COARSE MONOMEDIA FILTER PILOT TESTING

FINAL REPORT

Prepared for the
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SUMMARY

The City of Geneva (Geneva) owns and operates a conventional biological Wastewater Treatment Plant (WWTP) that serves a mix of residential, commercial, institutional, and recreational districts. In addition, the plant processes leachate from two landfills and septic tank waste. During wet weather, wastewater flow to the plant exceeds the design flow of 4.0 MGD by as much as 10.5 MGD. The New York State Department of Environmental Conservation (NYSDEC) has mandated that Geneva identify and implement a means of mitigating excess wet weather flow. Currently available wet weather abatement ideology includes the elimination of wet weather sources and/or implementation of collection system controls. When these measures fail to sufficiently reduce wet weather flows, treatment technologies must be implemented at the WWTP.

Wet weather treatment ideologies at the WWTP can be grouped into three categories: Flow Retention, Partial Treatment, and Full Treatment. Overflow retention facilities (ORF) and equalization basins are often used to retain excess flow and treat it when flow subsides. Partial treatment can be further divided into three categories: biological, chemical, and physical processes. Biological treatment processes are not conducive to intermittent operation and are subject to upset under erratic flow/loadings. Chemical treatment (disinfection) is often not sufficient and is typically used in conjunction with a biological or physical treatment process. Physical treatment alternatives include screening, sedimentation, and/or high rate sedimentation. Lastly, a WWTP upgrade will provide full treatment; however, unless dry weather flows have increased substantially from the original design values, the process will be oversized and present continuous operation and efficiency challenges.

Until recently, filtration was not seen as a potential wet weather treatment technology. In fact, at many plants where conventional tertiary filtration is used, the systems routinely blind during wet weather events and limit plant capacity. The New York State Energy Research and Development Authority (NYSERDA) recently co-funded a technology transfer project in conjunction with CRA Infrastructure and Engineering, Inc. (CRA), targeted at the evaluation of the feasibility of implementing Coarse Monomedia Filtration (CMF) at plants that are currently operating with or need tertiary treatment. CMF contrasts with conventional fine media filtration in that the media for a CMF system is larger and rounder and the bed depth is deeper. Based on the results of a feasibility study at Geneva and past successes in the implementation of CMF, NYSERDA, Geneva, and CRA were compelled to enter into a wastewater technology project to evaluate the feasibility of using CMF to treat raw, excess wet weather flows. This project consists of a pilot study to demonstrate the effectiveness of CMF in the treatment of raw wastewater and the extrapolation of pilot results to size a full-scale system. Additionally, the proposed full-scale CMF system will be compared to alternate treatment technologies.

The pilot unit used during this study was a Severn Trent Services Model 20 Filter Pilot Plant equipped with a programmable logic controller (PLC), two backwash pumps, centrifugal blower, mudwell pumps, and influent and effluent piping and valves. Godwin Pumps provided ancillary equipment such as influent pump, flow control valves, and piping. The filtration unit consisted of an 8'-0" diameter by 18'-6" tall cylindrical tank with two compartments serving as filter cells and two compartments serving as a clearwell and mudwell. Each filter cell contained 10 square feet (sf) of sand media 6' deep, supporting gravel, and a slotted steel underdrain.

The influent for the pilot unit was pumped from the Gulvin Park Pump Station wetwell downstream of the stations automatic screen (1-inch bar spacing). Filtrate was conveyed to the chlorine contact tank where it was combined with treated effluent from the Marsh Creek Treatment Plant. Influent samples were collected from the wetwell, and effluent samples were collected from a sample tap located on the filter effluent lines. The filters were backwashed when a high filter water level alarm was activated. Three types of backwashes were performed: short duration bump, normal backwash, and water backwash. Spent backwash was discharged to the mudwell and conveyed to the Gulvin Park Pump Station wetwell intake.

During the pilot testing, some operational challenges were experienced. It was determined that there were two primary issues that occasionally hindered testing. It was found that due to inclement weather, some of the equipment on the pilot unit became inoperable and required shutdown of the unit for repair. Additionally, since the pilot unit was primarily designed for processing of liquid that has already been treated somewhat or that is not as contaminated as raw sewage, some of the equipment was not well suited for the treatment of raw sewage. One such area was the pilot unit clearwell, which was not large enough to hold the volume of water required for an entire backwash. The clearwell appears to have been sized based on one filter processing 7-10 gpm/ft^2 while the other was being backwashed. It was found that due to the concentration of contaminants, sustained operation of the unit could only be maintained for an average of 90 minutes at 4-6 gpm/ft^2. Throughout testing it was therefore necessary to keep a fire hose in the clearwell to provide adequate water supply for backwashes.

A detailed sampling and analysis plan was established to meet the goals of the pilot study. Each sample was analyzed for Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and soluble BOD (SBOD) - insoluble BOD (IBOD) data was calculated. In addition, treatment plant flow data was obtained, certified daily precipitation data was obtained, and influent particle distribution analysis was performed.

A data validation process reviewed compliance with standard testing methods, comparable to historical data and accepted trend within the industry. Based on the data validation procedure, 39 of the 40 TSS results are considered valid. Six of the 40 BOD samples were eliminated because of significant non-conformances and/or pilot unit upset. Four of the valid results are estimated values because of slight deviations from acceptance criteria. Of the 26 soluble BOD (SBOD) samples, two results were eliminated because of significant non-conformance and/or pilot plant upset. Eight of the results are estimated values because of slight deviations from acceptance criteria. All other data obtained was validated and used where appropriate.

Pilot plant influent conditions and quality were also compared with equipment manufacturer's recommendations. During the pilot study, solids loadings ranged from 0.14 lbs/SF to 0.68 lbs/SF of filter surface area with an average of about 0.39 lbs/SF. This is approximately 40% of the manufacturer-projected solids loading of 1 lb/SF. It was found that approximately 20% of the particles in the influent are larger than the manufacturer's limit of 150 microns. These results indicate that some of the operational challenges such as reduced solids loading and runtimes encountered during testing may be due to excessive particle size.

Pilot plant effluent quality was compared with permitted discharge limitations. Of the 19 valid TSS effluent samples, 18 comply with the 7-day discharge limitation of 45 mg/L, 16 comply with the 30-day limitation of 30 mg/L, and 8 comply with the required 85% removal. Of the 14 valid BOD effluent samples, 11 comply with the 7-day limit of 45 mg/L, 7 comply with the 30-day limit of 30 mg/L, and 3 comply with the required 85% removal.

