	$ 681,878	$ 29,172,000
32, 33, 34, 35	NSI Tunnel	-	$ 28,371,900	$ 171,500	$ 33,254,700	$ 41,428,650	$ 216,892	$ 45,883,300
36	Detention Basin	Storage/CBOD	$ 992,811	$ 20,000	$ 1,304,600	$ 1,256,200	$ 25,400	$ 1,478,000
	Disinfection/Screen		$ -	$ -	$ -	$ 2,209,867	$ 115,320	$ 5,091,700
39	Separation	-	$ 300,000	$ 1,900	$ 289,700	$ 379,404	$ 2,403	$ 363,000
		Totals:	**$ 174,856,131**	**$ 1,365,955**	**$ 188,354,700**	**$ 264,172,882**	**$ 4,451,343**	**$ 325,879,000**

*Notes: Disinfection and screen costs are **not** included in 1998 Costs for Storage Basins, but are included in the 2005 Costs for these facilities.*
*Additional Treatment costs are **not** included in 1998 Costs for the OCI Tunnel and Rack 31/40, but are included in the 2005 Costs for these facilities*

City of Akron CSO LTCP
Cost Update - Summary of Disinfection Retrofit for Storage Basins Costs

Rack Number	Summary of 2005Cost Estimate (in 2005 $)		
	2005 Capital Cost	2005 Annaul O&M Cost	20 Year Total Present Worth (2025)
5 & 7	$ 2,514,456	$ 125,065	$ 5,672,900
14	$ 3,312,299	$ 151,053	$ 7,339,900
15	$ 2,931,896	$ 142,119	$ 6,543,400
22	$ 4,792,434	$ 190,034	$ 10,101,900
31 & 40	$ 3,073,070	$ 681,989	$ 14,206,100
36	$ 2,209,867	$ 115,320	$ 5,091,700
Totals:	**$ 18,834,100**	**$ 1,405,600**	**$ 48,955,900**

City of Akron CSO LTCP
Cost Update - 2005 Capital and O&M Costs - Disinfection Retrofit for Storage Basins

Item	Rack 5 & 7		Rack 14		Rack 15		Rack 22		Rack 31 & 40		Rack 36		Total Cost
	Equipment	**Structure**	**Equipment**	**Structure**	**Equipment**	**Structure**	**Equipment**	**Structure**	**Equipment**	**Structure**	**Equipment**	**Structure**	
Chemical Metering Pumps	$ 7,700	*See Note 1*	$ 11,500	*See Note 1*	$ 7,700	*See Note 1*	$ 11,500	*See Note 1*	*See Note 4*	*See Note 4*	*$ 7,700*	*See Note 1*	$ 46,100
Induction Mixers	$ 121,700	*See Note 1*	$ 182,500	*See Note 1*	$ 121,700	*See Note 1*	$ 182,500	*See Note 1*	*See Note 4*	*See Note 4*	*$ 121,700*	*See Note 1*	$ 730,100
Chemical Storage	$ 5,500	*See Note 1*	$ 16,000	*See Note 1*	$ 14,500	*See Note 1*	$ 26,000	*See Note 1*	*See Note 4*	*See Note 4*	*$ 10,000*	*See Note 1*	$ 72,000
Piping Allowance	$ 13,500	*See Note 1*	$ 21,000	*See Note 1*	$ 14,400	*See Note 1*	$ 22,000	*See Note 1*	*See Note 4*	*See Note 4*	*$ 13,900*	*See Note 1*	$ 84,800
Electrical Allowance	$ 20,200	*See Note 1*	$ 31,500	*See Note 1*	$ 21,600	*See Note 1*	$ 33,000	*See Note 1*	*See Note 4*	*See Note 4*	*$ 20,900*	*See Note 1*	$ 127,200
Instrumentation Allowance	$ 6,700	*See Note 1*	$ 10,500	*See Note 1*	$ 7,200	*See Note 1*	$ 11,000	*See Note 1*	*See Note 4*	*See Note 4*	*$ 7,000*	*See Note 1*	$ 42,400
Screens *(see Note 2)*	$ 703,543	$ 1,055,314	$ 909,960	$ 1,364,939	$ 827,278	$ 1,240,917	$ 1,360,173	$ 2,040,260	*See Note 4*	*See Note 4*	$ 607,467	$ 911,200	$ 11,021,052
Subtotal Capital Cost:	$ 878,843	$ 1,055,314	$ 1,182,960	$ 1,364,939	$ 1,014,378	$ 1,240,917	$ 1,646,173	$ 2,040,260	$ 1,144,358	$ 1,219,513	$ 788,667	$ 911,200	$ 14,487,522
30% Contingency:	$ 263,700	$ 316,600	$ 354,900	$ 409,500	$ 304,300	$ 372,300	$ 493,900	$ 612,100	$ 343,300	$ 365,900	$ 236,600	$ 273,400	$ 4,346,500
Total Capital Cost:	$ 1,142,543	$ 1,371,914	$ 1,537,860	$ 1,774,439	$ 1,318,678	$ 1,613,217	$ 2,140,073	$ 2,652,360	$ 1,487,658	$ 1,585,413	$ 1,025,267	$ 1,184,600	$ 18,834,022
Annual O&M Cost *(see Note 3)*:	$ 125,065		$ 151,053		$ 142,119		$ 190,034		$ 681,989		$ 115,320		$ 1,405,580
Total Cost:	**$2,639,500**		**$3,463,400**		**$3,074,000**		**$4,982,500**		**$3,755,100**		**$2,325,200**		**$ 20,239,700**

Note 1: With exception to screens, disnfection costs include equipment only. Refer to assumptions described in Section 3.3 in the City of Akron Long Term Control Plan Review and Disinfection Investigations, Final Report, May 2005

Note 2: Sreen costs are estimated based on EPA Combined Sewer Overflow Control Manual, EPA/625/R-93/007, September 1993, ENR = 4800. Costs include structure (assumed 60% total cost) and equipment (assumed 40% total cost), and are updated by ENR CCI to March 2005 (ENR = 7309).

Note 3: O&M costs are estimated based on EPA Combined Sewer Overflow Control Manual, EPA/625/R-93/007, September 1993, ENR = 4500, and are updated by ENR CCI to March 2005 (ENR = 7309).

Note 4: Disinfection and screen costs for this Rack are based on costs presented in the Long Term Control Plan - Additional Evaluations Report, May 2002. Costs are updated from May 2002 based on an average annual ENR inflation rate of 3.54%.

City of Akron CSO LTCP
Cost Update - Present Worth Analysis for Disinfection Retrofit for Storage Basins

COST UPDATE PARAMETERS	
O&M Cost Updating Parameters	
Date for Original Capital Costs:	Mar-05
Date for Capital Cost Update:	Mar-05
Years:	0.00
Average Annual ENR Inflation Rate:	3.54%

PRESENT WORTH PARAMETERS	
Economic Evaluation Parameters	**Period 1**
Start Year:	2005
End Year:	2025
Years for Present Worth Evaluation:	20
Interest Rate:	8.00%
Annual Inflation Rate for Capital Costs:	3.54%
Annual Inflation Rate for O&M Costs:	3.54%
Single Payment Present Worth Factor:	0.2145
Uniform Series Present Worth Factor:	9.8181
Gradient Series Present Worth Factor:	69.0898
Capital Recovery Factor:	0.1019
Equipment Service Life (yrs):	15
Structure Service Life (yrs):	50

Cost Update Summary	Rack 5 & 7	Rack 14	Rack 15	Rack 22	Rack 40 & 31	Rack 36
2005 Annual O&M Costs:	$ 125,065	$ 151,053	$ 142,119	$ 190,034	$ 681,989	$ 115,320
2005 Structure Capital Costs:	$ 1,371,914	$ 1,774,439	$ 1,613,217	$ 2,652,360	$ 1,585,413	$ 1,184,600
2005 Equipment Capital Costs:	$ 1,142,543	$ 1,537,860	$ 1,318,678	$ 2,140,073	$ 1,487,658	$ 1,025,267
2005 Total Capital Costs:	$ 2,514,456	$ 3,312,299	$ 2,931,896	$ 4,792,434	$ 3,073,070	$ 2,209,867
O&M Present Worth Analysis						
Start Year:	2005	2005	2005	2005	2005	2005
End Year:	2025	2025	2025	2025	2025	2025
Years for Present Worth Evaluation:	20	20	20	20	20	20
Annual O&M Cost at Start Year:	$ 125,065	$ 151,053	$ 142,119	$ 190,034	$ 681,989	$ 115,320
Annual O&M Cost at End Year:	$ 250,784	$ 302,895	$ 284,982	$ 381,061	$ 1,367,542	$ 231,242
Annual Incremental Increase	$ 6,617	$ 7,992	$ 7,519	$ 10,054	$ 36,082	$ 6,101
Present Worth of Constant O&M:	$ 1,227,908	$ 1,483,057	$ 1,395,350	$ 1,865,782	$ 6,695,870	$ 1,132,227
Present Worth of Incremental O&M:	$ 457,151	$ 552,144	$ 519,490	$ 694,632	$ 2,492,879	$ 421,529
Total Present Worth of O&M:	$ 1,685,059	$ 2,035,201	$ 1,914,840	$ 2,560,414	$ 9,188,749	$ 1,553,756
Capital Cost Present Worth Analysis	**Period 1**	**Period 1**	**Period 1**	**Period 1**	**Period 1**	**Period 1**
Start Year:	2005	2005	2005	2005	2005	2005
End Year:	2025	2025	2025	2025	2025	2025
Years for Present Worth Evaluation:	20	20	20	20	20	20
Structure:						
Replacement Cost at 2025 - Structure:	$ -	$ -	$ -	$ -	$ -	$ -
Salvage Value at 2025 - Stucture:	$ 823,148	$ 1,064,664	$ 967,930	$ 1,591,416	$ 951,248	$ 710,760
Present Worth of Salvage Value at 2025 - Structure:	$ 176,605	$ 228,422	$ 207,668	$ 341,435	$ 204,088	$ 152,492
Total Present Worth - Structure:	$ 1,195,309	$ 1,546,018	$ 1,405,550	$ 2,310,925	$ 1,381,324	$ 1,032,108
Equipment:						
Replacement Cost at 2020 - Equipment:	$ 1,925,284	$ 2,591,428	$ 2,222,088	$ 3,606,211	$ 2,506,833	$ 1,727,664
Salvage Value at 2020 - Equipment:	$ 1,283,523	$ 1,727,618	$ 1,481,392	$ 2,404,140	$ 1,671,222	$ 1,151,776
Present Worth of Salvage Value at 2020 - Equipment:	$ 275,377	$ 370,657	$ 317,830	$ 515,804	$ 358,558	$ 247,112
Total Present Worth - Equipment:	$ 2,792,449	$ 3,758,630	$ 3,222,936	$ 5,230,480	$ 3,635,933	$ 2,505,820
Total Present Worth of Disinfection Retrofit:	$ 5,672,900	$ 7,339,900	$ 6,543,400	$ 10,101,900	$ 14,206,100	$ 5,091,700
Equivalent Annual Cost:	$ 577,800	$ 747,600	$ 666,500	$ 1,029,000	$ 1,447,000	$ 518,700

City of Akron CSO LTCP
Cost Update - Summary of Additional Treatment & Disinfection at Rack 31/40 and OCI Tunnel

Item	Summary of 2002 Cost Estimate (in 1998 $)			Summary of Update to 2002 Cost Estimate (in 2005 $)		
	2002 Capital Cost	2002 O&M Cost	20 Year Total Present Worth (2018)	2005 Capital Cost	2005 Annaul O&M Cost	20 Year Total Present Worth (2025)
Rack 31/40 Additional Treatment & Disinfection	$ 15,140,563	$ 612,595	$ 27,880,900	$ 16,852,920	$ 681,878	$ 29,172,000
OCI Tunnel Additional Treatment & Disinfection	$ 27,221,213	$ 1,182,958	$ 46,425,000	$ 30,299,859	$ 1,316,747	$ 47,476,500
Totals:	**$ 42,361,776**	**$ 1,795,553**	**$ 74,305,900**	**$ 47,152,779**	**$ 1,998,625**	**$ 76,648,500**

City of Akron CSO LTCP
Cost Update - Present Worth Analysis for Additional Treatment & Disinfection at Rack 31/40 and OCI Tunnel

COST UPDATE PARAMETERS	
O&M Cost Updating Parameters	
Date for Original Capital Costs:	Feb-02
Date for Capital Cost Update:	Mar-05
Years:	3.08
Average Annual ENR Inflation Rate:	3.54%

PRESENT WORTH PARAMETERS	
Economic Evaluation Parameters	
Start Year:	2005
End Year:	2025
Years for Present Worth Evaluation:	20
Interest Rate:	8.00%
Annual Inflation Rate for Capital Costs:	3.54%
Annual Inflation Rate for O&M Costs:	3.54%
Single Payment Present Worth Factor:	0.2145
Uniform Series Present Worth Factor:	9.8181
Gradient Series Present Worth Factor:	69.0898
Capital Recovery Factor:	0.1019
Equipment Service Life (yrs):	15
Structure Service Life (yrs):	50

Cost Update Summary	Rack 31/40 Additional Treatment & Disinfection	OCI Tunnel Additional Treatment & Disinfection
2002 Annual O&M Costs:	$ 612,595	$ 1,182,958
2002 Structure Capital Costs:	$ 12,112,450	$ 25,315,728
2002 Equipment Capital Costs:	$ 3,028,113	$ 1,905,485
2002 Total Capital Costs:	$ 15,140,563	$ 27,221,213
2005 Annual O&M Costs:	$ 681,878	$ 1,316,747
2005 Structure Capital Costs:	$ 13,482,336	$ 28,178,869
2005 Equipment Capital Costs:	$ 3,370,584	$ 2,120,990
2005 Total Capital Costs:	$ 16,852,920	$ 30,299,859
O&M Present Worth Analysis		
Start Year:	2005	2005
End Year:	2025	2025
Years for Present Worth Evaluation:	20	20
Annual O&M Cost at Start Year:	$ 681,878	$ 1,316,747
Annual O&M Cost at End Year:	$ 1,367,319	$ 2,640,375
Annual Incremental Increase:	$ 36,076	$ 69,665
Present Worth of Constant O&M:	$ 6,694,777	$ 12,928,020
Present Worth of Incremental O&M:	$ 2,492,472	$ 4,813,115
Total Present Worth of O&M:	$ 9,187,250	$ 17,741,135
Capital Cost Present Worth Analysis		
Start Year:	2005	2005
End Year:	2025	2025
Years for Present Worth Evaluation:	20	20
Structure:		
Replacement Cost at 2025 - Structure:	$ -	$ -
Salvage Value at 2025 - Stucture:	$ 8,089,401	$ 16,907,321
Present Worth of Salvage Value at 2025 - Structure:	$ 1,735,567	$ 3,627,435
Total Present Worth - Structure:	$ 11,746,769	$ 24,551,433
Equipment:		
Replacement Cost at 2020 - Equipment:	$ 5,679,729	$ 3,574,054
Salvage Value at 2020 - Equipment:	$ 3,786,486	$ 2,382,702
Present Worth of Salvage Value at 2020 - Equipment:	$ 812,384	$ 511,205
Total Present Worth - Equipment:	$ 8,237,930	$ 5,183,839
Total Present Worth of Separation Alternative:	$ 29,172,000	$ 47,476,500
Equivalent Annual Cost:	$ 2,971,300	$ 4,835,600

City of Akron CSO LTCP

Cost Update - Update of 2002 to 2005 Capital and O&M Costs for Additional Treatment & Disinfection at Rack 31/40 and OCI Tunnel

2005 Capital & O&M Costs for Additional Treatment & Disinfection	
Average Annual ENR Inflation Rate:	3.54%
Period for Cost Update, 2/02-3/05 (yrs):	3.08