The pilot study confirmed that CMF is generally capable of TSS removal and can achieve the plant discharge limitations; however, particle size in the influent does have a significant effect on the performance of the unit. The effect on BOD removal is limited to primarily IBOD fraction, therefore, to consistently comply with the discharge permit, either pretreatment of the influent or blending of the effluent will likely need to be performed. An analysis of blending was performed using the current WWTP effluent quality and a projected full-scale CMF system effluent quality. The blended TSS concentrations would comply with the 7-day requirement of 45 mg/L; however, given the worst case scenario (maximum TSS out of the filter at peak flow), the effluent may occasionally exceed the 30-day permit level. The blended effluent would comply with BOD permit requirements at all times if average pilot effluent BOD levels are experienced; however, if maximum BOD concentration are experienced in the CMF effluent, the blended effluent may exceed both the 7-day average and the 30-day permit levels.

The full-scale implementation would divert any flow above the capacity of the WWTP to the filters. Filter effluent would be disinfected prior to blending with the WWTP effluent. Based on the performance of CMF in the pilot study, the loading rate for the full-scale system would need to be reduced from the recommended 8.0 gpm/ft^2 to less than 5.5 gpm/ft^2 with two filters out of service. The manufacturer recommended that the full-scale system be equipped with five filters, each 9' 5" x 48" 0". A mudwell of at least 3.75 MG would be required to mitigate the impact of backwash on the plant. It has been estimated that the order of magnitude capital cost for the proposed full-scale CMF system, associated buildings, and ancillary systems is approximately $5,000,000. The estimated annual operating cost is approximately $600, with daily energy requirements of approximately 53.5 kWh.

It was determined that the only alternative technology that provides comparable effluent quality and is both economically and physically feasible to implement in Geneva is the ACTIFLO process. ACTIFLO is a type of high rate sedimentation using a three-stage process. Pilot testing of ACTIFLO has reported TSS removals to be around 80% to 95% and BOD removals to be around 40% to 80%. Based on discussions with the manufacturer of ACTIFLO, it is estimated that a 10.5 MGD system of the same capacity as the CMF system will meet Geneva's requirements. The order of magnitude capital cost for the ACTIFLO equipment and associated ancillaries is approximately $3,300,000. The estimated annual operating cost, including chemical and energy costs, is approximately $14,000 with daily energy requirements of approximately 170 kWh.

CMF is an effective, energy-efficient method for treating raw wastewater during wet weather events, able to achieve an average TSS removal of 79%, and an average BOD removal of 62%. Estimated energy costs range from $4 to $115 per day for average to maximum wet weather flows, respectively. However, the operational challenges faced during the study show that CMF may not be a practical method for wet weather treatment without additional equipment.

The most likely cause of the operational challenges experienced was the large particle size. It is therefore concluded that CMF is suited for wet weather treatment when particles 150 microns or greater are first removed. Potential technologies for doing this include rotary screens or coarse dual media filters.

In the absence of a separate technology for removing large particles, CMF is not the best option for wet weather treatment at the City of Geneva. ACTIFLO is able to achieve a comparable effluent quality for a lower life cycle cost and will likely be able to handle the large particle size more efficiently.

1. INTRODUCTION

Treatment of excess wet weather flows in a wastewater treatment plant (WWTP) is increasingly the focus of regulatory agencies in New York State and around the country. One of the Environmental Protection Agency's (EPA's) and the New York State Department of Environmental Conservation's (NYSDEC's) nine minimum controls for combined sewer overflows (CSOs) is to maximize the transmission of flow to treatment plants, where the highest level of treatment can be accomplished at the lowest cost. Municipalities are faced with the monumental undertaking of implementing the recommendations of regulatory agencies despite aging infrastructure, inadequate WWTP capacity, lack of physical space to expand, and/or lack of funding to address any or all of the above. Nevertheless, CSOs and sanitary sewer overflows (SSOs) remain a hotly debated topic in the regulatory and municipal communities.

One municipality that must identify and implement a means of treating excess wet weather flow is the City of Geneva, New York (Geneva). Geneva owns and operates a biological WWTP. During wet weather, wastewater flow to the plant greatly exceeds the design flow. During these times, the biological process is often washed out and solids, including necessary microorganisms, are carried over to the secondary clarifier. This shift of solids from the aeration basin to the clarifier diminishes the efficiency of biological process efficiency and causes an increase in solids discharged from the treatment plant. As a result, treatment plant effluent periodically exceeds its permitted discharge levels for total suspended solids (TSS) and biochemical oxygen demand (BOD). These exceedances continue until the microbial population reestablishes itself and the biological process is stabilized.

In the past, the New York State Energy Research and Development Authority (NYSERDA) funded projects to evaluate the efficacy of coarse monomedia filter (CMF). A 1998 demonstration project on tertiary wastewater at the Tonawanda WWTP, Tonawanda, New York showed that significant chemical and electrical cost savings could be realized by replacing conventional sand filters with coarse monomedia filters. Similar results were reported by the Niagara County Sewer District WWTP after replacement of fine media with coarse monomedia.

Recently, NYSERDA co-funded two CMF treatment projects. The first is a technology transfer project performed in conjunction with CRA Infrastructure and Engineering Inc. (CRA). The goal of this project is to target plants that are currently operating with or need tertiary treatment and evaluate the feasibility of implementing CMF. The second project is being conducted at the Erie County Department of Environment and Planning Southtowns Sewage Treatment Plant. The goal of this project is to quantify the ability of CMF to treat partially treated (primary settled) wastewater.

The past successes of CMF has prompted NYSERDA, Geneva, and CRA to enter a wastewater technology project to evaluate the feasibility of using CMF to treat raw, excess wet weather flows. This project consists of a pilot study to demonstrate the effectiveness of CMF in the treatment of raw wastewater and, if successful, to determine design and operating parameters through the extrapolation of pilot results to size a full-scale system. Additionally, the proposed full-scale CMF system will be compared to alternate treatment technologies.

BACKGROUND

Geneva's WWTP is currently rated at 4.0 MGD. Wet weather flows can reach as much as 14.5 MGD. A review of plant operating records indicates that during the 12-month period from October 2002 to September 2003, the Facility logged 48 days with an average flow that exceeded 4 MGD. There were eight occurrences where the duration of elevated flows lasted for two days or more, with the longest occurrence lasting for eight days. Geneva has one permitted outfall (Outfall 001) with discharge limits as shown on Table 1.1.

Table 1.1. Geneva Wastewater Treatment Plant Permit Limitations

Parameter	7-Day Discharge Limitation (mg/L)	30-Day Discharge Limitation (mg/L)	Minimum Removal (%)
Total Suspended Solids	45	30	85
Biochemical Oxygen Demand	45	30	85

2. SCOPE OF PROJECT

The primary goal of this project was to conduct a pilot study to demonstrate the effectiveness of CMF in treating raw wastewater and determine the feasibility of implementing a full-scale CMF system. Specific study goals included:

- Determining pilot effluent water quality parameters, TSS, BOD, insoluble BOD (IBOD), and soluble BOD (SBOD) as a function of operating conditions including influent water quality and loading rate
- Comparing pilot effluent water quality with permitted discharge levels
- Determining full-scale design parameters such as maximum loading rate, filter run time, and backwash requirements
- Projecting full-scale effluent water quality and estimating blending proportions if effluent does not meet permit levels
- Sizing full-scale equipment and estimating capital construction costs
- Estimating operating parameters for a full-scale system including labor, maintenance and energy usage and estimating costs
- Identifying environmental benefits
- Estimating full-scale life-cycle costs
- Comparing CMF with alternative treatment technologies

The effectiveness of CMF will be evaluated based on the ability of the CMF pilot effluent to meet SPDES permit requirements, either on its own or when blended with WWTP effluent. The full-scale CMF system will be compared with alternate technology for ease of system operation and maintenance (O&M), estimated capital and O&M costs, energy efficiency, and environmental performance.

3. OVERVIEW OF WET WEATHER TREATMENT TECHNOLOGIES

Wet weather abatement technologies include a combination of the elimination of wet weather sources and implementation of collection system controls. These methods are typically employed as a first step to minimize impact on the downstream WWTP. However, when these measures fail to sufficiently reduce wet weather flows, treatment technologies must be implemented.

EXISTING WET WEATHER TREATMENT TECHNOLOGIES

Three categories of wet weather treatment technologies are available: biological, chemical, and physical processes. Biological treatment processes, though amenable to treating routine sanitary flow, are subject to upset under intermittent flows and erratic loadings, and therefore they are the least preferred treatment alternative. Chemical treatment, usually consisting of chlorine disinfection, addresses some bacteriological concerns but does not reduce particulate concentrations. The particulate loading often includes organic matter, which results in elevated levels of biochemical oxygen demand (BOD) on the receiving stream. This can lead to dissolved oxygen depletion and a negative effect on aquatic life. For that reason, chemical treatment is often used in conjunction with a physical treatment process. Physical treatment alternatives include screening and high rate sedimentation. Brief descriptions of these physical treatment processes, along with level of treatment achieved, and benefits and disadvantages, are contained in Table 3.1.

Two additional methods are commonly used for the treatment of wet weather flow: an overflow retention facility (ORF) and lastly, a WWTP upgrade. Brief descriptions of these methods along with level of treatment achieved, and benefits and disadvantages are also contained in Table 3.1.

An ORF is a large holding tank that contains excess flows until the WWTP has sufficient capacity to treat the flow. An ORF, however, has limited capacity and is designed based on the duration and magnitude of a typical wet weather event. In some cases, the capacity of the ORF is exceeded and partially treated (potentially as high as primary treated, depending on the size of the ORF) wastewater is discharged.

A WWTP upgrade involves increasing the capacity of a portion of or all of the treatment plant to meet the peak-hourly flow rate. This is usually cost-effective only when dry weather flows have increased substantially from the original design values. In either case, the ability of the system to fully treat excess flow is based on the magnitude and duration of the event. This means that occasionally, partially treated wastewater is discharged into the receiving water body.

Table 3.1. Summary of Existing Wet Weather Treatment Technologies

Treatment Technology	Description	Level of Treatment Achieved	Advantages	Disadvantages
Screening	Removal of coarse solids by interception. Typical set up includes a coarse screen (greater than 1" clear opening) followed by a fine screen (approximately 1/16-inch opening)	Level of treatment dependent on screen opening size, but usually considered preliminary treatment	Typically, no capital expense is required if existing screening facility at WWTP has sufficient capacity Relatively simple to operate and maintain Small footprint	Blended effluent may not meet SPDES permit limitations Cannot remove BOD
High-Rate Sedimentation (Ballast-assisted Sedimentation)	Removal of particles by coagulation of weighted microcarriers such as sand. Sludge is passed through a hydrocyclone to separate particles from microcarrier. Microcarrier is recirculated. Particles are disposed.	Primary treatment	Quick system startup Small footprint	Newer technology – not as proven as other methods
Overflow Retention Facility (ORF)	A storage basin sized to contain excess flow. When the treatment plant capacity is exceeded, excess is diverted to the ORF. When treatment plant capacity is available, the excess flow is conveyed treatment plant for subsequent treatment.	Full treatment in compliance with SPDES permit as long as capacity is not exceeded. Otherwise, primary treatment may be achieved prior to discharge.	All influent wastewater is treated to permit level prior to discharging Relatively inexpensive capital cost	Stagnant wastewater creates potential odor issues Accumulated settleable solids must be removed following usage Cause of excess flow is not addressed If capacity is exceeded, flow must be discharged without full treatment
Upgrade Wastewater Treatment Plant	Increase in treatment plant capacity to meet peak-hourly flow rate	Full treatment in compliance with SPDES permit	All influent wastewater is treated to permit level prior to discharging	Expensive unless upgrade is required for non-wet weather reasons

CMF AS A POTENTIAL WET WEATHER TREATMENT TECHNOLOGY

Until recently, filtration was not seen as a potential wet weather treatment technology. In fact, at many plants where conventional tertiary filtration is used, the systems routinely blind during wet weather events and limit plant capacity. A conventional fine media filtration system consists of a shallow bed (approximately 30-inch depth) that is filled with a fine media such as sand, anthracite, and/or garnet. Effluent TSS concentrations of less than 10 mg/L to 20 mg/L can be typically achieved.

CMF contrasts with conventional fine media filtration in that the media for a CMF system is larger and rounder and the bed depth is deeper. The larger and rounder media creates larger void spaces that allow deeper penetration of accumulated solids and therefore, longer filter run times. In addition the coarser media is heavier so backwashes can be combined with air scouring without loss of media. This allows better particle removal with less backwash water. Typical tertiary treatment design and operating parameters for conventional fine media and coarse monomedia filters are shown in Table 3.2.