	2002 Costs					2005 Costs				
Item	**Structure**	**Equipment**	**Total Capital**	**O&M**	**Total**	**Structure**	**Equipment**	**Total Capital**	**O&M**	**Total**
Rack 31/40 Additional Treatment & Disinfection	$ 12,112,450	$ 3,028,113	$ 15,140,563	$ 612,595	$ 15,753,158	$ 13,482,336	$ 3,370,584	$ 16,852,920	$ 681,878	$ 17,534,798
OCI Tunnel Additional Treatment & Disinfection	$ 25,315,728	$ 1,905,485	$ 27,221,213	$ 1,182,958	$ 28,404,171	$ 28,178,869	$ 2,120,990	$ 30,299,859	$ 1,316,747	$ 61,916,466
TOTAL:					**$ 44,157,329**					**$ 79,451,263**

City of Akron CSO LTCP
Cost Update - Summary of Basin Alternative Costs

Rack Number	Technology Selection	Parameter Control	Summary of 1998 Cost Estimate (in 1998 $) 1998 Capital Cost	1998 Annual O&M Cost	20 Year Total Present Worth (2018)	Summary of Update to 1998 Cost Estimate (in 2005 $) 2005 Capital Cost	2005 Annaul O&M Cost	20 Year Total Present Worth (2025)
3	Treatment	Events	$ 1,700,088	$ 76,560	$ 2,969,800	$ 2,151,000	$ 97,000	$ 3,249,500
5+7	Storage	Events	$ 1,672,788	$ 18,900	$ 1,941,200	$ 2,116,200	$ 24,000	$ 2,232,100
10+11	Treatment	Events	$ 3,723,641	$ 80,300	$ 4,990,800	$ 4,710,100	$ 101,800	$ 5,615,800
12	Treatment	CBOD	$ 2,201,448	$ 169,950	$ 5,074,700	$ 2,785,200	$ 215,100	$ 5,408,800
14	Storage	Hours	$ 1,984,786	$ 34,500	$ 2,512,800	$ 2,510,900	$ 43,700	$ 2,857,100
15	Storage	Hours	$ 1,651,178	$ 28,590	$ 2,090,800	$ 2,088,900	$ 36,300	$ 2,376,600
22	Storage	Hours	$ 1,282,976	$ 29,190	$ 1,742,000	$ 1,623,200	$ 37,000	$ 1,963,900
26+28	Treatment	CBOD	$ 2,561,620	$ 118,690	$ 4,532,800	$ 3,240,800	$ 150,300	$ 4,948,100
27+29	Treatment	Hours	$ 1,934,065	$ 104,005	$ 3,674,200	$ 2,446,900	$ 131,800	$ 3,982,200
36	Storage	CBOD	$ 992,811	$ 20,000	$ 1,304,600	$ 1,256,200	$ 25,400	$ 1,478,000
31+40	Storage	Events	$ 13,421,279	$ 179,270	$ 16,060,300	$ 16,974,500	$ 226,800	$ 18,347,500
		Totals:	**$ 33,126,679**	**$ 859,955**	**$ 46,894,000**	**$ 41,903,900**	**$ 1,089,200**	**$ 52,459,600**

Note: Storage Basin costs do not include disinfection or screening. Refer to Disinfection Retrofit Costs for Storage Basins

City of Akron CSO LTCP
Cost Update - 20 Year Present Worth (2005 - 2025)

Economic Factors	***Present Worth Factors***	***Useful Service Life***
Evaluation Period (yrs): 20	Single Payment: 0.2145	Structure (yrs): 50
Interest Rate: 8.00%	Uniform Series: 9.8181	Equipment (yrs): 15
Inflation Rate: 3.54%	Gradient Series: 69.0898	
Capital Recovery Factor: 0.1019		

Rack Number	Technology Selection	Parameter Control	Annual O&M Cost (2005)	Annual O&M Cost (2018)	Incremental Increase	20 -Year O&M Present Worth (2018)			Capital Cost			Salvage Value (2025)		Salvage Present Worth (2025)		Capital Present Worth (2025)		Total Present Worth	Equivalent Annual Cost
						Constant O&M	Incremental O&M	Total O&M	Structure (2005)	Equipment (2005)	Equipment (2020)	Structure	Equipment	Structure	Equipment	Structure	Equipment		
3	Treatment	Events	$ 97,000	$ 194,600	$ 5,200	$ 952,400	$ 359,300	$ 1,311,700	$ 1,979,000	$ 172,100	$ 290,100	$ 1,187,400	$ 193,400	$ 254,800	$ 41,500	$ 1,724,200	$ 213,600	$ 3,249,500	$ 331,000
3	Storage	Hours	$ 48,500	$ 97,300	$ 2,600	$ 476,200	$ 179,700	$ 655,900	$ 2,783,900	$ 242,100	$ 408,000	$ 1,670,400	$ 272,000	$ 358,400	$ 58,400	$ 2,425,500	$ 300,500	$ 3,381,900	$ 344,500
5+7	Storage	Events	$ 24,000	$ 48,200	$ 1,300	$ 235,700	$ 89,900	$ 325,600	$ 1,947,000	$ 169,300	$ 285,300	$ 1,168,200	$ 190,200	$ 250,700	$ 40,900	$ 1,696,300	$ 210,200	$ 2,232,100	$ 227,400
5+7	Treatment	Events	$ 69,300	$ 139,000	$ 3,700	$ 680,400	$ 255,700	$ 936,100	$ 2,051,900	$ 178,500	$ 300,800	$ 1,231,200	$ 200,600	$ 264,200	$ 43,100	$ 1,787,700	$ 221,600	$ 2,945,400	$ 300,000
10+11	Treatment	Events	$ 101,800	$ 204,200	$ 5,400	$ 999,500	$ 373,100	$ 1,372,600	$ 4,333,300	$ 376,900	$ 635,200	$ 2,600,000	$ 423,500	$ 557,900	$ 90,900	$ 3,775,400	$ 467,800	$ 5,615,800	$ 572,000
10+11	Storage	Hours	$ 64,000	$ 128,400	$ 3,400	$ 628,400	$ 235,000	$ 863,400	$ 5,496,200	$ 478,000	$ 805,500	$ 3,297,800	$ 537,000	$ 707,600	$ 115,300	$ 4,788,600	$ 593,300	$ 6,245,300	$ 636,100
12	Treatment	CBOD	$ 215,100	$ 431,400	$ 11,400	$ 2,111,900	$ 787,700	$ 2,899,600	$ 2,562,400	$ 222,900	$ 375,700	$ 1,537,500	$ 250,500	$ 329,900	$ 53,800	$ 2,232,500	$ 276,700	$ 5,408,800	$ 550,900
12	Storage	Hours	$ 110,400	$ 221,400	$ 5,900	$ 1,084,000	$ 407,700	$ 1,491,700	$ 4,451,900	$ 387,200	$ 652,500	$ 2,671,200	$ 435,000	$ 573,200	$ 93,400	$ 3,878,700	$ 480,600	$ 5,851,000	$ 596,000
14	Storage	Hours	$ 43,700	$ 87,700	$ 2,400	$ 429,100	$ 165,900	$ 595,000	$ 2,310,100	$ 200,900	$ 338,600	$ 1,386,100	$ 225,800	$ 297,400	$ 48,500	$ 2,012,700	$ 249,400	$ 2,857,100	$ 291,100
14	Treatment	CBOD	$ 146,300	$ 293,400	$ 7,800	$ 1,436,400	$ 539,000	$ 1,975,400	$ 1,694,100	$ 147,400	$ 248,400	$ 1,016,500	$ 165,600	$ 218,100	$ 35,600	$ 1,476,000	$ 183,000	$ 3,634,400	$ 370,200
15	Storage	Hours	$ 36,300	$ 72,800	$ 2,000	$ 356,400	$ 138,200	$ 494,600	$ 1,921,800	$ 167,200	$ 281,800	$ 1,153,100	$ 187,900	$ 247,400	$ 40,400	$ 1,674,400	$ 207,600	$ 2,376,600	$ 242,100
15	Treatment	CBOD	$ 111,600	$ 223,800	$ 6,000	$ 1,095,800	$ 414,600	$ 1,510,400	$ 1,711,900	$ 148,900	$ 251,000	$ 1,027,200	$ 167,400	$ 220,400	$ 36,000	$ 1,491,500	$ 184,900	$ 3,186,800	$ 324,600
22	Storage	Hours	$ 37,000	$ 74,200	$ 2,000	$ 363,300	$ 138,200	$ 501,500	$ 1,493,400	$ 129,900	$ 218,900	$ 896,100	$ 146,000	$ 192,300	$ 31,400	$ 1,301,100	$ 161,300	$ 1,963,900	$ 200,100
22	Treatment	Hours	$ 135,800	$ 272,400	$ 7,200	$ 1,333,400	$ 497,500	$ 1,830,900	$ 1,872,400	$ 162,900	$ 274,600	$ 1,123,500	$ 183,100	$ 241,100	$ 39,300	$ 1,631,300	$ 202,200	$ 3,664,400	$ 373,300
26+28	Treatment	CBOD	$ 150,300	$ 301,400	$ 8,000	$ 1,475,700	$ 552,800	$ 2,028,500	$ 2,981,600	$ 259,300	$ 437,000	$ 1,789,000	$ 291,400	$ 383,900	$ 62,600	$ 2,597,700	$ 321,900	$ 4,948,100	$ 504,000
26+28	Storage	Events	$ 39,100	$ 78,500	$ 2,100	$ 383,900	$ 145,100	$ 529,000	$ 2,792,600	$ 242,900	$ 409,400	$ 1,675,600	$ 273,000	$ 359,500	$ 58,600	$ 2,433,100	$ 301,500	$ 3,263,600	$ 332,500
27+29	Treatment	Hours	$ 131,800	$ 264,300	$ 7,000	$ 1,294,100	$ 483,700	$ 1,777,800	$ 2,251,200	$ 195,800	$ 330,000	$ 1,350,800	$ 220,000	$ 289,900	$ 47,300	$ 1,961,300	$ 243,100	$ 3,982,200	$ 405,600
27+29	Storage	CBOD	$ 25,400	$ 51,000	$ 1,400	$ 249,400	$ 96,800	$ 346,200	$ 2,319,500	$ 201,700	$ 339,900	$ 1,391,700	$ 226,600	$ 298,600	$ 48,700	$ 2,020,900	$ 250,400	$ 2,617,500	$ 266,600
36	Storage	CBOD	$ 25,400	$ 51,000	$ 1,400	$ 249,400	$ 96,800	$ 346,200	$ 1,155,800	$ 100,500	$ 169,400	$ 693,500	$ 113,000	$ 148,800	$ 24,300	$ 1,007,000	$ 124,800	$ 1,478,000	$ 150,600
36	Treatment	CBOD	$ 87,200	$ 174,900	$ 4,700	$ 856,200	$ 324,800	$ 1,181,000	$ 1,267,800	$ 110,300	$ 185,900	$ 760,700	$ 124,000	$ 163,300	$ 26,700	$ 1,104,500	$ 137,000	$ 2,422,500	$ 246,800

2005 O&M Costs

Average Annual Inflation Rate:	3.54%
Period for Cost Update, 6/98-3/05 (yrs):	6.75

	Screen						Disinfection					
	Storage			Treatment			Storage			Treatment		
Rack	Hours	Event	CBOD	Hours	Event	CBOD	Hours	Event	CBOD	Hours	Event	CBOD
3	$ 6,400	$ 6,100	$ 6,200	$ 6,200	$ 6,500	$ 6,400	$ 60,800	$ 41,800	$ 38,600	$ 44,100	$ 50,600	$ 49,400
5+7	$ 5,700	$ 5,700	$ 5,600	$ 5,700	$ 6,000	$ 5,700	$ 31,700	$ 31,700	$ 28,500	$ 31,300	$ 36,100	$ 31,700
10+11	$ 7,600	$ 6,300	$ 6,100	$ 6,000	$ 6,400	$ 6,400	$ 75,900	$ 44,300	$ 38,000	$ 34,600	$ 51,900	$ 45,600
12	$ 8,600	$ 7,600	$ 7,400	$ 7,600	$ 8,000	$ 8,300	$ 120,200	$ 88,600	$ 75,900	$ 88,600	$ 101,200	$ 111,300
14	$ 6,400	$ 6,300	$ 6,200	$ 6,300	$ 6,300	$ 7,000	$ 54,400	$ 44,300	$ 39,300	$ 44,300	$ 51,300	$ 76,600
15	$ 6,200	$ 6,100	$ 6,100	$ 6,100	$ 6,200	$ 6,400	$ 49,400	$ 38,000	$ 35,500	$ 38,000	$ 50,000	$ 57,000
22	$ 6,200	$ 6,300	$ 6,100	$ 7,100	$ 6,400	$ 6,100	$ 50,000	$ 44,300	$ 35,500	$ 70,100	$ 52,500	$ 35,500
26+28	$ -	$ 6,400	$ 6,500	$ 6,400	$ 6,500	$ 7,500	$ -	$ 50,000	$ 50,600	$ 50,000	$ 64,500	$ 78,500
27+29	$ -	$ 5,800	$ 5,700	$ 5,800	$ 6,100	$ 6,400	$ -	$ 31,700	$ 31,700	$ 31,700	$ 39,300	$ 45,600
36	$ 5,700	$ 5,700	$ 5,700	$ 5,800	$ 6,000	$ 6,400	$ 31,700	$ 31,400	$ 31,700	$ 36,300	$ 36,100	$ 45,600
31+40	$ -	$ 11,100	$ 11,400	$ 11,000	$ 12,400	$ -	$ -	$ 183,400	$ 189,800	$ 188,500	$ 189,100	$ -

	Pump						Fans					
	Storage			Treatment			Storage			Treatment		
Rack	Hours	Event	CBOD	Hours	Event	CBOD	Hours	Event	CBOD	Hours	Event	CBOD
3	$ 38,000	$ 24,700	$ 23,400	$ 26,000	$ 31,000	$ 27,900	$ 10,500	$ 7,300	$ 6,900	$ 7,700	$ 8,900	$ 8,400
5+7	$ 18,400	$ 18,400	$ 18,400	$ 17,100	$ 20,900	$ 19,700	$ 5,600	$ 5,600	$ 5,300	$ 5,500	$ 6,300	$ 5,700
10+11	$ 50,600	$ 26,600	$ 22,800	$ 20,900	$ 34,200	$ 27,200	$ 13,400	$ 7,800	$ 6,700	$ 6,200	$ 9,300	$ 8,000
12	$ 88,600	$ 57,000	$ 50,600	$ 63,300	$ 75,900	$ 75,900	$ 21,800	$ 15,400	$ 13,400	$ 16,000	$ 18,600	$ 19,600
14	$ 34,200	$ 26,600	$ 25,300	$ 27,200	$ 33,600	$ 49,400	$ 9,500	$ 7,800	$ 7,100	$ 7,800	$ 9,200	$ 13,300
15	$ 27,900	$ 22,800	$ 20,300	$ 22,800	$ 30,400	$ 38,000	$ 8,400	$ 6,700	$ 6,200	$ 6,700	$ 8,700	$ 10,200
22	$ 28,500	$ 26,600	$ 20,300	$ 46,200	$ 34,800	$ 20,300	$ 8,500	$ 7,800	$ 6,200	$ 12,400	$ 9,400	$ 6,200
26+28	$ -	$ 30,400	$ 30,400	$ 30,400	$ 40,500	$ 50,600	$ -	$ 8,700	$ 8,800	$ 8,700	$ 11,200	$ 13,700
27+29	$ -	$ 18,600	$ 19,700	$ 82,300	$ 26,200	$ 27,200	$ -	$ 5,600	$ 5,700	$ 12,000	$ 7,200	$ 8,000
36	$ 19,000	$ 17,800	$ 19,700	$ 17,800	$ 20,900	$ 27,200	$ 5,700	$ 5,500	$ 5,700	$ 6,000	$ 6,300	$ 8,000
31+40	$ -	$ 188,500	$ 158,100	$ 158,100	$ 234,000	$ -	$ -	$ 38,300	$ 36,000	$ 35,800	$ 43,600	$ -