TABLE 3.2. Comparison of CMF and Conventional Fine Media Filtration Processes when Used for Tertiary Treatment

Parameter	CMF	Conventional Fine Media Filtration
Media	Coarse sand	Sand or Anthracite[2]
Media Size (mm)	2.3 to 3.0	0.5 to 1.0 (Sand) 1.0 to 2.0 (Anthracite)[2]
Typical Bed Depth (in)	72	30[2]
Filtration Rate (gpm/SF)	4 to 10	5 or less[3]
Filter Run Time (hr)	8 to 48[1]	2 to 20
Backwash Rate (gpm/SF)	7	20
Typical Backwash Period (min)	30	10[3]

[1]As seen at both the Tonawanda and Niagara County WWTPs
[2]Metcalf & Eddy, 1991
[3]Recommended Standards for Wastewater Facilities, 2004

Due to the ability of CMF to accumulate more solids per filter run, CMF pilot testing of primary settled wastewater was recently performed at the Village Creek Wastewater Treatment Plant in Birmingham, Alabama and the Choccolocco Creek Wastewater Treatment Plant, City of Anniston, Alabama. The results from these studies show that CMF effectively removes TSS and BOD from primary treated (settled) wastewater to levels that, when the primary treated wastewater is blended with treatment plant effluent, the blended effluent is generally compliant with the discharge permit (Severn Trent, 2004). The potential of using CMF for treating raw wastewater is derived from the positive results obtained from pilot studies and full-scale implementation of primary treated wastewater.

Though CMF is proving itself as an alternative conventional tertiary treatment technology and as a means of treating primary settled wastewater, there are numerous differences between filtering a preliminary screened wastewater and filtering a partially or fully treated wastewater. The primary difference is that screened effluent has a larger particle loading as well as larger particles. Preliminary screening can remove 5% to 10% of the influent suspended solids with screen openings of 0.09 inches to 0.25 inches. That removal increases to 10% to 15% with 0.03-inch to 0.06-inch screens (Metcalf and Eddy, 1991). Maximum particle size is approximately equal to the size of the screen opening. It is important to note, however, that many plants are equipped with screens having openings in the range of 0.75 to 1 inch. Secondary effluent typically contains particles varying in size from 1 to 15 microns and 50 to 150 microns with few particles larger than 500 microns (Metcalf and Eddy, 1991).

4. PILOT STUDY MATERIALS AND METHODS

PILOT UNIT SETUP

The pilot unit used during this study was a Severn Trent Services Model 20 Filter Pilot Plant equipped with a programmable logic controller (PLC), two backwash pumps, centrifugal blower, mudwell pumps, and influent and effluent piping and valves. Godwin Pumps provided ancillary equipment such as influent pump, flow control valves, and conveyance piping. A layout of the pilot equipment set up is contained in Appendix A.

The filtration unit consisted of an 8'-0" diameter by 18'-6" tall cylindrical tank divided into four compartments. Two of the compartments served as filter cells (Filters 1 and 2) with each filter cell containing 6'-0" of sand media with a grain size of 2 mm to 3 mm and a surface area of 10 square feet (sf). The media was supported by five layers of reverse graded gravel and a slotted steel underdrain. The two remaining compartments served as a clearwell and mudwell.

The process water used for the pilot study was continuously pumped from the Gulvin Park Pump Station wet well. The suction line was located downstream of the Facility's automatic screen (1-inch bar spacing). The Gulvin Park Pump Station serves a typical residential community consisting of a mix of residential, commercial, institutional, and recreational districts. There are no industrial facilities tributary to the pump station. Flow is highly variable due to unidentified sources of infiltration and inflow.

PROCESS DESCRIPTION

Filter influent was pumped directly from the wet well intake using a self-priming, 20-HP pump with a 4" diameter discharge. A recirculation line was used on the pump discharge for finer flow control. Flow was diverted to either or both of the filter cells by automatic influent valves. Filtrate from both filter cells was combined in the clearwell and then conveyed to the chlorine contact tank where it was combined with treated effluent from the Marsh Creek Treatment Plant. Influent samples were collected from the wet well, and effluent samples were collected from a sample tap located on the filter effluent lines. A process flow diagram is shown in Appendix A.

Filters were backwashed when a high filter water level alarm was activated or when a predetermined amount of time had passed. The pilot unit manufacturer suggested that backwashes should also be performed when 1 pound of solids accumulates per square foot of filter surface area. This method was not employed due to the delay in obtaining solids accumulation data.

Three types of backwashes were performed:

- Short duration bump: consisting of a 60-second backwash to dislodge gas buildup and relieve solids compaction. This method was employed up to 12 times between normal backwashes.
- Normal backwash: consisting of 30 seconds of reverse air flow to agitate the filter surface, 15 minutes of reverse air and backwash water flow to remove captured solids, and 5 minutes of reverse flow to rinse residual solids and air bubbles. This method was routinely used on most test runs.
- Backwash only: consisting of 20 minutes of reverse flow only through the filter media to remove captured solids.

Spent backwash was discharged to the mudwell and conveyed to the Gulvin Park Pump Station wet well intake. In most cases, influent samples were collected prior to discharging backwash water. In instances when operational issues forced backwashing prior to influent sample collection, the effect on influent concentration is not expected to be significant since the volume of flow from the filter was much smaller than the volume of flow into the pump station.

SAMPLING AND ANALYSIS PLAN

A detailed sampling and analysis plan was established to ensure that the pilot study goals would be met. Where appropriate, data were procured from Geneva and the Northeast Regional Climate Center, a division of the National Oceanic and Atmospheric Administration, to supplement data obtained by the study. A matrix outlining the sampling and analysis plan is contained in Table 4.1. Pilot unit sampling locations are shown in Appendix A.

Table 4.1. Summary of Sampling and Analysis Plan

Parameter	Location	Collection Methodology	Analysis Methodology
Pilot Plant Influent: TSS BOD SBOD Particle Size	Gulvin Park Pump Station wet well	Sample bailer	Standard Methods
Pilot Plant Effluent TSS BOD SBOD	Effluent sample tap on clear well discharge line	Sample Tap	Standard Methods
Pilot Plant Influent and Effluent: IBOD	N/A	N/A	Calculated: IBOD concentration = BOD concentration – SBOD concentration
Treatment Plant Flow Rate	Provided by Geneva		
Treatment Plant Influent Concentrations TSS BOD	Provided by Geneva		
Treatment Plant Effluent Concentrations TSS BOD	Provided by Geneva		
Precipitation	Northeast Regional Climate Center		

5. PILOT STUDY RESULTS

VALIDITY OF DATA

Data used in the evaluation were collected from five sources. Treatment plant flow data (Appendix B) were obtained from plant personnel and are considered valid and proportional to flow conditions at the Gulvin Park Pump Station. Certified daily precipitation data were obtained from the Northeast Regional Climate Center, for the Geneva Research Farm Substation (Appendix C). Precipitation data are considered representative of conditions within the Gulvin Park Pump Station and Treatment Plant service areas. TSS, BOD and SBOD analyses were performed by the treatment plant's laboratory and Life Sciences Laboratories, Inc., an independent laboratory contracted for this study. Complete data are contained in Appendix D. IBOD results were calculated by subtracting SBOD concentrations from BOD concentrations. Testwell Laboratories, Inc., conducted particle size analyses (Appendix E).