	Total O&M Costs					
	Storage			Treatment		
Rack	Hours	Event	CBOD	Hours	Event	CBOD
3	$ 48,500	$ 32,000	$ 30,300	$ 84,000	$ 97,000	$ 92,100
5+7	$ 24,000	$ 24,000	$ 23,700	$ 59,600	$ 69,300	$ 62,800
10+11	$ 64,000	$ 34,400	$ 29,500	$ 67,700	$ 101,800	$ 87,200
12	$ 110,400	$ 72,400	$ 64,000	$ 175,500	$ 203,700	$ 215,100
14	$ 43,700	$ 34,400	$ 32,400	$ 85,600	$ 100,400	$ 146,300
15	$ 36,300	$ 29,500	$ 26,500	$ 73,600	$ 95,300	$ 111,600
22	$ 37,000	$ 34,400	$ 26,500	$ 135,800	$ 103,100	$ 68,100
26+28	$ -	$ 39,100	$ 39,200	$ 95,500	$ 122,700	$ 150,300
27+29	$ -	$ 24,200	$ 25,400	$ 131,800	$ 78,800	$ 87,200
36	$ 24,700	$ 23,300	$ 25,400	$ 65,900	$ 69,300	$ 87,200
31+40	$ -	$ 226,800	$ 194,100	$ 393,400	$ 479,100	$ -

1998 O&M Costs (Reproduced from Facilities Plan '98 - April 30, 1999)

	Screen						Disinfection					
	Storage			**Treatment**			**Storage**			**Treatment**		
Rack	**Hours**	**Event**	**CBOD**	**Hours**	**Event**	**CBOD**	**Hours**	**Event**	**CBOD**	**Hours**	**Event**	**CBOD**
3	$ 5,000	$ 4,800	$ 4,850	$ 4,900	$ 5,100	$ 5,000	$ 48,000	$ 33,000	$ 30,500	$ 34,800	$ 40,000	$ 39,000
5+7	$ 4,500	$ 4,500	$ 4,400	$ 4,500	$ 4,725	$ 4,500	$ 25,000	$ 25,000	$ 22,500	$ 24,700	$ 28,500	$ 25,000
10+11	$ 5,950	$ 4,950	$ 4,800	$ 4,725	$ 5,000	$ 5,000	$ 60,000	$ 35,000	$ 30,000	$ 27,300	$ 41,000	$ 36,000
12	$ 6,800	$ 6,000	$ 5,800	$ 6,000	$ 6,300	$ 6,500	$ 95,000	$ 70,000	$ 60,000	$ 70,000	$ 80,000	$ 88,000
14	$ 5,000	$ 4,925	$ 4,900	$ 4,950	$ 4,975	$ 5,500	$ 43,000	$ 35,000	$ 31,000	$ 35,000	$ 40,500	$ 60,500
15	$ 4,900	$ 4,750	$ 4,750	$ 4,750	$ 4,900	$ 5,000	$ 39,000	$ 30,000	$ 28,000	$ 30,000	$ 39,500	$ 45,000
22	$ 4,900	$ 4,925	$ 4,750	$ 5,550	$ 5,000	$ 4,750	$ 39,500	$ 35,000	$ 28,000	$ 55,400	$ 41,500	$ 28,000
26+28	$ -	$ 5,000	$ 5,100	$ 5,000	$ 5,075	$ 5,900	$ -	$ 39,500	$ 40,000	$ 39,500	$ 51,000	$ 62,000
27+29	$ -	$ 4,550	$ 4,500	$ 4,550	$ 4,800	$ 5,000	$ -	$ 25,000	$ 25,000	$ 25,000	$ 31,000	$ 36,000
36	$ 4,500	$ 4,500	$ 4,500	$ 4,550	$ 4,725	$ 5,000	$ 25,000	$ 24,800	$ 25,000	$ 28,700	$ 28,500	$ 36,000
31+40	$ -	$ 8,700	$ 9,000	$ 8,650	$ 9,750	$ -	$ -	$ 145,000	$ 150,000	$ 149,000	$ 149,500	$ -

	Pump						Fans					
	Storage			**Treatment**			**Storage**			**Treatment**		
Rack	**Hours**	**Event**	**CBOD**	**Hours**	**Event**	**CBOD**	**Hours**	**Event**	**CBOD**	**Hours**	**Event**	**CBOD**
3	$ 30,000	$ 19,500	$ 18,500	$ 20,500	$ 24,500	$ 22,000	$ 8,300	$ 5,730	$ 5,385	$ 6,020	$ 6,960	$ 6,600
5+7	$ 14,500	$ 14,500	$ 14,500	$ 13,500	$ 16,500	$ 15,500	$ 4,400	$ 4,400	$ 4,140	$ 4,270	$ 4,973	$ 4,500
10+11	$ 40,000	$ 21,000	$ 18,000	$ 16,500	$ 27,000	$ 21,500	$ 10,595	$ 6,095	$ 5,280	$ 4,853	$ 7,300	$ 6,250
12	$ 70,000	$ 45,000	$ 40,000	$ 50,000	$ 60,000	$ 60,000	$ 17,180	$ 12,100	$ 10,580	$ 12,600	$ 14,630	$ 15,450
14	$ 27,000	$ 21,000	$ 20,000	$ 21,500	$ 26,500	$ 39,000	$ 7,500	$ 6,093	$ 5,590	$ 6,145	$ 7,198	$ 10,500
15	$ 22,000	$ 18,000	$ 16,000	$ 18,000	$ 24,000	$ 30,000	$ 6,590	$ 5,275	$ 4,875	$ 5,275	$ 6,840	$ 8,000
22	$ 22,500	$ 21,000	$ 16,000	$ 36,500	$ 27,500	$ 16,000	$ 6,690	$ 6,093	$ 4,875	$ 9,745	$ 7,400	$ 4,875
26+28	$ -	$ 24,000	$ 24,000	$ 24,000	$ 32,000	$ 40,000	$ -	$ 6,850	$ 6,910	$ 6,850	$ 8,808	$ 10,790
27+29	$ -	$ 14,700	$ 15,500	$ 65,000	$ 20,700	$ 21,500	$ -	$ 4,425	$ 4,500	$ 9,455	$ 5,650	$ 6,250
36	$ 15,000	$ 14,000	$ 15,500	$ 14,000	$ 16,500	$ 21,500	$ 4,450	$ 4,330	$ 4,500	$ 4,725	$ 4,973	$ 6,250
31+40		$ 149,000	$ 125,000	$ 125,000	$ 185,000	$ -	$ -	$ 30,270	$ 28,400	$ 28,265	$ 34,425	$ -

	Total O&M Costs					
	Storage			**Treatment**		
Rack	**Hours**	**Event**	**CBOD**	**Hours**	**Event**	**CBOD**
3	$ 38,300	$ 25,230	$ 23,885	$ 66,220	$ 76,560	$ 72,600
5+7	$ 18,900	$ 18,900	$ 18,640	$ 46,970	$ 54,698	$ 49,500
10+11	$ 50,595	$ 27,095	$ 23,280	$ 53,378	$ 80,300	$ 68,750
12	$ 87,180	$ 57,100	$ 50,580	$ 138,600	$ 160,930	$ 169,950
14	$ 34,500	$ 27,093	$ 25,590	$ 67,595	$ 79,173	$ 115,500
15	$ 28,590	$ 23,275	$ 20,875	$ 58,025	$ 75,240	$ 88,000
22	$ 29,190	$ 27,093	$ 20,875	$ 107,195	$ 81,400	$ 53,625
26+28	$ -	$ 30,850	$ 30,910	$ 75,350	$ 96,883	$ 118,690
27+29	$ -	$ 19,125	$ 20,000	$ 104,005	$ 62,150	$ 68,750
36	$ 19,450	$ 18,330	$ 20,000	$ 51,975	$ 54,698	$ 68,750
31+40	$ -	$ 179,270	$ 153,400	$ 310,915	$ 378,675	$ -

Storage Tanks:
O&M includes only fans and pumps

Treatment Tanks:
O&M includes fans, pumps, screens, disinfection

* - O&M figures for screens and disinfection are from Fig 5-2 of EPA CSO Control Manual, Sept. 93.
O&M figures for pumps are from Fact Sheet 1.1.2C, EPA/430/9-78-009, Oct. 78.
O&M figures for fans are equal to 10% of the sum of O&M costs for screens, disinfection and pumps

City of Akron CSO LTCP
Cost Update - 20 Year Present Worth (2005 - 2025)

2005 Capital Costs for Storage based on "Hours" Criteria

Average Annual Inflation Rate: **3.54%**

Period for Cost Update, 6/98-3/05 (yrs): **6.75**

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	160,000	1.20	10,667	$ 32,600	$ 71,200	$ 27,300	$ 2,300	$ 5,900	$ 1,036,500	$ 155,500	$ 28,600	$ 339,400	$ 578,400	2133	$ 49,900	$ -	$ -	$ -	$ 2,327,600	$ 3,025,900	$ 2.53	$ 2,783,900	$ 242,100
5+7	20,730	0.16	1,382	$ 4,300	$ 35,800	$ 16,900	$ 1,800	$ 5,900	$ 552,600	$ 82,900	$ 15,200	$ 93,700	$ 812,200	276	$ 6,500	$ -	$ -	$ -	$ 1,627,800	$ 2,116,200	$ 13.65	$ 1,947,000	$ 169,300
10+11	219,230	1.64	14,615	$ 44,600	$ 59,400	$ 23,800	$ 2,100	$ 5,900	$ 1,257,500	$ 188,700	$ 34,600	$ 413,900	$ 2,496,500	2923	$ 68,400	$ -	$ -	$ -	$ 4,595,400	$ 5,974,100	$ 3.64	$ 5,496,200	$ 478,000
12	400,700	3.00	26,713	$ 81,500	$ 177,500	$ 51,500	$ 3,500	$ 5,900	$ 1,991,200	$ 298,700	$ 54,800	$ 605,200	$ 327,600	5343	$ 124,900	$ -	$ -	$ -	$ 3,722,300	$ 4,839,000	$ 1.61	$ 4,451,900	$ 387,200
14	168,600	1.26	11,240	$ 34,300	$ 116,500	$ 37,100	$ 2,800	$ 5,900	$ 1,068,000	$ 160,200	$ 29,400	$ 350,800	$ 73,800	2248	$ 52,600	$ -	$ -	$ -	$ 1,931,400	$ 2,510,900	$ 2	$ 2,310,100	$ 200,900
15	90,300	0.68	6,020	$ 18,400	$ 63,400	$ 25,000	$ 2,200	$ 5,900	$ 788,000	$ 118,200	$ 21,700	$ 236,700	$ 299,100	1204	$ 28,200	$ -	$ -	$ -	$ 1,606,800	$ 2,088,900	$ 3	$ 1,921,800	$ 167,200
22	47,400	0.35	3,160	$ 9,700	$ 35,800	$ 16,900	$ 1,800	$ 5,900	$ 641,400	$ 96,200	$ 17,700	$ 157,700	$ 250,700	632	$ 14,800	$ -	$ -	$ -	$ 1,248,600	$ 1,623,200	$ 4.58	$ 1,493,400	$ 129,900
26+28	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
27+29	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
36	30,000	0.22	2,000	$ 6,100	$ 51,600	$ 21,500	$ 2,000	$ 5,900	$ 583,200	$ 87,500	$ 16,100	$ 118,300	$ 53,000	400	$ 9,400	$ -	$ -	$ -	$ 954,600	$ 1,241,000	$ 5.53	$ 1,141,800	$ 99,300
31+40	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Note: "NA" - No basin volume will reduce hours of overflow

2005 Capital Costs for Storage based on "CBOD" Criteria

Average Annual Inflation Rate: **3.54%**

Period for Cost Update, 6/98-3/05 (yrs): **6.75**

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	orage Cost (30% Cor	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	46,260	0.35	3,084	$ 9,500	$ 71,200	$ 27,300	$ 2,300	$ 5,900	$ 637,500	$ 95,700	$ 17,600	$ 155,300	$ 578,400	617	$ 14,500	$ -	$ -	$ -	$ 1,615,200	$2,099,800	$ 6	$ 1,931,900	$ 168,000
5+7	20,728	0.16	1,382	$ 4,300	$ 35,800	$ 16,900	$ 1,800	$ 5,900	$ 552,600	$ 82,900	$ 15,200	$ 93,700	$ 812,200	276	$ 6,500	$ -	$ -	$ -	$ 1,627,800	$2,116,200	$ 14	$ 1,947,000	$ 169,300
10+11	36,800	0.28	2,453	$ 7,500	$ 59,400	$ 23,800	$ 2,100	$ 5,900	$ 605,900	$ 90,900	$ 16,700	$ 134,500	$ 2,496,500	491	$ 11,500	$ -	$ -	$ -	$ 3,454,700	$ 4,491,200	$ 16.32	$ 4,132,000	$ 359,300
12	131,400	0.98	8,760	$ 26,800	$ 177,500	$ 51,500	$ 3,500	$ 5,900	$ 933,000	$ 140,000	$ 25,700	$ 299,800	$ 327,600	1752	$ 41,000	$ -	$ -	$ -	$ 2,032,300	$ 2,642,000	$ 2.69	$ 2,430,700	$ 211,400
14	83,600	0.63	5,573	$ 17,000	$ 116,500	$ 37,100	$ 2,800	$ 5,900	$ 764,800	$ 114,800	$ 21,100	$ 225,500	$ 73,800	1115	$ 26,100	$ -	$ -	$ -	$ 1,405,400	$ 1,827,100	$ 2.92	$ 1,681,000	$ 146,200
15	41,480	0.31	2,765	$ 8,500	$ 63,400	$ 25,000	$ 2,200	$ 5,900	$ 621,500	$ 93,300	$ 17,100	$ 145,000	$ 299,100	553	$ 13,000	$ -	$ -	$ -	$ 1,294,000	$ 1,682,200	$ 5.42	$ 1,547,700	$ 134,600
22	19,700	0.15	1,313	$ 4,100	$ 35,800	$ 16,900	$ 1,800	$ 5,900	$ 549,200	$ 82,400	$ 15,200	$ 90,700	$ 250,700	263	$ 6,200	$ -	$ -	$ -	$ 1,058,900	$ 1,376,600	$ 9.34	$ 1,266,500	$ 110,200
26+28	80,150	0.60	5,343	$ 16,300	$ 111,000	$ 35,800	$ 2,700	$ 5,900	$ 752,900	$ 113,000	$ 20,800	$ 219,600	$ 1,017,000	1069	$ 25,000	$ -	$ -	$ -	$ 2,320,000	$ 3,016,000	$ 5.03	$ 2,774,800	$ 241,300
27+29	32,998	0.25	2,200	$ 6,800	$ 51,600	$ 21,500	$ 2,000	$ 5,900	$ 593,200	$ 89,000	$ 16,400	$ 125,600	$ 1,017,000	440	$ 10,300	$ -	$ -	$ -	$ 1,939,300	$ 2,521,100	$ 10.21	$ 2,319,500	$ 201,700
36	31,700	0.24	2,113	$ 6,500	$ 51,600	$ 21,500	$ 2,000	$ 5,900	$ 588,900	$ 88,400	$ 16,200	$ 122,400	$ 53,000	423	$ 9,900	$ -	$ -	$ -	$ 966,300	$ 1,256,200	$ 5.30	$ 1,155,800	$ 100,500
31+40	1,039,940	7.78	69,329	$ 211,400	$ 1,210,900	$ 207,300	$ 7,800	$ 20,300	$ 5,255,300	$ 788,300	$ 144,600	$ 1,103,600	$ 1,622,900	13866	$ 324,000	$ -	$ -	$ -	$ 10,896,400	$ 14,165,400	$ 1.82	$ 13,032,200	$ 1,133,300

2005 Capital Costs for Storage based on "Events" Criteria

Average Annual Inflation Rate: **3.54%**

Period for Cost Update, 6/98-3/05 (yrs): **6.75**

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	49,400	0.37	3,293	$ 10,100	$ 72,800	$ 27,700	$ 2,400	$ 5,900	$ 648,100	$ 97,300	$ 17,900	$ 161,900	$ 578,400	659	$ 15,400	$ -	$ -	$ -	$ 1,637,900	$ 2,129,300	$ 5.76	$ 1,959,000	$ 170,400
5+7	20,730	0.16	1,382	$ 4,300	$ 35,800	$ 16,900	$ 1,800	$ 5,900	$ 552,600	$ 82,900	$ 15,200	$ 93,700	$ 812,200	276	$ 6,500	$ -	$ -	$ -	$ 1,627,800	$ 2,116,200	$ 13.65	$ 1,947,000	$ 169,300
10+11	48,360	0.36	3,224	$ 9,900	$ 72,000	$ 27,500	$ 2,300	$ 5,900	$ 644,600	$ 96,700	$ 17,800	$ 159,700	$ 2,496,500	645	$ 15,100	$ -	$ -	$ -	$ 3,548,000	$ 4,612,400	$ 12.75	$ 4,243,500	$ 369,000
12	179,000	1.34	11,933	$ 36,400	$ 231,900	$ 64,400	$ 4,100	$ 5,900	$ 1,106,400	$ 166,000	$ 30,500	$ 364,300	$ 327,600	2387	$ 55,800	$ -	$ -	$ -	$ 2,393,300	$ 3,111,300	$ 2.32	$ 2,862,400	$ 249,000
14	96,020	0.72	6,401	$ 19,600	$ 129,800	$ 40,200	$ 2,900	$ 5,900	$ 807,900	$ 121,200	$ 22,300	$ 246,100	$ 73,800	1280	$ 30,000	$ -	$ -	$ -	$ 1,499,700	$ 1,949,700	$ 2.71	$ 1,793,800	$ 156,000
15	50,150	0.38	3,343	$ 10,200	$ 74,400	$ 28,200	$ 2,400	$ 5,900	$ 650,600	$ 97,600	$ 17,900	$ 163,400	$ 299,100	669	$ 15,700	$ -	$ -	$ -	$ 1,365,400	$ 1,775,100	$ 4.73	$ 1,633,100	$ 142,100
22	36,320	0.27	2,421	$ 7,400	$ 56,300	$ 22,900	$ 2,100	$ 5,900	$ 604,300	$ 90,700	$ 16,700	$ 133,400	$ 250,700	484	$ 11,400	$ -	$ -	$ -	$ 1,201,800	$ 1,562,400	$ 5.75	$ 1,437,500	$ 125,000
26+28	81,250	0.61	5,417	$ 16,600	$ 114,500	$ 39,900	$ 3,000	$ 5,900	$ 756,700	$ 113,500	$ 20,900	$ 221,500	$ 1,017,000	1083	$ 25,400	$ -	$ -	$ -	$ 2,334,900	$ 3,035,400	$ 4.99	$ 2,792,600	$ 242,900
27+29	32,000	0.24	2,133	$ 6,600	$ 50,000	$ 21,100	$ 2,000	$ 5,900	$ 589,900	$ 88,500	$ 16,300	$ 123,200	$ 1,017,000	427	$ 10,000	$ -	$ -	$ -	$ 1,930,500	$ 2,509,700	$ 10.49	$ 2,309,000	$ 200,800
36	22,000	0.16	1,467	$ 4,500	$ 37,400	$ 17,400	$ 1,800	$ 5,900	$ 556,800	$ 83,600	$ 15,400	$ 97,300	$ 53,000	293	$ 6,900	$ -	$ -	$ -	$ 880,000	$ 1,144,000	$ 6.95	$ 1,052,500	$ 91,600
31+40	1,263,160	9.45	84,211	$ 256,800	$ 1,446,800	$ 237,300	$ 8,300	$ 20,300	$ 6,644,400	$ 996,700	$ 182,800	$ 1,247,400	$ 1,622,900	16842	$ 393,600	$ -	$ -	$ -	$ 13,057,300	$ 16,974,500	$ 1.80	$ 15,616,600	$ 1,358,000

City of Akron CSO LTCP
Cost Update - 20 Year Present Worth (2005 - 2025)

2005 Capital Costs for Treatment based on "Hours" Criteria

Average Annual Inflation Rate: **3.54%**
Period for Cost Update, 6/98-3/05 (yrs): **6.75**

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	24,070	0.18	1,605	$ 4,900	$ 39,800	$ 18,100	$ 1,800	$ 5,900	$ 563,600	$ 84,600	$ 15,500	$ 102,900	$ 578,400	321	$ 7,500	$ 19,000	$ 26,500	$ 90,900	$ 1,559,400	$ 2,027,300	$ 11.26	$ 1,865,200	$ 162,200
5+7	10,100	0.08	673	$ 2,100	$ 24,000	$ 13,500	$ 1,600	$ 5,900	$ 517,700	$ 77,700	$ 14,300	$ 59,600	$ 812,200	135	$ 3,200	$ 19,000	$ 12,800	$ 60,800	$ 1,624,400	$ 2,111,800	$ 27.95	$ 1,942,900	$ 169,000
10+11	15,970	0.12	1,065	$ 3,300	$ 31,900	$ 15,800	$ 1,700	$ 5,900	$ 536,900	$ 80,600	$ 14,800	$ 79,500	$ 2,496,500	213	$ 5,000	$ 19,000	$ 18,800	$ 75,200	$ 3,384,900	$ 4,400,400	$ 36.84	$ 4,048,400	$ 352,100
12	77,580	0.58	5,172	$ 15,800	$ 111,000	$ 35,800	$ 2,700	$ 5,900	$ 744,000	$ 111,600	$ 20,500	$ 215,100	$ 327,600	1034	$ 24,200	$ 31,700	$ 71,000	$ 156,500	$ 1,873,400	$ 2,435,500	$ 4.20	$ 2,240,700	$ 194,900
14	25,160	0.19	1,677	$ 5,200	$ 43,700	$ 19,200	$ 1,900	$ 5,900	$ 567,200	$ 85,100	$ 15,600	$ 105,900	$ 73,800	335	$ 7,900	$ 19,000	$ 27,500	$ 92,800	$ 1,070,700	$ 1,392,000	$ 7	$ 1,280,700	$ 111,400
15	18,990	0.14	1,266	$ 3,900	$ 35,800	$ 16,900	$ 1,800	$ 5,900	$ 546,900	$ 82,100	$ 15,100	$ 88,700	$ 299,100	253	$ 6,000	$ 19,000	$ 21,700	$ 81,500	$ 1,224,400	$ 1,591,800	$ 11	$ 1,464,500	$ 127,400
22	55,000	0.41	3,667	$ 11,200	$ 83,000	$ 30,700	$ 2,500	$ 5,900	$ 667,000	$ 100,100	$ 18,400	$ 173,200	$ 250,700	733	$ 17,200	$ 19,000	$ 53,200	$ 133,400	$ 1,565,500	$ 2,035,200	$ 4.95	$ 1,872,400	$ 162,900
26+28	30,000	0.22	2,000	$ 6,100	$ 47,600	$ 20,400	$ 1,900	$ 5,900	$ 583,200	$ 87,500	$ 16,100	$ 118,300	$ 1,017,000	400	$ 9,400	$ 31,700	$ 31,900	$ 100,700	$ 2,077,700	$ 2,701,100	$ 12.04	$ 2,485,100	$ 216,100
27+29	13,160	0.10	877	$ 2,700	$ 28,000	$ 14,600	$ 1,600	$ 5,900	$ 527,700	$ 79,200	$ 14,600	$ 70,400	$ 1,017,000	175	$ 4,100	$ 31,700	$ 16,000	$ 68,700	$ 1,882,200	$ 2,446,900	$ 24.86	$ 2,251,200	$ 195,800
36	11,670	0.09	778	$ 2,400	$ 24,000	$ 13,500	$ 1,600	$ 5,900	$ 522,900	$ 78,500	$ 14,400	$ 65,300	$ 53,000	156	$ 3,700	$ 19,000	$ 14,400	$ 65,000	$ 883,600	$ 1,148,700	$ 13.16	$ 1,056,900	$ 91,900
31+40	232,350	1.74	15,490	$ 47,300	$ 288,900	$ 69,600	$ 4,000	$ 20,300	$ 1,307,700	$ 196,200	$ 36,000	$ 429,300	$ 1,622,900	3098	$ 72,400	$ 44,300	$ 179,000	$ 260,300	$ 4,578,200	$ 5,951,700	$ 3.42	$ 5,475,600	$ 476,200

2005 Capital Costs for Treatment based on "CBOD" Criteria

Average Annual Inflation Rate: **3.54%**
Period for Cost Update, 6/98-3/05 (yrs): **6.75**

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	orage Cost (30% Cor	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	27,792	0.21	1,853	$ 5,700	$ 47,600	$ 20,400	$ 1,900	$ 5,900	$ 575,900	$ 86,400	15900	$ 112,700	$ 578,400	371	$ 8,700	$ 19,000	$ 29,900	$ 97,200	$ 1,605,600	$ 2,087,300	$ 10	$ 1,920,400	$ 167,000
5+7	13,702	0.10	913	$ 2,800	$ 28,000	$ 14,600	$ 1,600	$ 5,900	$ 529,500	$ 79,500	$ 14,600	$ 72,200	$ 812,200	183	$ 4,300	$ 19,000	$ 16,500	$ 70,000	$ 1,670,700	$ 2,172,000	$ 21	$ 1,998,300	$ 173,800
10+11	25,920	0.19	1,728	$ 5,300	$ 43,700	$ 19,200	$ 1,900	$ 5,900	$ 569,700	$ 85,500	$ 15,700	$ 107,900	$ 2,496,500	346	$ 8,100	$ 19,000	$ 28,200	$ 94,100	$ 3,500,700	$ 4,551,000	$ 23	$ 4,187,000	$ 364,100
12	106,488	0.80	7,099	$ 21,700	$ 144,300	$ 43,700	$ 3,100	$ 5,900	$ 844,600	$ 126,700	$ 23,300	$ 262,600	$ 327,600	1420	$ 33,200	$ 31,700	$ 92,800	$ 181,200	$ 2,142,400	$ 2,785,200	$ 3.50	$ 2,562,400	$ 222,900
14	57,700	0.43	3,847	$ 11,800	$ 86,900	$ 31,900	$ 2,600	$ 5,900	$ 676,100	$ 101,500	$ 18,600	$ 178,500	$ 73,800	769	$ 18,000	$ 19,000	$ 55,400	$ 136,400	$ 1,416,400	$ 1,841,400	$ 4.27	$ 1,694,100	$ 147,400
15	37,500	0.28	2,500	$ 7,700	$ 59,400	$ 23,800	$ 2,100	$ 5,900	$ 608,200	$ 91,300	$ 16,800	$ 136,100	$ 299,100	500	$ 11,700	$ 19,000	$ 38,500	$ 111,700	$ 1,431,300	$ 1,860,700	$ 6.63	$ 1,711,900	$ 148,900
22	17,424	0.13	1,162	$ 3,600	$ 31,900	$ 15,800	$ 1,700	$ 5,900	$ 541,700	$ 81,300	$ 14,900	$ 84,000	$ 250,700	232	$ 5,500	$ 19,000	$ 20,200	$ 78,300	$ 1,154,500	$ 1,500,900	$ 11.52	$ 1,380,900	$ 120,100
26+28	70,600	0.53	4,707	$ 14,400	$ 99,900	$ 33,200	$ 2,600	$ 5,900	$ 720,100	$ 108,100	$ 19,900	$ 202,700	$ 1,017,000	941	$ 22,000	$ 31,700	$ 65,600	$ 149,800	$ 2,492,900	$ 3,240,800	$ 6.14	$ 2,981,600	$ 259,300
27+29	29,790	0.22	1,986	$ 6,100	$ 47,600	$ 20,400	$ 1,900	$ 5,900	$ 582,500	$ 87,400	$ 16,100	$ 117,700	$ 1,017,000	397	$ 9,300	$ 31,700	$ 31,700	$ 100,400	$ 2,075,700	$ 2,698,500	$ 12.11	$ 2,482,700	$ 215,900
36	26,200	0.20	1,747	$ 5,400	$ 43,700	$ 19,200	$ 1,900	$ 5,900	$ 570,700	$ 85,600	$ 15,700	$ 108,600	$ 53,000	349	$ 8,200	$ 19,000	$ 28,500	$ 94,600	$ 1,060,000	$ 1,378,000	$ 7.03	$ 1,267,800	$ 110,300
31+40	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	#VALUE!	$ -	$ -	$ -	$ -	$ -	$ -	#VALUE!	$ -	$ -

Note: "NA" - No basin volume will reduce CBOD

2005 Capital Costs for Treatment based on "Events" Criteria

Average Annual Inflation Rate: **3.54%**
Period for Cost Update, 6/98-3/05 (yrs): **6.75**

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	32,580	0.24	2,172	$ 6,700	$ 50,800	$ 21,300	$ 2,000	$ 5,900	$ 591,800	$ 88,800	$ 16,300	$ 124,600	$ 578,400	434	$ 10,200	$ 19,000	$ 34,200	$ 104,600	$ 1,654,600	$ 2,151,000	$ 8.83	$ 1,979,000	$ 172,100
5+7	17,470	0.13	1,165	$ 3,600	$ 31,100	$ 15,600	$ 1,700	$ 5,900	$ 541,900	$ 81,300	$ 15,000	$ 84,100	$ 812,200	233	$ 5,500	$ 19,000	$ 20,300	$ 78,400	$ 1,715,600	$ 2,230,300	$ 17.07	$ 2,051,900	$ 178,500
10+11	37,220	0.28	2,481	$ 7,600	$ 57,100	$ 23,100	$ 2,100	$ 5,900	$ 607,300	$ 91,100	$ 16,700	$ 135,500	$ 2,496,500	496	$ 11,600	$ 19,000	$ 38,300	$ 111,300	$ 3,623,100	$ 4,710,100	$ 16.92	$ 4,333,300	$ 376,900
12	100,080	0.75	6,672	$ 20,400	$ 139,600	$ 47,200	$ 3,400	$ 5,900	$ 822,100	$ 123,400	$ 22,700	$ 252,600	$ 327,600	1334	$ 31,200	$ 31,700	$ 88,000	$ 176,100	$ 2,091,900	$ 2,719,500	$ 3.63	$ 2,502,000	$ 217,600
14	35,900	0.27	2,393	$ 7,300	$ 55,500	$ 22,700	$ 2,100	$ 5,900	$ 602,900	$ 90,500	$ 16,600	$ 132,400	$ 73,800	479	$ 11,200	$ 19,000	$ 37,100	$ 109,400	$ 1,186,400	$ 1,542,400	$ 5.74	$ 1,419,100	$ 123,400
15	29,580	0.22	1,972	$ 6,100	$ 46,800	$ 20,100	$ 1,900	$ 5,900	$ 581,800	$ 87,300	$ 16,000	$ 117,200	$ 299,100	394	$ 9,300	$ 19,000	$ 31,500	$ 100,000	$ 1,342,000	$ 1,744,600	$ 7.88	$ 1,605,100	$ 139,600
22	38,850	0.29	2,590	$ 7,900	$ 59,400	$ 23,800	$ 2,100	$ 5,900	$ 612,700	$ 91,900	$ 16,900	$ 139,200	$ 250,700	518	$ 12,200	$ 19,000	$ 39,700	$ 113,500	$ 1,394,900	$ 1,813,400	$ 6.24	$ 1,668,400	$ 145,100
26+28	49,670	0.37	3,311	$ 10,100	$ 73,600	$ 28,000	$ 2,400	$ 5,900	$ 649,000	$ 97,400	$ 17,900	$ 162,500	$ 1,017,000	662	$ 15,500	$ 31,700	$ 48,800	$ 127,200	$ 2,287,000	$ 2,973,100	$ 8.00	$ 2,735,300	$ 237,900
27+29	22,760	0.17	1,517	$ 4,700	$ 38,200	$ 17,600	$ 1,800	$ 5,900	$ 559,300	$ 83,900	$ 15,400	$ 99,400	$ 1,017,000	303	$ 7,100	$ 31,700	$ 25,300	$ 88,600	$ 1,995,900	$ 2,594,700	$ 15.24	$ 2,387,200	$ 207,600
36	17,210	0.13	1,147	$ 3,500	$ 31,100	$ 15,600	$ 1,700	$ 5,900	$ 541,000	$ 81,200	$ 14,900	$ 83,300	$ 53,000	229	$ 5,400	$ 19,000	$ 20,000	$ 77,800	$ 953,400	$ 1,239,500	$ 9.63	$ 1,140,400	$ 99,200
31+40	273,530	2.05	18,235	$ 55,600	$ 340,600	$ 82,700	$ 4,700	$ 20,300	$ 1,468,100	$ 220,300	$ 40,400	$ 475,800	$ 1,622,900	3647	$ 85,300	$ 44,300	$ 205,400	$ 280,700	$ 4,947,100	$ 6,431,300	$ 3.14	$ 5,916,800	$ 514,600