TSS and BOD analytical results were evaluated by the laboratories to determine if analytical procedures complied with analytical standards. For 12 of the results, acceptance criteria were slightly exceeded. However, it was the laboratory's opinion that for these samples, results could be estimated. CRA also reviewed the data with respect to pilot plant operations. Analytical data that were collected during normal pilot plant operations and complied with Standard Methods, or were estimated by the laboratory, are considered valid results and are presented in Table 5.1. Results that deviated significantly from acceptance criteria, or data that were collected during a plant upset, are not reported here and are eliminated from further evaluation.

Table 5.1. Pilot Plant Data

Date	Sample Time	BOD		SBOD		TSS	
		Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Effluent (mg/L)
11/24/04	11:17 AM	259	-- NR	-- NC	-- NC	168	36
11/24/04	2:10 PM	250	-- NR	-- NC	-- NC	108	24
12/01/04	1:30 AM	100	71	29 Est.	31 Est.	46	17
12/01/04	3:55 AM	72 Est.	30 Est.	5 Est.	14 Est.	46	12
12/01/04	6:00 AM	45 Est.	15 Est.	43 Est.	13 Est.	52	12
12/06/04	2:00 PM	290	24	62	13	84	4
12/07/04	9:02 AM	-- NC	-- NC	-- NC	-- NC	90	28
12/07/04	11:12 AM	-- NC	-- NC	-- NC	-- NC	90	8
12/07/04	12:07 PM	217	-- NR	98	61 Est.	96	20
12/07/04	1:01 PM	-- NC	-- NC	-- NC	-- NC	156	19
12/07/04	1:55 PM	36	-- NV	17	-- NV	92	-- NV
12/08/04	3:04 PM	233	-- NR	85	-- NR	91	12
12/09/04	11:23 AM	221	-- NR	78	45	82	25
12/09/04	1:40 PM	250	14	109	10 Est.	92	4
12/10/04	12:15 PM	99	43	-- NC	-- NC	-- NC	-- NC
12/10/04	1:15 PM	83	34	-- NC	-- NC	52	10
12/10/04	2:15 PM	100	17	-- NC	-- NC	72	8
12/10/04	3:15 PM	120	27	-- NC	-- NC	-- NC	-- NC
12/10/04	4:00 PM	120	16	-- NC	-- NC	-- NC	-- NC
12/23/04	10:15 AM	200	73	71	42	210	33
12/23/04	11:11 AM	160	140	58	94	120	61
01/13/05	11:30 AM	55	35	22	22	54	14
01/13/05	1:45 PM	68	35	27	25	76	14

Notes:

XX Est.: Value estimated by laboratory. Minimum depletion requirement of 2 mg/L not satisfied. However, it was the laboratory's opinion that the minimum depletion requirement was nearly met so that values could be estimated.

-- NC : Sample not collected

-- NR : Sample collected but result not reported by laboratory due to significant non-conformance with Standard Methods

-- NV : Sample collected, results reported but data not valid due to pilot plant upset

Based on the data validation procedure, 39 of the 40 total suspended solids results are considered valid. The one result that was eliminated (December 7, 2004, at 13:55 – TSS effluent) was collected during a major pilot plant upset. At that time, one of the air valves was inoperable. Effluent appeared turbid and results showed that the effluent concentration exceeded the influent concentration. The pilot unit was shut down immediately after sampling and the pilot unit vendor performed necessary repairs.

Biochemical oxygen demand analysis is a more complicated procedure than TSS analysis. As a result, the laboratory deemed fewer results acceptable. Of the 40 BOD samples submitted for analysis, five results were eliminated because of significant non-conformances and one (December 7, 2004, at 13:55 – BOD effluent) was eliminated due to the plant upset described above. Four (10%) of the valid results are estimated values because of slight deviations from acceptance criteria. Of the 26 soluble BOD (SBOD) samples submitted for analysis, one result was eliminated because of significant non-conformance, and one was eliminated due to pilot plant upset. Eight (31%) of the results are estimated values because of slight deviations from acceptance criteria.

Four samples were collected from the pilot plant influent to determine particle size. The first two samples were analyzed to determine the distribution of particles with diameters less than 100 microns. Since a portion of this sample contained particles greater than 100 microns that were not analyzed, it was eliminated from further evaluation. The second and third samples were analyzed for all particle sizes and are considered acceptable.

OPERATIONAL CHALLENGES

During the pilot unit operation, filter run times were often much shorter than had been anticipated. Though the manufacturer projected filter run times of two hours or more, during this study the run times ranged from 250 minutes to only four minutes with an average of approximately 90 minutes. It was found that by lowering the flow rate to 4-6 gpm/ft2 through the filter as opposed to the 7-10 gpm/ft2 originally planned, run times could be extended to some degree.

The pilot unit clearwell was not large enough to hold the volume of water required for an entire backwash. Under the design filtration rate of 7 to 10 gpm/ft^2, the filtrate from the filter in operation normally provides an adequate backwash water supply in the clearwell. However, due to the reduced flow rates used during this study, the filter in operation was unable to keep up with the backwash water demand. Throughout testing, it was necessary to keep a fire hose in the clearwell to provide adequate water during backwashes.

The backwash air valves often stuck. This was most likely due to the inclement weather and extreme environment, as most testing was performed during November and December, when the nightly low temperate often reached 20ºF, and the valves lacked insulation or heat tracing. Because of this, at times air was directed into either the wrong filter, or neither filter. This rendered backwashes ineffective. A few days were spent trying to diagnose and correct the problem. It is unknown exactly how many backwashes were done without the air scour, and this likely affected some of the filter run times.

Difficulty was also experienced with the mudwell pump, again most likely due to the inclement weather. The majority of the last day of testing was spent troubleshooting this problem. The mudwell had completely filled due to pump control failures, and the drain at the bottom of the mudwell was not able to empty it at a rate fast enough to keep the filter unit in service.

INFLUENT WASTEWATER EVALUATION

Influent pilot plant wastewater was evaluated to determine if the results conform to generally accepted trends and if the water quality was within range of historical conditions. Influent data that conform to these evaluation criteria are considered representative of full-scale conditions. Additionally, the fraction of BOD that is insoluble was determined and the particle size distribution of the influent was examined to determine the impact on operations and if CMF is an appropriate wet weather technology for Geneva.

Comparison of Influent Water Quality with Expected Water Quality

Influent water quality data obtained during the study conforms to the generally accepted principle that the concentration of contaminates decreases as flow rate increases due to wet weather events. As shown in Figure 5.1, TSS concentrations generally decrease as treatment plant flow rate increases. BOD concentrations also decrease as flow rate increases (Figure 5.2).