City of Akron CSO LTCP

Cost Update - 20 Year Present Worth (2005 - 2025)

1998 Capital Costs for Storage based on "Hours" Criteria (Reproduced from Facilities Plan '98 - April 30, 1999)

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	160,000	1.20	10,667	$ 25,712	$ 56,273	$ 21,519	$ 1,800	$ 4,622	$ 819,518	$ 122,928	$ 22,537	$ 268,335	$ 457,300	2133	$ 39,415	-	-	-	$ 1,839,958	$ 2,391,945	$ 2.00	$ 2,200,590	$ 191,356
5+7	20,730	0.16	1,382	$ 3,331	$ 28,290	$ 13,352	$ 1,350	$ 4,622	$ 436,904	$ 65,536	$ 12,015	$ 74,052	$ 642,200	276	$ 5,107	-	-	-	$ 1,286,759	$ 1,672,787	$ 10.79	$ 1,538,964	$ 133,823
10+11	219,230	1.64	14,615	$ 35,230	$ 46,946	$ 18,796	$ 1,650	$ 4,622	$ 994,279	$ 149,142	$ 27,343	$ 327,227	$ 1,974,000	2923	$ 54,006	-	-	-	$ 3,633,240	$ 4,723,212	$ 2.88	$ 4,345,355	$ 377,857
12	400,700	3.00	26,713	$ 64,392	$ 140,351	$ 40,704	$ 2,700	$ 4,622	$ 1,574,447	$ 236,167	$ 43,297	$ 478,473	$ 259,000	5343	$ 98,710	-	-	-	$ 2,942,863	$ 3,825,722	$ 1.28	$ 3,519,665	$ 306,058
14	168,600	1.26	11,240	$ 27,094	$ 92,094	$ 29,296	$ 2,150	$ 4,622	$ 844,447	$ 126,667	$ 23,222	$ 277,333	$ 58,300	2248	$ 41,534	-	-	-	$ 1,526,759	$ 1,984,786	$ 1.57	$ 1,826,003	$ 158,783
15	90,300	0.68	6,020	$ 14,511	$ 50,055	$ 19,704	$ 1,700	$ 4,622	$ 623,067	$ 93,460	$ 17,134	$ 187,139	$ 236,500	1204	$ 22,245	-	-	-	$ 1,270,137	$ 1,651,178	$ 2.44	$ 1,519,084	$ 132,094
22	47,400	0.35	3,160	$ 7,617	$ 28,290	$ 13,352	$ 1,350	$ 4,622	$ 507,099	$ 76,065	$ 13,945	$ 124,687	$ 198,200	$ 632	$ 11,677	-	-	-	$ 986,904	$ 1,282,976	$ 4	$ 1,180,337	$ 102,638
26+28	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	$ -	-	-	-	$ -	$ -	$ -	$ -	$ -
27+29	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	$ -	-	-	-	$ -	$ -	$ -	$ -	$ -
36	30,000	0.22	2,000	$ 4,821	$ 40,727	$ 16,981	$ 1,550	$ 4,622	$ 461,138	$ 69,171	$ 12,681	$ 93,469	$ 41,900	400	$ 7,390	-	-	-	$ 754,451	$ 980,786	$ 4.37	$ 902,323	$ 78,463
31+40	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	$ -	-	-	-	$ -	$ -	$ -	$ -	$ -

Note: "NA" - No basin volume will reduce hours of overflow

1998 Capital Costs for Storage based on "CBOD" Criteria (Reproduced from Facilities Plan '98 - April 30, 1999)

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	46,260	0.35	3,084	$ 7,434	$ 56,273	$ 21,519	$ 1,800	$ 4,622	$ 504,069	$ 75,610	$ 13,862	$ 122,789	$ 457,300	617	$ 11,396				$ 1,276,674	$1,659,677	$ 5	$ 1,526,903	$ 132,774
5+7	20,728	0.16	1,382	$ 3,331	$ 28,290	$ 13,352	$ 1,350	$ 4,622	$ 436,899	$ 65,535	$ 12,015	$ 74,048	$ 642,200	276	$ 5,106				$ 1,286,748	$1,672,772	$ 11	$ 1,538,951	$ 133,822
10+11	36,800	0.28	2,453	$ 5,914	$ 46,946	$ 18,796	$ 1,650	$ 4,622	$ 479,026	$ 71,854	$ 13,173	$ 106,308	$ 1,974,000	491	$ 9,065				$ 2,731,354	$3,550,760	$ 13	$ 3,266,699	$ 284,061
12	131,400	0.98	8,760	$ 21,116	$ 140,351	$ 40,704	$ 2,700	$ 4,622	$ 737,704	$ 110,656	$ 20,287	$ 237,026	$ 259,000	1752	$ 32,370				$ 1,606,536	$2,088,496	$ 2	$ 1,921,417	$ 167,080
14	83,600	0.63	5,573	$ 13,434	$ 92,094	$ 29,296	$ 2,150	$ 4,622	$ 604,707	$ 90,706	$ 16,629	$ 178,267	$ 58,300	1115	$ 20,594				$ 1,110,801	$1,444,041	$ 2	$ 1,328,518	$ 115,523
15	41,480	0.31	2,765	$ 6,666	$ 50,055	$ 19,704	$ 1,700	$ 4,622	$ 491,392	$ 73,709	$ 13,513	$ 114,636	$ 236,500	553	$ 10,218				$ 1,022,715	$1,329,529	$ 4	$ 1,223,167	$ 106,362
22	19,700	0.15	1,313	$ 3,166	$ 28,290	$ 13,352	$ 1,350	$ 4,622	$ 434,223	$ 65,133	$ 11,941	$ 71,713	$ 198,200	263	$ 4,853				$ 836,843	$ 1,087,895	$ 7.38	$ 1,000,864	$ 87,032
26+28	80,150	0.60	5,343	$ 12,880	$ 87,707	$ 28,259	$ 2,100	$ 4,622	$ 595,289	$ 89,293	$ 16,370	$ 173,596	$ 804,100	1069	$ 19,744				$ 1,833,962	$ 2,384,150	$ 3.98	$ 2,193,418	$ 190,732
27+29	32,998	0.25	2,200	$ 5,303	$ 40,727	$ 16,981	$ 1,550	$ 4,622	$ 469,013	$ 70,352	$ 12,898	$ 99,250	$ 804,100	440	$ 8,129				$ 1,532,924	$ 1,992,801	$ 8.07	$ 1,833,377	$ 159,424
36	31,700	0.24	2,113	$ 5,094	$ 40,727	$ 16,981	$ 1,550	$ 4,622	$ 465,601	$ 69,840	$ 12,804	$ 96,772	$ 41,900	423	$ 7,809				$ 763,701	$ 992,811	$ 4.19	$ 913,386	$ 79,425
31+40	1,039,940	7.78	69,329	$ 167,116	$ 957,447	$ 163,852	$ 6,100	$ 16,000	$ 4,155,379	$ 623,307	$ 114,273	$ 872,563	$ 1,283,215	13866	$ 256,183				$ 8,615,436	$ 11,200,067	$ 1.44	$10,304,061	$ 896,005

1998 Capital Costs for Storage based on "Events" Criteria (Reproduced from Facilities Plan '98 - April 30, 1999)

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	49,400	0.37	3,293	$ 7,938	$ 57,517	$ 21,881	$ 1,820	$ 4,622	$ 512,422	$ 76,863	$ 14,092	$ 127,976	$ 457,300	659	$ 12,169				$ 1,294,601	$ 1,682,981	$ 4.55	$ 1,548,343	$ 134,639
5+7	20,730	0.16	1,382	$ 3,331	$ 28,290	$ 13,352	$ 1,350	$ 4,622	$ 436,904	$ 65,536	$ 12,015	$ 74,052	$ 642,200	276	$ 5,107				$ 1,286,760	$ 1,672,788	$ 10.79	$ 1,538,965	$ 133,823
10+11	48,360	0.36	3,224	$ 7,771	$ 56,895	$ 21,700	$ 1,810	$ 4,622	$ 509,653	$ 76,448	$ 14,015	$ 126,272	$ 1,974,000	645	$ 11,913				$ 2,805,100	$ 3,646,630	$ 10.08	$ 3,354,900	$ 291,730
12	179,000	1.34	11,933	$ 28,765	$ 183,344	$ 50,867	$ 3,190	$ 4,622	$ 874,796	$ 131,219	$ 24,057	$ 287,991	$ 259,000	2387	$ 44,096				$ 1,891,947	$ 2,459,531	$ 1.84	$ 2,262,768	$ 196,762
14	96,020	0.72	6,401	$ 15,430	$ 102,623	$ 31,785	$ 2,270	$ 4,622	$ 638,814	$ 95,822	$ 17,567	$ 194,522	$ 58,300	1280	$ 23,654				$ 1,185,410	$ 1,541,033	$ 2.15	$ 1,417,751	$ 123,283
15	50,150	0.38	3,343	$ 8,059	$ 58,761	$ 22,244	$ 1,840	$ 4,622	$ 514,420	$ 77,163	$ 14,147	$ 129,197	$ 236,500	669	$ 12,354				$ 1,079,307	$ 1,403,099	$ 3.74	$ 1,290,851	$ 112,248
22	36,320	0.27	2,421	$ 5,837	$ 44,458	$ 18,070	$ 1,610	$ 4,622	$ 477,760	$ 71,664	$ 13,138	$ 105,432	$ 198,200	484	$ 8,947				$ 949,739	$ 1,234,660	$ 4.54	$ 1,135,887	$ 98,773
26+28	81,250	0.61	5,417	$ 13,057	$ 90,475	$ 31,500	$ 2,350	$ 4,622	$ 598,289	$ 89,743	$ 16,453	$ 175,094	$ 804,100	1083	$ 20,015				$ 1,845,698	$ 2,399,408	$ 3.95	$ 2,207,455	$ 191,953
27+29	32,000	0.24	2,133	$ 5,142	$ 39,483	$ 16,619	$ 1,530	$ 4,622	$ 466,389	$ 69,958	$ 12,826	$ 97,348	$ 804,100	427	$ 7,883				$ 1,525,900	$ 1,983,671	$ 8.29	$ 1,824,977	$ 158,694
36	22,000	0.16	1,467	$ 3,535	$ 29,534	$ 13,715	$ 1,370	$ 4,622	$ 440,214	$ 66,032	$ 12,106	$ 76,879	$ 41,900	293	$ 5,420				$ 695,327	$ 903,925	$ 5.49	$ 831,611	$ 72,314
31+40	1,263,160	9.45	84,211	$ 202,987	$ 1,143,943	$ 187,626	$ 6,510	$ 16,000	$ 5,253,780	$ 788,067	$ 144,479	$ 986,280	$ 1,283,215	16842	$ 311,172				$ 10,324,060	$ 13,421,279	$ 1.42	$12,347,576	$ 1,073,702

City of Akron CSO LTCP
Cost Update - 20 Year Present Worth (2005 - 2025)

1998 Capital Costs for Treatment based on "Hours" Criteria (Reproduced from Facilities Plan '98 - April 30, 1999)

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	24,070	0.18	1,605	$ 3,868	$ 31,399	$ 14,259	$ 1,400	$ 4,622	$ 445,615	$ 66,842	$ 12,254	$ 81,360	$ 457,300	321	$ 5,930	$ 15,000	$ 20,930	$ 71,856	$ 1,232,637	$ 1,602,428	$ 8.90	$ 1,474,233	$ 128,194
5+7	10,100	0.08	673	$ 1,623	$ 18,962	$ 10,630	$ 1,200	$ 4,622	$ 409,333	$ 61,400	$ 11,257	$ 47,076	$ 642,200	135	$ 2,488	$ 15,000	$ 10,065	$ 48,025	$ 1,283,881	$ 1,669,045	$ 22.09	$ 1,535,521	$ 133,524
10+11	15,970	0.12	1,065	$ 2,566	$ 25,181	$ 12,444	$ 1,300	$ 4,622	$ 424,529	$ 63,679	$ 11,675	$ 62,830	$ 1,974,000	213	$ 3,934	$ 15,000	$ 14,811	$ 59,401	$ 2,675,972	$ 3,478,764	$ 29.12	$ 3,200,463	$ 278,301
12	77,580	0.58	5,172	$ 12,467	$ 87,707	$ 28,259	$ 2,100	$ 4,622	$ 588,289	$ 88,243	$ 16,178	$ 170,069	$ 259,000	1034	$ 19,111	$ 25,000	$ 56,136	$ 123,681	$ 1,480,862	$ 1,925,121	$ 3.32	$ 1,771,111	$ 154,010
14	25,160	0.19	1,677	$ 4,043	$ 34,509	$ 15,167	$ 1,450	$ 4,622	$ 448,463	$ 67,269	$ 12,333	$ 83,662	$ 58,300	335	$ 6,198	$ 15,000	$ 21,726	$ 73,348	$ 846,090	$ 1,099,918	$ 5.84	$ 1,011,924	$ 87,993
15	18,990	0.14	1,266	$ 3,052	$ 28,290	$ 13,352	$ 1,350	$ 4,622	$ 432,375	$ 64,856	$ 11,890	$ 70,073	$ 236,500	253	$ 4,678	$ 15,000	$ 17,139	$ 64,372	$ 967,550	$ 1,257,814	$ 8.86	$ 1,157,189	$ 100,625
22	55,000	0.41	3,667	$ 8,838	$ 65,601	$ 24,241	$ 1,950	$ 4,622	$ 527,369	$ 79,105	$ 14,503	$ 136,934	$ 198,200	733	$ 13,549	$ 15,000	$ 42,006	$ 105,435	$ 1,237,353	$ 1,608,559	$ 4	$ 1,479,874	$ 128,685
26+28	30,000	0.22	2,000	$ 4,821	$ 37,618	$ 16,074	$ 1,500	$ 4,622	$ 461,138	$ 69,171	$ 12,681	$ 93,469	$ 804,100	400	$ 7,390	$ 25,000	$ 25,200	$ 79,587	$ 1,642,371	$ 2,135,082	$ 10	$ 1,964,276	$ 170,807
27+29	13,160	0.10	877	$ 2,115	$ 22,071	$ 11,537	$ 1,250	$ 4,622	$ 417,246	$ 62,587	$ 11,474	$ 55,618	$ 804,100	175	$ 3,242	$ 25,000	$ 12,581	$ 54,299	$ 1,487,742	$ 1,934,065	$ 19.65	$ 1,779,340	$ 154,725
36	11,670	0.09	778	$ 1,875	$ 18,962	$ 10,630	$ 1,200	$ 4,622	$ 413,390	$ 62,009	$ 11,368	$ 51,563	$ 41,900	156	$ 2,875	$ 15,000	$ 11,369	$ 51,355	$ 698,118	$ 907,553	$ 10.40	$ 834,949	$ 72,604
31+40	232,350	1.74	15,490	$ 37,338	$ 228,390	$ 54,963	$ 3,150	$ 16,000	$ 1,033,962	$ 155,094	$ 28,434	$ 339,431	$ 1,283,215	3098	$ 57,238	$ 35,000	$ 141,528	$ 205,754	$ 3,619,499	$ 4,705,348	$ 2.71	$ 4,328,920	$ 376,428

1998 Capital Costs for Treatment based on "CBOD" Criteria (Reproduced from Facilities Plan '98 - April 30, 1999)

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	27,792	0.21	1,853	$ 4,466	$ 37,618	$ 16,074	$ 1,500	$ 4,622	$ 455,350	$ 68,302	$ 12,522	$ 89,074	$ 457,300	371	$ 6,846	$ 15,000	$ 23,627	$ 76,813	$ 1,269,115	$ 1,649,850	$ 7.94	$ 1,517,862	$ 131,988
5+7	13,702	0.10	913	$ 2,202	$ 22,071	$ 11,537	$ 1,250	$ 4,622	$ 418,650	$ 62,797	$ 11,513	$ 57,050	$ 642,200	183	$ 3,375	$ 15,000	$ 13,017	$ 55,326	$ 1,320,610	$ 1,716,793	$ 17	$ 1,579,449	$ 137,343
10+11	25,920	0.19	1,728	$ 4,165	$ 34,509	$ 15,167	$ 1,450	$ 4,622	$ 450,450	$ 67,568	$ 12,387	$ 85,246	$ 1,974,000	346	$ 6,385	$ 15,000	$ 22,278	$ 74,368	$ 2,767,595	$ 3,597,873	$ 19	$ 3,310,043	$ 287,830
12	106,488	0.80	7,099	$ 17,112	$ 114,029	$ 34,481	$ 2,400	$ 4,622	$ 667,806	$ 100,171	$ 18,365	$ 207,626	$ 259,000	1420	$ 26,233	$ 25,000	$ 73,316	$ 143,260	$ 1,693,421	$ 2,201,448	$ 3	$ 2,025,332	$ 176,116
14	57,700	0.43	3,847	$ 9,272	$ 68,710	$ 25,148	$ 2,000	$ 4,622	$ 534,598	$ 80,190	$ 14,701	$ 141,131	$ 58,300	769	$ 14,214	$ 15,000	$ 43,738	$ 107,806	$ 1,119,432	$ 1,455,261	$ 3	$ 1,338,840	$ 116,421
15	37,500	0.28	2,500	$ 6,026	$ 46,946	$ 18,796	$ 1,650	$ 4,622	$ 480,873	$ 72,131	$ 13,224	$ 107,577	$ 236,500	500	$ 9,238	$ 15,000	$ 30,415	$ 88,269	$ 1,131,268	$ 1,470,648	$ 5	$ 1,352,996	$ 117,652
22	17,424	0.13	1,162	$ 2,800	$ 25,181	$ 12,444	$ 1,300	$ 4,622	$ 428,305	$ 64,246	$ 11,778	$ 66,375	$ 198,200	232	$ 4,292	$ 15,000	$ 15,939	$ 61,852	$ 912,335	$ 1,186,035	$ 9	$ 1,091,152	$ 94,883
26+28	70,600	0.53	4,707	$ 11,345	$ 78,933	$ 26,185	$ 2,000	$ 4,622	$ 569,346	$ 85,402	$ 15,657	$ 160,261	$ 804,100	941	$ 17,392	$ 25,000	$ 51,847	$ 118,387	$ 1,970,477	$ 2,561,620	$ 4.85	$ 2,356,691	$ 204,930
27+29	29,790	0.22	1,986	$ 4,787	$ 37,618	$ 16,074	$ 1,500	$ 4,622	$ 460,587	$ 69,088	$ 12,666	$ 93,056	$ 804,100	397	$ 7,339	$ 25,000	$ 25,051	$ 79,328	$ 1,640,816	$ 2,133,061	$ 9.57	$ 1,962,416	$ 170,645
36	26,200	0.20	1,747	$ 4,210	$ 34,509	$ 15,167	$ 1,450	$ 4,622	$ 451,183	$ 67,677	$ 12,408	$ 85,825	$ 41,900	349	$ 6,454	$ 15,000	$ 22,481	$ 74,739	$ 837,624	$ 1,088,912	$ 5.56	$ 1,001,799	$ 87,113
31+40	NA	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Note: "NA" - No basin volume will reduce CBOD

1998 Capital Costs for Treatment based on "Events" Criteria (Reproduced from Facilities Plan '98 - April 30, 1999)

Rack Number	Storage Volume (ft^3)	Storage Volume (MG)	Basin Size (ft^2)	Land Acquisition	Excavation	Backfill	Fencing	Access Rd.	Tank Cost	Tie Down/ Anchor System	Washdown	Pumps (Construction Cost)	Piping	Air Changes (cfm)	Odor Control	Control Bldg	Screens	Disinfection	Total Cost	Total Storage Cost (30% Contigency)	Total Cost per Gallon	Capital Costs (92% of total)	Equip. Costs (8% of total)
3	32,580	0.24	2,172	$ 5,236	$ 40,105	$ 16,800	$ 1,540	$ 4,622	$ 467,913	$ 70,187	$ 12,868	$ 98,456	$ 457,300	434	$ 8,026	$ 15,000	$ 27,015	$ 82,693	$ 1,307,760	$ 1,700,088	$ 6.98	$ 1,564,081	$ 136,007
5+7	17,470	0.13	1,165	$ 2,807	$ 24,559	$ 12,263	$ 1,290	$ 4,622	$ 428,424	$ 64,264	$ 11,782	$ 66,485	$ 642,200	233	$ 4,304	$ 15,000	$ 15,975	$ 61,927	$ 1,355,902	$ 1,762,673	$ 13.49	$ 1,621,659	$ 141,014
10+11	37,220	0.28	2,481	$ 5,981	$ 45,080	$ 18,252	$ 1,620	$ 4,622	$ 480,134	$ 72,020	$ 13,204	$ 107,071	$ 1,974,000	496	$ 9,169	$ 15,000	$ 30,224	$ 87,963	$ 2,864,339	$ 3,723,641	$ 13.37	$ 3,425,750	$ 297,891
12	100,080	0.75	6,672	$ 16,083	$ 110,374	$ 37,307	$ 2,670	$ 4,622	$ 650,032	$ 97,505	$ 17,876	$ 199,664	$ 259,000	1334	$ 24,654	$ 25,000	$ 69,579	$ 139,194	$ 1,653,560	$ 2,149,627	$ 2.87	$ 1,977,657	$ 171,970
14	35,900	0.27	2,393	$ 5,769	$ 43,836	$ 17,889	$ 1,600	$ 4,622	$ 476,653	$ 71,498	$ 13,108	$ 104,663	$ 58,300	479	$ 8,844	$ 15,000	$ 29,318	$ 86,501	$ 937,600	$ 1,218,880	$ 4.54	$ 1,121,370	$ 97,510
15	29,580	0.22	1,972	$ 4,753	$ 36,996	$ 15,893	$ 1,490	$ 4,622	$ 460,036	$ 69,005	$ 12,651	$ 92,643	$ 236,500	394	$ 7,287	$ 15,000	$ 24,902	$ 79,068	$ 1,060,847	$ 1,379,101	$ 6.23	$ 1,268,773	$ 110,328
22	38,850	0.29	2,590	$ 6,243	$ 46,946	$ 18,796	$ 1,650	$ 4,622	$ 484,437	$ 72,666	$ 13,322	$ 110,001	$ 198,200	518	$ 9,570	$ 15,000	$ 31,336	$ 89,730	$ 1,102,519	$ 1,433,275	$ 4.93	$ 1,318,613	$ 114,662
26+28	49,670	0.37	3,311	$ 7,982	$ 58,139	$ 22,063	$ 1,830	$ 4,622	$ 513,141	$ 76,971	$ 14,111	$ 128,417	$ 804,100	662	$ 12,236	$ 25,000	$ 38,547	$ 100,565	$ 1,807,724	$ 2,350,041	$ 6.33	$ 2,162,038	$ 188,003
27+29	22,760	0.17	1,517	$ 3,657	$ 30,156	$ 13,896	$ 1,380	$ 4,622	$ 442,196	$ 66,329	$ 12,160	$ 78,542	$ 804,100	303	$ 5,607	$ 25,000	$ 19,966	$ 70,014	$ 1,577,626	$ 2,050,914	$ 12.05	$ 1,886,841	$ 164,073
36	17,210	0.13	1,147	$ 2,766	$ 24,559	$ 12,263	$ 1,290	$ 4,622	$ 427,749	$ 64,162	$ 11,763	$ 65,860	$ 41,900	229	$ 4,240	$ 15,000	$ 15,774	$ 61,498	$ 753,446	$ 979,480	$ 7.61	$ 901,121	$ 78,358
31+40	273,530	2.05	18,235	$ 43,956	$ 269,270	$ 65,385	$ 3,680	$ 16,000	$ 1,160,807	$ 174,121	$ 31,922	$ 376,179	$ 1,283,215	3647	$ 67,383	$ 35,000	$ 162,398	$ 221,936	$ 3,911,252	$ 5,084,628	$ 2.49	$ 4,677,858	$ 406,770

City of Akron CSO LTCP
Cost Update - Summary of Tunnel Alternative Costs
(Assumes Independent Review Costs for Tunnel Construction)

Tunnel Alternative	Summary of 1998 Cost Estimate (in 1998 $)			Summary of Update to 1998 Cost Estimate (in 2005 $)		
	1998 Capital Cost	1998 O&M Cost	20 Year Total Present Worth (2018)	2005 Capital Cost	2005 Annaul O&M Cost	20 Year Total Present Worth (2025)
NSI	$ 28,371,900	$ 171,500	$ 33,254,700	$ 41,428,650	$ 216,892	$ 45,883,300
OCI	$ 93,446,078	$ 293,200	$ 90,587,300	$ 92,744,982	$ 370,804	$ 93,493,800
Totals:	**$ 121,817,978**	**$ 464,700**	**$ 123,842,000**	**$ 134,173,632**	**$ 587,696**	**$ 139,377,100**

City of Akron CSO LTCP
Cost Update - Present Worth Analysis for Tunnel Alternatives
(Assumes Independent Review Costs for Tunnel Construction)

COST UPDATE PARAMETERS	
O&M Cost Updating Parameters	
Date for Original Capital Costs:	Jun-98
Date for Capital Cost Update:	Mar-05
Years:	6.75
Average Annual ENR Inflation Rate:	3.54%

PRESENT WORTH PARAMETERS		
Economic Evaluation Parameters	**Period 1**	**Period 2**
Start Year:	2005	2005
End Year:	2025	2025
Years for Present Worth Evaluation:	20	20
Interest Rate:	8.00%	8.00%
Annual Inflation Rate for Capital Costs:	3.54%	3.54%
Annual Inflation Rate for O&M Costs:	3.54%	3.54%
Single Payment Present Worth Factor:	0.2145	0.2145
Uniform Series Present Worth Factor:	9.8181	9.8181
Gradient Series Present Worth Factor:	69.0898	69.0898
Capital Recovery Factor:	0.1019	0.1019
Equipment Service Life (yrs):	15	15
Structure Service Life (yrs):	50	50

Cost Update Summary	**NSI TUNNEL**		**OCI TUNNEL**	
1998 Annual O&M Costs:	$ 171,500		$ 293,200	
1998 Capital Costs:	N/A		N/A	
2005 Annual O&M Costs:	$ 216,892		$ 370,804	
2005 Total Capital Costs:	$ 41,428,650		$ 92,744,982	
2005 Structure Capital Costs:	$ 34,115,648		$ 86,380,542	
2005 Equipment Capital Costs:	$ 5,415,985		$ 5,415,931	
O&M Present Worth Analysis	**Period 1**	**Period 2**	**Period 1**	**Period 2**
Start Year:	2005	2005	2005	2005
End Year:	2025	2025	2025	2025
Years for Present Worth Evaluation:	20	20	20	20
Annual O&M Cost at Start Year:	$ 216,892	$ 216,892	$ 370,804	$ 370,804
Annual O&M Cost at End Year:	$ 434,918	$ 434,918	$ 743,545	$ 743,545
Annual Incremental Increase:	$ 11,475	$ 11,475	$ 19,618	$ 19,618
Present Worth of Constant O&M:	$ 2,129,481	$ 2,129,481	$ 3,640,605	$ 3,640,605
Present Worth of Incremental O&M:	$ 792,808	$ 792,808	$ 1,355,401	$ 1,355,401
Total Present Worth of O&M:	$ 2,922,289	$ 2,922,289	$ 4,996,006	$ 4,996,006
Capital Cost Present Worth Analysis	**Period 1**	**Period 2**	**Period 1**	**Period 2**
Start Year:	2005	2005	2005	2005
End Year:	2025	2025	2025	2025
Years for Present Worth Evaluation:	20	20	20	20
Structure:				
Replacement Cost at 2025 - Structure:	$ -	N/A	$ -	N/A
Salvage Value at 2025 - Stucture:	$ 20,469,389	N/A	$ 51,828,325	N/A
Present Worth of Salvage Value at 2025 - Structure:	$ 4,391,671	N/A	$ 11,119,674	N/A
Replacement Cost at 2025 - Structure:	N/A	$ -	N/A	$ -
Salvage Value at 2025 - Stucture:	N/A	$ 20,469,389	N/A	$ 51,828,325
Present Worth of Salvage Value at 2025 - Structure:	N/A	$ 4,391,671	N/A	$ 11,119,674
Total Present Worth - Structure:	$ 29,723,977	$ 29,723,977	$ 75,260,868	$ 75,260,868
Equipment:				
Replacement Cost at 2020 - Equipment:	$ 9,126,408	N/A	$ 9,126,317	N/A
Salvage Value at 2020 - Equipment:	$ 6,084,272	N/A	$ 6,084,211	N/A
Present Worth of Salvage Value at 2020 - Equipment:	$ 1,305,370	N/A	$ 1,305,357	N/A
Replacement Cost at 2020 - Equipment:	N/A	$ 9,126,408	N/A	$ 9,126,317
Salvage Value at 2020 - Equipment:	N/A	$ 6,084,272	N/A	$ 6,084,211
Present Worth of Salvage Value at 2020 - Equipment:	N/A	$ 1,305,370	N/A	$ 1,305,357
Total Present Worth - Equipment:	$ 13,237,023	$ 13,237,023	$ 13,236,892	$ 13,236,892
Total Present Worth of Separation Alternative:	$ 45,883,300	$ 45,883,300	$ 93,493,800	$ 93,493,800
Equivalent Annual Cost:	$ 4,673,400	$ 4,673,400	$ 9,522,600	$ 9,522,600

City of Akron CSO LTCP
Cost Update to Tunnel Alternatives
(Assumes Independent Review Capital Costs for Tunnel Construction)

OCI Tunnel			
ITEM	**Sub-Item**	**Cost**	
Mobilization	Mobilization	$	652,500
Shafts	Shaft R16/17	$	1,148,400
	Shaft R18/19	$	1,148,400
	Shaft North St.	$	1,148,400
	Shaft Exit	$	704,700
Main Tunnel	TBM Setup	$	645,975
	Tunnel drive	$	22,093,650
	TBM maintenance	$	117,450
	TBM removal	$	417,600
	Tunnel cleanup	$	189,225
	Final liner	$	4,280,400
R16/17 to Main	TBM Setup	$	645,975
	Tunnel drive	$	6,368,400
	TBM maintenance	$	58,725
	TBM removal	$	417,600
	Tunnel cleanup	$	91,350
	Final liner	$	1,924,875
R18/19 to Main	TBM Setup	$	645,975
	Tunnel drive	$	4,241,250
	TBM maintenance	$	45,675
	TBM removal	$	417,600
	Tunnel cleanup	$	58,725
	Final liner	$	1,592,100
Microtunnels	From R21	$	548,100
	From R23	$	1,057,050
	From R24	$	1,840,050
	2ft microtunnel	$	130,500
	Demobilization	$	250,000
	Total direct cost	$	52,880,650
10%	Indirects	$	5,288,065
	Directs + Indirects	$	58,168,715
10%	Profit	$	5,816,872
	Directs + Indirects + Profit	$	63,985,587
35%	Contingency	$	22,394,955
	Total Cost (tunnel)	$	86,380,542
'98 Plan Update	Land Acquisition	$	948,509
	Total (non-mechanical)	$	87,329,051
'98 Plan Update	Mechanical Equipment	$	5,415,931
	Total	**$**	**92,744,982**

Main Assumptions
1. 3 separate TBM's used to mine large diameter tunnels.
2. Tunnels mined using EPB type TBM's (not in EPB mode) with ribs and lagging primary liners.
3. Cast-in-place final liner in all large diameter tunnels.
4. Main Tunnel
5. R16/17 to Main
6. R18/19 to Main
7. Final liner advance rate = 75ft/day.