Figure 5.1. Influent TSS Concentrations as a Function of Flow Rate

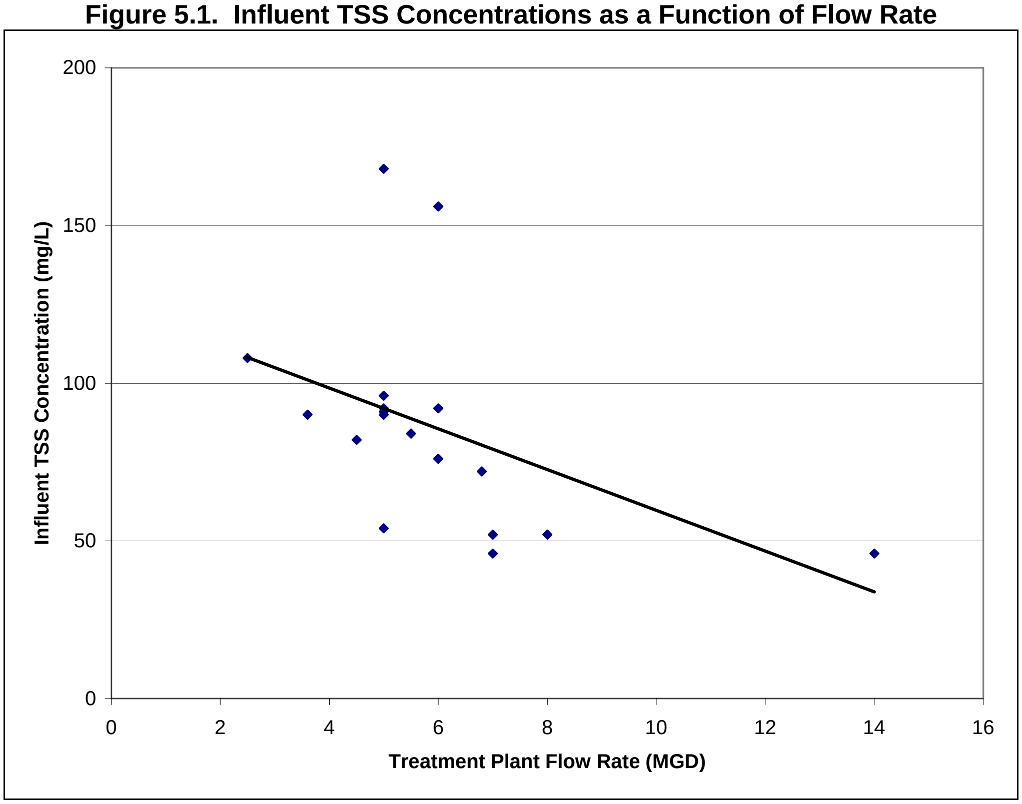
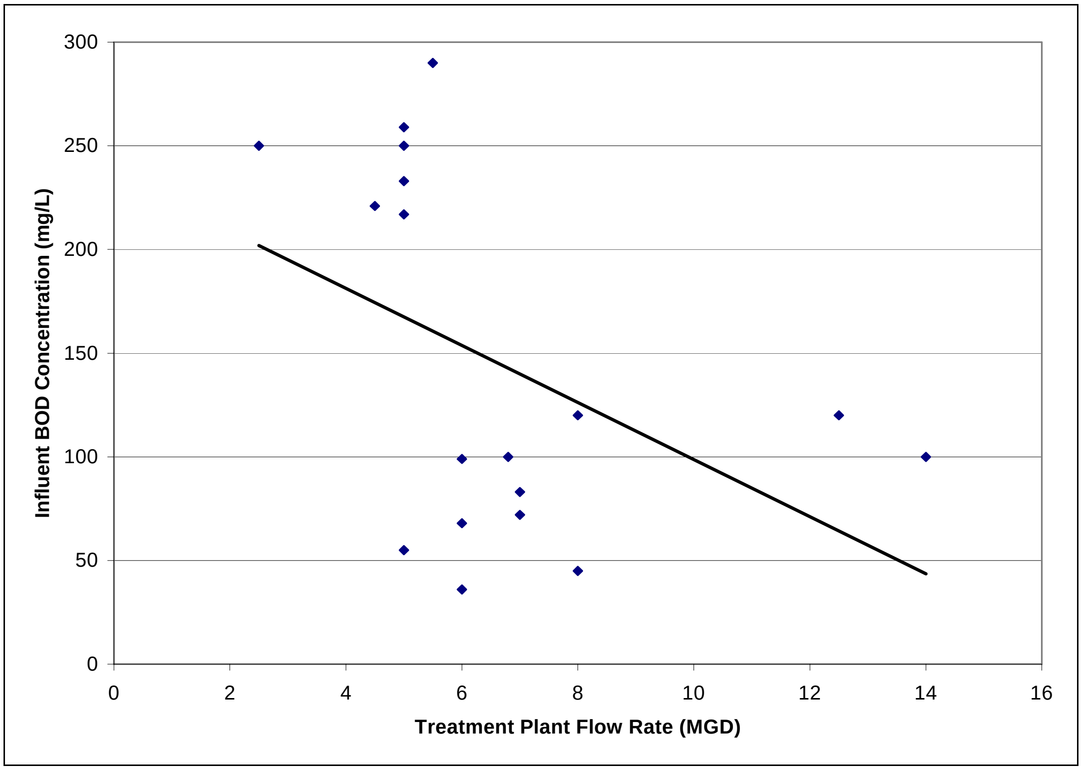


Figure 5.2. Influent BOD Concentrations as a Function of Flow Rate



Historical water quality data for the Gulvin Park Pump Station are not available, however influent water quality data are routinely monitored at the Marsh Creek Wastewater Treatment Plant which is the Gulvin Park Pump Station discharge point. Based on discussions with operators, treatment plant influent concentrations are expected to be slightly greater than influent concentrations at the Gulvin Park Pump Station due to the direct discharge of concentrated industrial wastewater and septage to the treatment plant. This difference is expected to increase during wet weather events because infiltration and inflow are reportedly greater in the sewers tributary to the Gulvin Park Pump Station than in the remainder of the collection system (Malcolm Pirnie, 2004). As a result, only a general comparison of pilot data and historical treatment plant data can be made.

Three-year historical treatment plant influent data from January 2001, through December 2003, (Malcolm Pirnie, 2004) were compared with pilot plant influent concentrations. Pilot study influent TSS concentrations are within the treatment plant historical ranges, but are less than the historical average under all flow ranges evaluated. Pilot plant influent BOD concentrations are also within historical ranges and are less than the historical averages. As expected, pilot influent also appears more influenced by wet weather events than treatment plant influent. Based on the conformance of pilot plant influent data with evaluation criteria, pilot influent water quality is considered representative of actual conditions at the Gulvin Park Pump Station.