NSI Tunnel			
ITEM	**Sub-Item**	**Cost**	
Mobilization	Mobilization	$	250,000
Shafts	Shaft R32	$	155,000
	Shaft R33	$	1,805,000
	Shaft R34	$	2,320,000
	Shaft R35	$	2,115,000
Main Tunnel	TBM Setup	$	345,000
	Tunnel drive	$	6,710,000
	TBM maintenance	$	420,000
	TBM removal	$	90,000
	Tunnel cleanup	$	235,000
	Final liner	$	6,280,000
Microtunnel	Tunnel drive	$	60,000
	Demobilization	$	100,000
	Total direct cost	$	20,885,000
10%	Indirects	$	2,088,500
	Directs + Indirects	$	22,973,500
10%	Profit	$	2,297,350
	Directs + Indirects + Profit	$	25,270,850
35%	Contingency	$	8,844,798
	Total Cost (tunnel)	$	34,115,648
'98 Plan Update	Land Acquisition	$	1,897,018
	Total (non-mechanical)	$	36,012,665
'98 Plan Update	Mechanical Equipment	$	5,415,985
	Total	**$**	**41,428,650**

Main Assumptions
1. 10.5m excavated diameter.
2. Tunnel mined using rock TBM.
3. Average TBM ; 105ft /day
4. Rockbolt and mesh primary support throughout tunnel length.
5. Grouted in place concrete pipe final liner.

City of Akron CSO LTCP
Cost Update - Summary of Sewer Separation Alternative Costs

Rack Number	Summary of 1998 Cost Estimate (in 1998 $)			Summary of Update to 1998 Cost Estimate (in 2005 $)		
	1998 Capital Cost	1998 O&M Cost	20 Year Total Present Worth (2018)	2005 Capital Cost	2005 Annaul O&M Cost	20 Year Total Present Worth (2025)
8	$ 2,326,353	$ 4,600	$ 2,052,900	$ 2,942,090	$ 5,818	$ 2,641,800
9	$ 210,926	$ 2,000	$ 215,300	$ 266,754	$ 2,529	$ 266,500
13	$ 4,326,241	$ 7,200	$ 3,799,800	$ 5,471,305	$ 9,106	$ 4,889,700
21	$ 2,199,483	$ 10,400	$ 2,044,200	$ 2,781,640	$ 13,153	$ 2,600,800
25	$ 2,974,494	$ 8,300	$ 2,672,100	$ 3,761,780	$ 10,497	$ 3,419,000
30	$ 7,573,977	$ 6,900	$ 6,544,700	$ 9,578,646	$ 8,726	$ 8,463,200
39	$ 300,000	$ 1,900	$ 289,700	$ 379,404	$ 2,403	$ 363,000
Totals:	**$ 19,911,500**	**$ 41,300**	**$ 17,618,700**	**$ 25,181,700**	**$ 52,300**	**$ 22,644,000**

City of Akron CSO LTCP
Cost Update - Present Worth Analysis - Sewer Separation Alternatives

COST UPDATE PARAMETERS	
Capital & O&M Cost Updating Parameters	
Date for Original Capital Costs:	Jun-98
Date for Capital Cost Update:	Mar-05
Years:	6.75
Average Annual ENR Inflation Rate:	3.54%

PRESENT WORTH PARAMETERS		
Economic Evaluation Parameters	**Period 1**	**Period 2**
Start Year:	2005	2005
End Year:	2025	2025
Years for Present Worth Evaluation:	20	20
Interest Rate:	8.00%	8.00%
Annual Inflation Rate for Capital Costs:	3.54%	3.54%
Annual Inflation Rate for O&M Costs:	3.54%	3.54%
Single Payment Present Worth Factor:	0.2145	0.2145
Uniform Series Present Worth Factor:	9.8181	9.8181
Gradient Series Present Worth Factor:	69.0898	69.0898
Capital Recovery Factor:	0.1019	0.1019
Equipment Service Life (yrs):	15	15
Structure Service Life (yrs):	50	50

Cost Update Summary	RACK 8		RACK 9		RACK 13		RACK 21		RACK 25		RACK 30		RACK 39	
1998 Annual O&M Costs:	$ 4,600		$ 2,000		$ 7,200		$ 10,400		$ 8,300		$ 6,900		$ 1,900	
1998 Capital Costs:	$ 2,326,353		$ 210,926		$ 4,326,241		$ 2,199,483		$ 2,974,494		$ 7,573,977		$ 300,000	
2005 Annual O&M Costs:	$ 5,818		$ 2,529		$ 9,106		$ 13,153		$ 10,497		$ 8,726		$ 2,403	
2005 Total Capital Costs:	$ 2,942,088		$ 266,754		$ 5,471,303		$ 2,781,638		$ 3,761,779		$ 9,578,644		$ 379,404	
2005 Structure Capital Costs:	$ 2,942,088		$ 266,754		$ 5,471,303		$ 2,781,638		$ 3,761,779		$ 9,578,644		$ 379,404	
2005 Equipment Capital Costs:	$ -		$ -		$ -		$ -		$ -		$ -		$ -	
O&M Present Worth Analysis	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**
Start Year:	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
End Year:	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025
Years for Present Worth Evaluation:	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Annual O&M Cost at Start Year:	$ 5,818	$ 5,818	$ 2,529	$ 2,529	$ 9,106	$ 9,106	$ 13,153	$ 13,153	$ 10,497	$ 10,497	$ 8,726	$ 8,726	$ 2,403	$ 2,403
Annual O&M Cost at End Year:	$ 11,665	$ 11,665	$ 5,072	$ 5,072	$ 18,259	$ 18,259	$ 26,374	$ 26,374	$ 21,049	$ 21,049	$ 17,498	$ 17,498	$ 4,818	$ 4,818
Annual Incremental Increase	$ 308	$ 308	$ 134	$ 134	$ 482	$ 482	$ 696	$ 696	$ 555	$ 555	$ 462	$ 462	$ 127	$ 127
Present Worth of Constant O&M:	$ 57,117	$ 57,117	$ 24,834	$ 24,834	$ 89,401	$ 89,401	$ 129,135	$ 129,135	$ 103,059	$ 103,059	$ 85,676	$ 85,676	$ 23,592	$ 23,592
Present Worth of Incremental O&M:	$ 21,265	$ 21,265	$ 9,246	$ 9,246	$ 33,284	$ 33,284	$ 48,077	$ 48,077	$ 38,369	$ 38,369	$ 31,897	$ 31,897	$ 8,783	$ 8,783
Total Present Worth of O&M:	$ 78,382	$ 78,382	$ 34,079	$ 34,079	$ 122,685	$ 122,685	$ 177,212	$ 177,212	$ 141,429	$ 141,429	$ 117,573	$ 117,573	$ 32,375	$ 32,375
Capital Cost Present Worth Analysis	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**
Start Year:	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
End Year:	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025
Years for Present Worth Evaluation:	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Structure:														
Replacement Cost at 2025 - Structure:	$ -	N/A	$ -	N/A	$ -	N/A	$ -	N/A	$ -	N/A	$ -	N/A	$ -	N/A
Salvage Value at 2025 - Stucture:	$ 1,765,253	N/A	$ 160,052	N/A	$ 3,282,782	N/A	$ 1,668,983	N/A	$ 2,257,067	N/A	$ 5,747,187	N/A	$ 227,642	N/A
Present Worth of Salvage Value at 2025 - Structure:	$ 378,732	N/A	$ 34,339	N/A	$ 704,315	N/A	$ 358,077	N/A	$ 484,250	N/A	$ 1,233,049	N/A	$ 48,840	N/A
Replacement Cost at 2025 - Structure:	N/A	$ -	N/A	$ -	N/A	$ -	N/A	$ -	N/A	$ -	N/A	$ -	N/A	$ -
Salvage Value at 2025 - Stucture:	N/A	$ 1,765,253	N/A	$ 160,052	N/A	$ 3,282,782	N/A	$ 1,668,983	N/A	$ 2,257,067	N/A	$ 5,747,187	N/A	$ 227,642
Present Worth of Salvage Value at 2025 - Structure:	N/A	$ 378,732	N/A	$ 34,339	N/A	$ 704,315	N/A	$ 358,077	N/A	$ 484,250	N/A	$ 1,233,049	N/A	$ 48,840
Total Present Worth - Structure:	$ 2,563,357	$ 2,563,357	$ 232,415	$ 232,415	$ 4,766,988	$ 4,766,988	$ 2,423,561	$ 2,423,561	$ 3,277,529	$ 3,277,529	$ 8,345,596	$ 8,345,596	$ 330,563	$ 330,563
Equipment:														
Replacement Cost at 2020 - Equipment:	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Salvage Value at 2020 - Equipment:	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Present Worth of Salvage Value at 2020 - Equipment:	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Replacement Cost at 2020 - Equipment:	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Salvage Value at 2020 - Equipment:	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Present Worth of Salvage Value at 2020 - Equipment:	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Present Worth - Equipment:	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Present Worth of Separation Alternative:	$ 2,641,800	$ 2,641,800	$ 266,500	$ 266,500	$ 4,889,700	$ 4,889,700	$ 2,600,800	$ 2,600,800	$ 3,419,000	$ 3,419,000	$ 8,463,200	$ 8,463,200	$ 363,000	$ 363,000
Equivalent Annual Cost:	$ 269,100	$ 269,100	$ 27,200	$ 27,200	$ 498,100	$ 498,100	$ 264,900	$ 264,900	$ 348,300	$ 348,300	$ 862,000	$ 862,000	$ 37,000	$ 37,000

City of Akron CSO LTCP
Cost Update - Update of 1998 to 2005 Capital Costs - Sewer Separation Alternatives

2005 Capital Costs for Separation Alternatives	
Average Annual ENR Inflation Rate:	3.54%
Period for Cost Update, 6/98-3/05 (yrs):	6.75

ITEM		RACK 8			RACK 9			RACK 13			RACK 21			RACK 25			RACK 30			RACK 39		
Storm Sewer	**Unit**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**
8"	l.f.	150	$ 119.82	$ 17,974	90	$ 116.31	$ 10,468	160	$ 120.33	$ 19,252		$ -	$ -	150	$ 119.82	$ 17,974	3,500	$ 328.45	$ 1,149,560		$ -	$ -
10"	l.f.		$ -	$ -		$ -	$ -	1,920	$ 228.22	$ 438,176		$ -	$ -	770	$ 174.40	$ 134,287		$ -	$ -			-
12"	l.f.	650	$ 171.92	$ 111,747	500	$ 166.27	$ 83,137	1,725	$ 215.92	$ 372,469	350	$ 139.76	$ 48,915	1,950	$ 225.52	$ 439,755	1,375	$ 201.82	$ 277,502			-
15"	l.f.		$ -	$ -		$ -	$ -	340	$ 174.75	$ 59,413		$ -	$ -		$ -	$ -	1,025	$ 197.36	$ 202,293			-
18"	l.f.	250	$ 194.33	$ 48,581		$ -	$ -	500	$ 201.56	$ 100,782	700	$ 173.92	$ 121,744	285	$ 194.98	$ 55,570	960	$ 214.07	$ 205,509			-
21"	l.f.	2,300	$ 269.92	$ 620,823		$ -	$ -	215	$ 219.15	$ 47,117	950	$ 199.40	$ 189,430	365	$ 215.62	$ 78,701		$ -	$ -			-
24"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -	1,050	$ 222.13	$ 233,232	1,025	$ 259.74	$ 266,231	450	$ 246.95	$ 111,127			-
27"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -			-
30"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -			-
36"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -	2,900	$ 407.29	$ 1,181,132		$ -	$ -		$ -	$ -			-
42"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -			-
48"	l.f.		$ -	$ -		$ -	$ -	945	$ 560.07	$ 529,268		$ -	$ -	325	$ 552.17	$ 179,457		$ -	$ -			-
60"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -			-
72"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -			-
96"	l.f.		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -		$ -	$ -			-
	Unit	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Cost Estimate Details for this Rack Not Available**		
	no. mhs.	11			4			19			20			17			22					
Manholes	v.l.f./mh	9.6	$ 651.06	$ 68,752	6.8	$ 651.06	$ 17,709	10.8	$ 651.06	$ 133,597	6.0	$ 651.06	$ 78,127	9.6	$ 651.06	$ 106,252	16.9	$ 651.06	$ 242,063			-
House Drain Pipes / Storm Laterals	**Unit**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**			
	ea.	90	$ 3,255.28	$ 292,975	5	$ 3,255.28	$ 16,276	160	$ 3,255.28	$ 520,845	175	$ 3,255.28	$ 569,674	130	$ 3,255.28	$ 423,187	195	$ 3,255.28	$ 634,780			-
Catch Basins	**Unit**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**			
New	ea.	2	$ 4,231.87	$ 8,464	1	$ 4,231.87	$ 4,232	3	$ 4,231.87	$ 12,696	3	$ 4,231.87	$ 12,696	3	$ 4,231.87	$ 12,696	3	$ 4,231.87	$ 12,696			-
Replace (10%)	ea.	3	$ 4,231.87	$ 12,696	2	$ 4,231.87	$ 8,464	5	$ 4,231.87	$ 21,159	5	$ 4,231.87	$ 21,159	6	$ 4,231.87	$ 25,391	5	$ 4,231.87	$ 21,159			-
	Unit	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**			
Sheeting	sq.ft.	45,192	$ 31.74	$ 1,434,549	0	$ 31.74	$ -	91,074	$ 31.74	$ 2,891,001	0	$ 31.74	$ -	53,452	$ 31.74	$ 1,696,750	201,504	$ 31.74	$ 6,396,427			-
	Unit	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**			
Maintain Traffic	l.s.	1	$ 81,383	$ 81,383	1	$ 31,617	$ 31,617	1	$ 81,383	$ 81,383	1	$ 81,383	$ 81,383	1	$ 81,383	$ 81,383	1	$ 81,383	$ 81,383			-
Excavation	**Unit**	**Lump Sum**	**Unit Cost**	**Cost**	**Quanity**	**Unit Cost**	**Cost**	**Lump Sum**	**Unit Cost**	**Cost**	**Lump Sum**	**Unit Cost**	**Cost**	**Lump Sum**	**Unit Cost**	**Cost**	**Lump Sum**	**Unit Cost**	**Cost**	**Lump Sum**	**Unit Cost**	**Cost**
Dewatering	l.s.	1	$ 244,147	$ 244,147	1	$ 94,851	$ 94,851	1	$ 244,147	$ 244,147	1	$ 244,147	$ 244,147	1	$ 244,147	$ 244,147	1	$ 244,147	$ 244,147	1	$ -	$ -
	TOTAL:			**$2,942,090**			**$266,754**			**$5,471,305**			**$2,781,640**			**$3,761,780**			**$9,578,646**			**$379,404**

City of Akron CSO LTCP
Summary of 1998 Capital Costs - Sewer Separation Alternatives

ITEM		RACK 8			RACK 9			RACK 13			RACK 21			RACK 25			RACK 30			RACK 39		
Storm Sewer	Unit	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost
8"	l.f.	150	$ 94.75	$ 14,212	90	$ 91.97	$ 8,277	160	$ 95.14	$ 15,223			$ -	150	$ 94.75	$ 14,212	3,500	$ 259.71	$ 908,974			$ -
10"	l.f.			$ -			$ -	1,920	$ 180.45	$ 346,472			$ -	770	$ 137.90	$ 106,183			$ -			-
12"	l.f.	650	$ 135.94	$ 88,360	500	$ 131.48	$ 65,738	1,725	$ 170.73	$ 294,517	350	$ 110.51	$ 38,678	1,950	$ 178.32	$ 347,721	1,375	$ 159.58	$ 219,425			-
15"	l.f.			$ -			$ -	340	$ 138.17	$ 46,979			$ -			$ -	1,025	$ 156.05	$ 159,956			-
18"	l.f.	250	$ 153.66	$ 38,414			$ -	500	$ 159.38	$ 79,690	700	$ 137.52	$ 96,265	285	$ 154.18	$ 43,940	960	$ 169.27	$ 162,499			-
21"	l.f.	2,300	$ 213.43	$ 490,894			$ -	215	$ 173.28	$ 37,256	950	$ 157.67	$ 149,785	365	$ 170.49	$ 62,230			$ -			-
24"	l.f.			$ -			$ -			$ -	1,050	$ 175.64	$ 184,420	1,025	$ 205.38	$ 210,513	450	$ 195.27	$ 87,870			-
27"	l.f.			$ -			$ -			$ -			$ -			$ -			$ -			-
30"	l.f.			$ -			$ -			$ -			$ -			$ -			$ -			-
36"	l.f.			$ -			$ -			$ -	2,900	$ 322.05	$ 933,939			$ -			$ -			-
42"	l.f.			$ -			$ -			$ -			$ -			$ -			$ -			-
48"	l.f.			$ -			$ -	945	$ 442.86	$ 418,500			$ -	325	$ 436.61	$ 141,899			$ -			-
60"	l.f.			$ -			$ -			$ -			$ -			$ -			$ -			-
72"	l.f.			$ -			$ -			$ -			$ -			$ -			$ -			-
96"	l.f.			$ -			$ -			$ -			$ -			$ -			$ -			-
	Unit	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Qua	Cost Estimate Details for this Rack Not Available	
	no. mhs.	11			4			19			20			17			22					
Manholes	v.l.f./mh	9.6	$ 514.80	$ 54,363	6.8	$ 514.80	$ 14,003	10.8	$ 514.80	$ 105,637	6.0	$ 514.80	$ 61,776	9.6	$ 514.80	$ 84,015	16.9	$ 514.80	$ 191,403			-
House Drain Pipes / Storm Laterals	Unit	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Qua		
	ea.	90	$ 2,574	$ 231,660	5	$ 2,574	$ 12,870	160	$ 2,574	$ 411,840	175	$ 2,574	$ 450,450	130	$ 2,574	$ 334,620	195	$ 2,574	$ 501,930			-
Catch Basins	Unit	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Qua		
New	ea.	2	$ 3,346.20	$ 6,692	1	$ 3,346.20	$ 3,346	3	$ 3,346.20	$ 10,039	3	$ 3,346.20	$ 10,039	3	$ 3,346.20	$ 10,039	3	$ 3,346.20	$ 10,039			-
Replace (10%)	ea.	3	$ 3,346.20	$ 10,039	2	$ 3,346.20	$ 6,692	5	$ 3,346.20	$ 16,731	5	$ 3,346.20	$ 16,731	6	$ 3,346.20	$ 20,077	5	$ 3,346.20	$ 16,731			-
	Unit	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Qua		
Sheeting	sq.ft.	45,192	$ 25.10	$ 1,134,319	0	$ 25.10	$ -	91,074	$ 25.10	$ 2,285,957	0	$ 25.10	$ -	53,452	$ 25.10	$ 1,341,645	201,504	$ 25.10	$ 5,057,750			-
	Unit	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Quanity	Unit Cost	Cost	Qua		
Maintain Traffic	l.s.	1	$ 64,350	$ 64,350	1	$ 25,000	$ 25,000	1	$ 64,350	$ 64,350	1	$ 64,350	$ 64,350	1	$ 64,350	$ 64,350	1	$ 64,350	$ 64,350			-
Excavation	Unit	Lump Sum	Unit Cost	Cost	Quanity	Unit Cost	Cost	Lump Sum	Unit Cost	Cost	Lump Sum	Unit Cost	Cost	Lump Sum	Unit Cost	Cost	Lump Sum	Unit Cost	Cost	Lump Sum	Unit Cost	Cost
Dewatering	l.s.	1	$ 193,050	$ 193,050	1	$ 75,000	$ 75,000	1	$ 193,050	$ 193,050	1	$ 193,050	$ 193,050	1	$ 193,050	$ 193,050	1	$ 193,050	$ 193,050	1		$ -
	TOTAL:			$2,326,353			$210,926			$4,326,241			$2,199,483			$2,974,494			$7,573,977			$300,000

APPENDIX D

EXECUTIVE SUMMARY OF ACTIFLO PILOT PROGRAM

Section 1 Executive Summary

The Akron Water Pollution Control Station (WPCS) can receive wet weather wastewater flows in excess of 280 MGD. The plant's treatment capacity is limited by its secondary treatment facility, which has a capacity of 110 MGD. Wastewater flows greater than 110 MGD (up to 170 MGD) receive pretreatment and primary treatment and are routed around the secondary treatment facility before being blended with the secondary effluent prior to disinfection and final discharge. This re-routed flow, which will be referred to as secondary bypass, may occasionally include overflow from the storm retention tanks (SRT). The plant currently has a split National Pollutant Discharge Elimination System (NPDES) permit, which allows higher limits on the secondary bypass flow than on the plant final effluent. The City of Akron is evaluating possible additional treatment of secondary bypass. The City of Akron has also studied their combined sewer collection system and is planning construction of treatment or storage basins at several combined sewer overflow (CSO) locations. Additional treatment facilities may be required at such locations. To address these two treatment areas, this study evaluated a ballasted flocculation technology, specifically the U.S. Filter/Kruger ACTIFLO process as described in Section 2, for the treatment of wet weather flows.

U.S. Filter/Kruger ACTIFLO pilot unit at Akron WPCS.

ACTIFLO has three full scale installations in the United States that are being used to treat wet weather flows. Of these installations, discussed in Section 3, two are at plants and one is at a remote site treating CSO. All of the installations reported overall treatment satisfaction with the ACTIFLO process and the CSO facility indicated that remote operation worked well. Related ACTIFLO pilot studies also reported good wet weather treatment. Refer to the summary at the end of Section 3.

A three-week pilot test of ACTIFLO, detailed in Section 4, was performed at Akron WPCS to evaluate the use of this technology for treatment of Akron's wet weather flows. The results showed that ACTIFLO can meet Akron's NPDES final effluent limits, which were used to evaluate the process. Rise rates from 30 gpm/s.f. to 80 gpm/s.f. provided equal treatment, ferric chloride and aluminum sulfate (alum) at doses of 40 mg/l and 50 mg/l, respectively, emerged as the most efficient chemicals to achieve the treatment goals, and anionic polymer dosed at 0.7 mg/l was the most efficient polymer for treatment. Both wet and dry start-ups were successful, although draining the tanks for a dry start-up, which is against U.S. Filter/Kruger's recommendations, proved to be problematic. ACTIFLO regained effective treatment within nine minutes after loss of coagulant, polymer, chemical, sand, and power tests. The process also worked effectively under steady-state conditions. Chlorinating and dechlorinating upstream of ACTIFLO had no impact on the system, although it would be more efficient to disinfect downstream of ACTIFLO because more solids would be removed, thereby allowing for more efficient disinfection. UV disinfection after ACTIFLO is also feasible if alum is the chosen coagulant. ACTIFLO does not significantly affect dissolved oxygen or pH, unless ferric chloride is used, which could lower the pH close to the plant's 6.5 NPDES limit. Total suspended solids of 2 mg/l to 8 mg/l (average 93% removal) and total phosphorus of 0.1 mg/l to 0.6 mg/l (average 88% removal) were consistently attained using the alum and ferric chloride doses noted above. Effluent CBOD values at the same coagulant doses were 18 mg/l to 24 mg/l. (average 57% removal). Fecal coliform counts were inconclusive, but a collimated beam test performed on the ACTIFLO effluent revealed that counts could be removed to as low as 136/100ml if alum is the selected coagulant. The ACTIFLO pilot unit produced large quantities of sludge with approximately 0.2% solids. Mixed with the plant's secondary sludge, the ACTIFLO sludge is treatable using the plant's existing gravity belt thickeners to achieve 6% to 6.5% solids.

Akron WPCS final effluent outfall into the Cuyahoga River.

As outlined in Section 5, recommended ACTIFLO units for Akron WPCS would consist of four 35 MGD trains at a design rise rate of 60 gpm/s.f., but could treat flows up to 210 MGD at higher rise rates. The units would require approximately 6,000 s.f. of space, plus additional footprint space for chemical and sand facilities, sludge storage, and recirculation pumps. Alum and anionic polymer are recommended to be used at doses of 50 mg/l and 0.7 mg/l, respectively. ACTIFLO should fit into Akron's secondary bypass hydraulics without pumping, and sludge should be stored and blended with the plant's secondary sludge for processing with their existing equipment. No additional screening is required, and little operator interface is anticipated, with the exception of routine maintenance of equipment and chemical inventory. ACTIFLO effluent should be blended with plant secondary effluent for chlorination and dechlorination using the plant's existing facilities prior to discharging into the Cuyahoga River.

The design parameters for a CSO treatment facility would be similar to that described for the plant, except a slightly lower design rise rate may be required if higher strength wastewater is anticipated. Screening would be required at CSOs. Screenings and sludge would be disposed of in the storage basins to be constructed upstream of ACTIFLO then sent by gravity back to Akron WPCS for treatment once the wet weather event subsides. Remote operation of ACTIFLO is feasible; all of the necessary equipment can be automated and a supervisory control and data acquisition (SCADA) system can be implemented to monitor and control the system without an operator being present.

ACTIFLO is a viable treatment process that could be used at the Akron WPCS to treat secondary bypass or in the collection system to treat CSO to enable Akron to continue to meet water quality standards at its outfalls during wet weather events.

APPENDIX E

EXECUTIVE SUMMARY OF DENSADEG PILOT PROGRAM

ARCADIS FPS

Section 1 Executive Summary

The Akron Water Pollution Control Station (WPCS) can receive wet weather wastewater flows in excess of 280 MGD. The plant's treatment capacity is limited by its secondary treatment facility, which has a capacity of 110 MGD. Wastewater flows greater than 110 MGD (up to 170 MGD) receive primary treatment and are routed around the secondary treatment facility before being blended with the secondary effluent prior to disinfection and final discharge. This re-routed flow, which will be referred to as secondary bypass, may occasionally include overflow from the storm retention tanks (SRT). The plant currently has a split National Pollutant Discharge Elimination System (NPDES) permit, which allows higher effluent limits on the secondary bypass flow than on the plant final effluent. The City of Akron is evaluating possible additional treatment of the secondary bypass. The City of Akron has also studied their combined sewer collection system and is planning construction of treatment or storage basins at several combined sewer overflow (CSO) locations. Additional treatment facilities may be required at such locations. To address these two treatment areas, this study evaluates a high rate clarification technology, the Infilco Degremont, Inc. DensaDeg process as described in Section 2, for the treatment of wet weather flows.

Infilco Degremont DensaDeg pilot unit at Akron WPCS.

DensaDeg has eleven full scale installations planned or constructed in the United States. Of these installations, discussed in Section 3, one will be used to treat wet weather flows. All of the installations reported overall treatment satisfaction with the DensaDeg process. Related DensaDeg pilot studies also reported good wet weather treatment. Refer to the summary at the end of Section 3.

A four-week pilot test of DensaDeg, detailed in Section 4, was performed at Akron WPCS to evaluate the use of this technology for treatment of Akron's wet weather flows. The results showed that DensaDeg can meet Akron's NPDES final effluent limits, which were used to evaluate the process. When treating primary effluent wastewater, rise rates from 30 gpm/s.f. to 65 gpm/s.f. provided equal treatment; ferric chloride and aluminum sulfate (alum) at doses of 50 mg/l and 90 mg/l, respectively, emerged as the most efficient chemicals to achieve the treatment goals. Anionic polymer dosed at 2.0 mg/l was the most efficient polymer for treatment at 40 gpm/s.f. Both wet and dry start-ups were successful. DensaDeg regained effective treatment within 27 minutes after loss of coagulant, polymer, sludge, and power tests. The process also worked effectively under steady-state conditions. Chlorinating and dechlorinating upstream of DensaDeg had no impact on the system, although it would be more efficient to disinfect downstream of DensaDeg because more solids would be removed. UV disinfection after DensaDeg is also feasible if alum is the chosen coagulant. DensaDeg does not significantly affect dissolved oxygen or pH, unless ferric chloride is used, which could lower the pH close to the plant's 6.5 NPDES limit. Total suspended solids of 4 mg/l to 12 mg/l (average 83% removal) and total phosphorus of 0.1 mg/l to 0.3 mg/l (average 91% removal) were attained using the alum and ferric chloride doses noted above. Effluent CBOD values at the same coagulant doses were 15 mg/l to 16 mg/l (average 55% removal) and fecal coliform counts were 86,000/100 ml to 110,000/100 ml (average 95% removal). A collimated beam test performed on the DensaDeg effluent revealed that counts could be removed to as low as 173/100ml if alum is the selected coagulant. The DensaDeg pilot unit produced sludge with approximately 0.5% solids when treating primary effluent. Mixed with the plant's secondary sludge, the DensaDeg sludge is treatable using the plant's existing gravity belt thickeners to achieve 6% to 6.5% solids.


Akron WPCS final effluent outfall into the Cuyahoga River.

As outlined in Section 5, DensaDeg units for Akron WPCS could consist of four 40 MGD trains at a design rise rate of 40 gpm/s.f., but could treat flows up to 210 MGD at higher rise rates. The units would require approximately 14,000 s.f. of space plus additional footprint space for chemical facilities, sludge storage, and recirculation pumps. Alum and anionic polymer are recommended to be used at doses of 90 mg/l and 2.0 mg/l, respectively. DensaDeg should fit into Akron's secondary bypass hydraulics without pumping, and sludge should be stored and blended with the plant's secondary sludge for processing with existing equipment. No additional screening is required and little operator interface is anticipated with the exception of routine maintenance of equipment and chemical inventory. DensaDeg effluent should be blended with plant secondary effluent for chlorination and dechlorination using the plant's existing facilities prior to discharge to the Cuyahoga River.

The design parameters for a CSO treatment facility would be similar to that described for the plant, except a slightly lower design rise rate should be considered if higher strength wastewater is anticipated. Screening would be required at CSOs. Screenings and sludge would be disposed of in the storage basins to be constructed upstream of DensaDeg then sent by gravity back to Akron WPCS for treatment once the wet weather event subsides. Remote operation of DensaDeg is feasible; all of the necessary equipment can be automated and a supervisory control and data acquisition (SCADA) system can be implemented to monitor and control the system without an operator being present.

The city has several feasible alternatives available to manage wet weather flows, as presented in Section 6. The two high rate clarification technologies evaluated in Phases I and II of this Study are viable options along with construction of additional flow equalization, or a combination of the above. Either high rate clarification process could be used for wet weather, primary or tertiary treatment or a blending of these applications. Brief comments on cost and non-cost issues for each alternative are discussed in Section 6. Only capital costs are presented and are not intended to be used as a means of comparing alternatives.

DensaDeg is a viable treatment process for use at the Akron WPCS to treat secondary bypass or in the collection system to treat CSO to enable Akron to continue to meet water quality standards at its outfalls during wet weather events. An alternatives evaluation study should be performed to evaluate and recommend a wet weather strategy once the city's water quality goals are established.