Table 5.2. Comparison of Historical and Pilot Study Influent TSS Concentrations

	Historic Data		Pilot Data	
Flow range (MGD)	# of days	Influent TSS (mg/L)	# of days	Influent TSS (mg/L)
<2.0	70	253	0	---
2.0 - 3.5	800	249	1	108
3.6 - 6.0	183	212	10	104
6.1 – 10	33	253	5	55
>10	5	206	2	61

Table 5.3. Comparison of Historical and Pilot Study Influent BOD Concentrations

	Historic Data		Pilot Data	
Flow range (MGD)	# of days	Influent TSS (mg/L)	# of days	Influent TSS (mg/L)
<2.0	70	377	0	---
2.0 - 3.5	800	331	1	250
3.6 - 6.0	183	227	10	201
6.1 – 10	33	236	5	79
>10	5	217	2	96

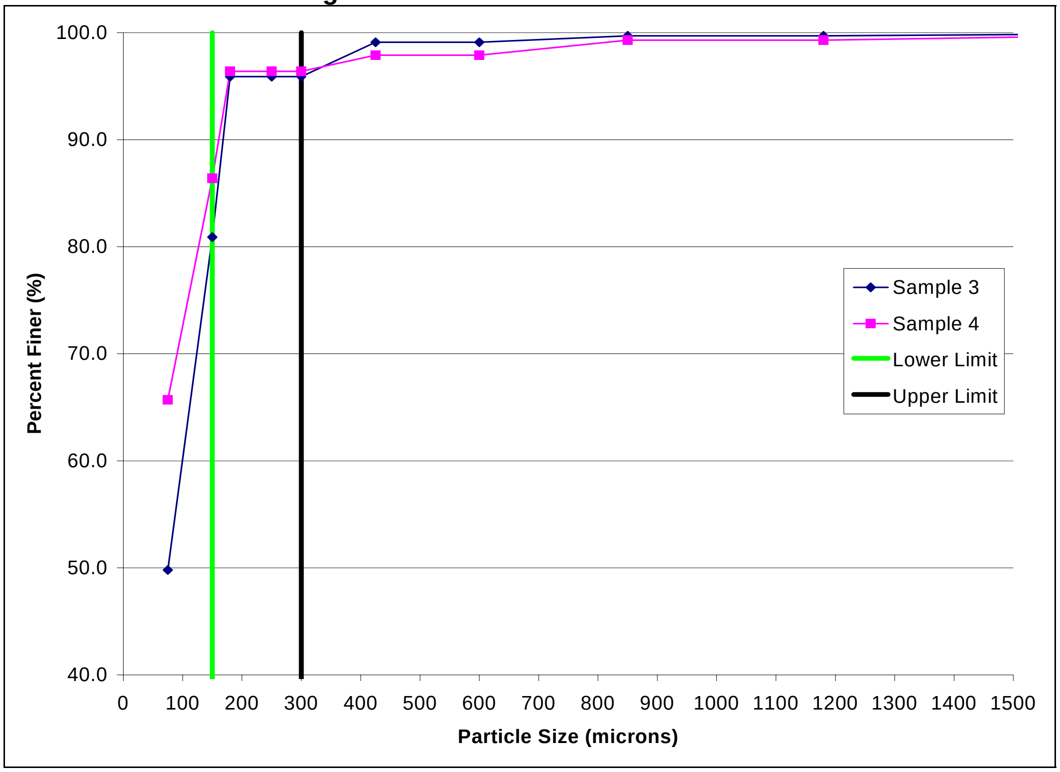
<u>Appropriateness for Implementing CMF based on Influent Water Quality</u>

For CMF to provide stand-alone treatment, Gulvin Park Pump Station influent should contain a higher percentage of IBOD than SBOD and the particles should be easily retained by the media without clogging. The influent BOD was generally comprised of between 50% and 90% insoluble BOD. One sample (Sample ID December 1, 2004, 06:00) contained less than 4% IBOD. This sample contained less than 50 mg/L BOD and it is possible that the insoluble fraction was removed upstream by an unknown mechanism. Since CMF has been proven to remove the insoluble portion of BOD and the majority of Gulvin Park influent BOD is insoluble, CMF could be used to remove a portion of BOD from Gulvin Park influent.

A particle size distribution analysis was conducted to determine if raw influent wastewater is amenable to CMF without premature clogging of the media. The CMF pilot unit supplier indicated that operational difficulties such as reduced filter run times may be encountered if filter influent contains particles with diameters in excess of 150 to 300 microns. These difficulties are typically not encountered during CMF treatment of primary settled wastewater (as seen in the Village Creek, Alabama pilot testing) because sedimentation can remove particles with diameters greater than 185 microns.

Particle size distribution results (Figure 5.3), show less than 20% of the particles in Gulvin Park raw influent have particles with diameters greater than 150 microns. Four percent of the particles have diameters greater than 300 microns. These results indicate that the operational challenges encountered during CMF pilot testing of raw wastewater at the Gulvin Park Pump Station may be due to particle size.

Figure 5.3. Particle Size Distribution



EFFLUENT WATER QUALITY

During the study, 20 sets of TSS and 14 sets of BOD influent and effluent samples were collected and analyzed. The results were compared with permitted Plant discharge limitations to determine compliance.

Additionally, CMF effluent was evaluated relative to influent water quality and operational conditions to determine trends and identify performance limits. The parameters and conditions that varied include:

- Influent TSS concentration
- Influent BOD concentration
- Insoluble fraction of influent BOD
- Filter loading rate

Comparison of Effluent Quality with Discharge Limitations

Pilot plant effluent quality was compared with permitted discharge limitations, as shown in Table 5.4.

Table 5.4 Comparison of Effluent Quality with Discharge Limitations

Date	Sample Time	TSS – Effluent Concentration			TSS – Removal		BOD - Effluent Concentration			BOD – Removal	
		Measured Value (mg/L)	Meets 7-Day Limit (45 mg/L)	Meets 30-Day Limit (30 mg/L)	Calculated Value (%)	Meets 30-Day Limit (85%)	Measured Value (mg/L)	Meets 7-Day Limit (45 mg/L)	Meets 30-Day Limit (30 mg/L)	Calculated Value (%)	Meets 30-Day Limit (85%)
11/24/04	11:17 AM	36	Yes	No	78.6%	No	--	--	--	--	--
11/24/04	2:10 PM	24	Yes	Yes	77.8%	No	--	--	--	--	--
12/01/04	1:30 AM	17	Yes	Yes	63.0%	No	71	No	No	29.0%	No
12/01/04	3:55 AM	12	Yes	Yes	73.9%	No	30	Yes	Yes	58.3%	No
12/01/04	6:00 AM	12	Yes	Yes	76.9%	No	15	Yes	Yes	66.7%	No
12/06/04	2:00 PM	4	Yes	Yes	95.2%	Yes	24	Yes	Yes	91.7%	Yes
12/07/04	9:02 AM	28	Yes	Yes	68.9%	No	--	--	--	--	--
12/07/04	11:12 AM	8	Yes	Yes	91.1%	Yes	--	--	--	--	--
12/07/04	12:07 PM	20	Yes	Yes	79.2%	No	--	--	--	--	--
12/07/04	1:01 PM	19	Yes	Yes	87.8%	Yes	--	--	--	--	--
12/08/04	3:04 PM	12	Yes	Yes	86.8%	Yes	--	--	--	--	--
12/09/04	11:23 AM	25	Yes	Yes	69.5%	No	--	--	--	--	--
12/09/04	1:40 PM	4	Yes	Yes	95.7%	Yes	14	Yes	Yes	94.4%	Yes
12/10/04	12:15 PM	--	--	--	--	--	43	Yes	No	56.6%	No
12/10/04	1:15 PM	10	Yes	Yes	80.8%	No	34	Yes	No	59.0%	No
12/10/04	2:15 PM	8	Yes	Yes	88.9%	Yes	17	Yes	Yes	83.0%	No
12/10/04	3:15 PM	--	--	--	--	--	27	Yes	Yes	77.5%	No
12/10/04	4:00 PM	--	--	--	--	--	16	Yes	Yes	86.7%	Yes
12/23/04	10:15 AM	33	Yes	No	84.3%	No	73	No	No	63.5%	No
12/23/04	11:11 AM	61	No	No	49.2%	No	140	No	No	12.5%	No
01/13/05	11:30 AM	14	Yes	Yes	74.1%	Yes	35	Yes	No	36.4%	No
01/13/05	1:45 PM	14	Yes	Yes	81.6%	Yes	35	Yes	No	48.5%	No

TSS concentrations in the effluent of the CMF units ranged from 4 mg/L to 61 mg/L with an average of 20 mg/L. Removals ranged from 49% to nearly 96% with an average of 79%. Based on these results, 18 samples (95%) comply with the seven-day discharge limitation of 45 mg/L, 16 samples (84%) comply with the 30-day limitation of 30 mg/L and eight removal results (42%) comply with the required 85% removal.

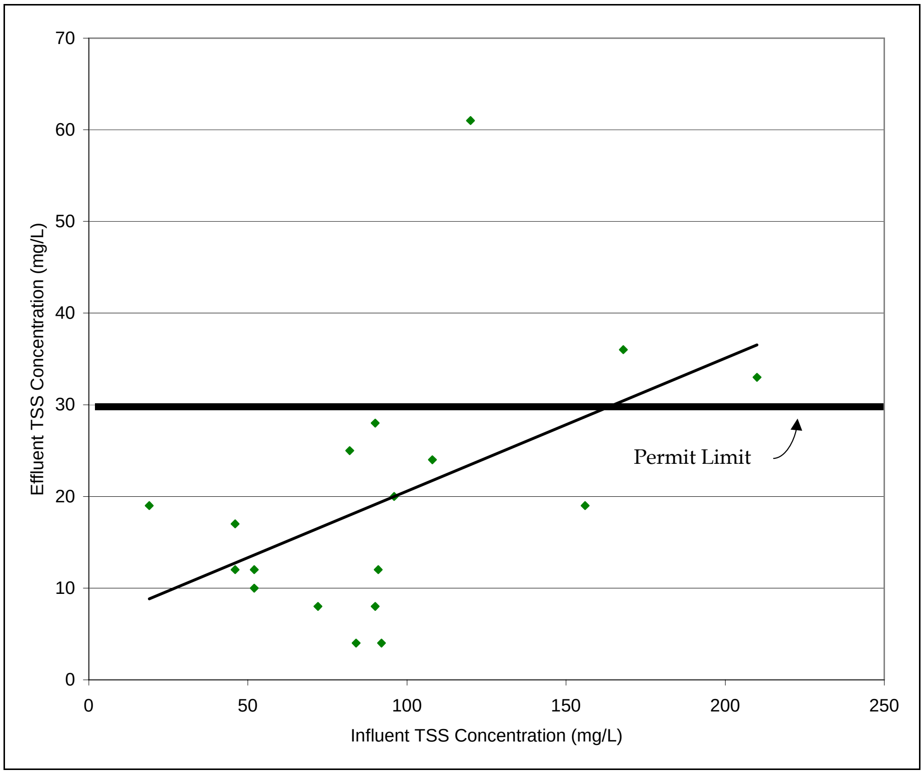
Effluent BOD concentrations ranged from 14 to 140 mg/L with an average of 41 mg/L. The percentage of BOD removed ranged from 13% to 94 with an average of 62%. Based on these results, 11 samples (79%) comply with the seven-day limit of 45 mg/L, seven (50%) comply with the 30-day limit of 30 mg/L and three (21%) comply with the required 85% removal.

Generally, CMF achieves the TSS discharge limitations but only has a moderate effect on BOD. To consistently comply with the discharge permit, CMF effluent will likely need to be blended with treatment plant effluent.

Effect of Influent Concentration

The effect of TSS influent concentration on TSS effluent concentration is shown in Figure 5.4. The effluent TSS concentration generally increases as the influent TSS concentration increases. The percent removal of TSS remained relatively consistent (refer to Table 5.2). Due to the prolonged wet weather throughout the pilot study period, a true first flush situation was never observed. CMF proves equally effective across the influent concentration range experienced.

FIGURE 5.4. Effluent TSS Concentration as a Function of Influent TSS Concentration



Influent total BOD concentration had little effect on the effluent BOD concentration and the BOD removed. BOD removals are somewhat dependent on the IBOD fraction in the influent. As shown in Table 5.5, CMF removes up to 97% of the IBOD with an average value of 65%. The one instance when no IBOD was removed occurred when the influent IBOD concentration was 2 mg/L (Sample ID. December 1, 2004, at 06:00). The next lowest IBOD removal was 44% (Sample ID December 1, 2001, at 01:30). Additionally, influent BOD samples generally contained more than 50% IBOD. This contrasts with the IBOD concentration in the effluent samples that ranged 13% to 56% with an average of 38%. This indicates that CMF is effective at removing IBOD.

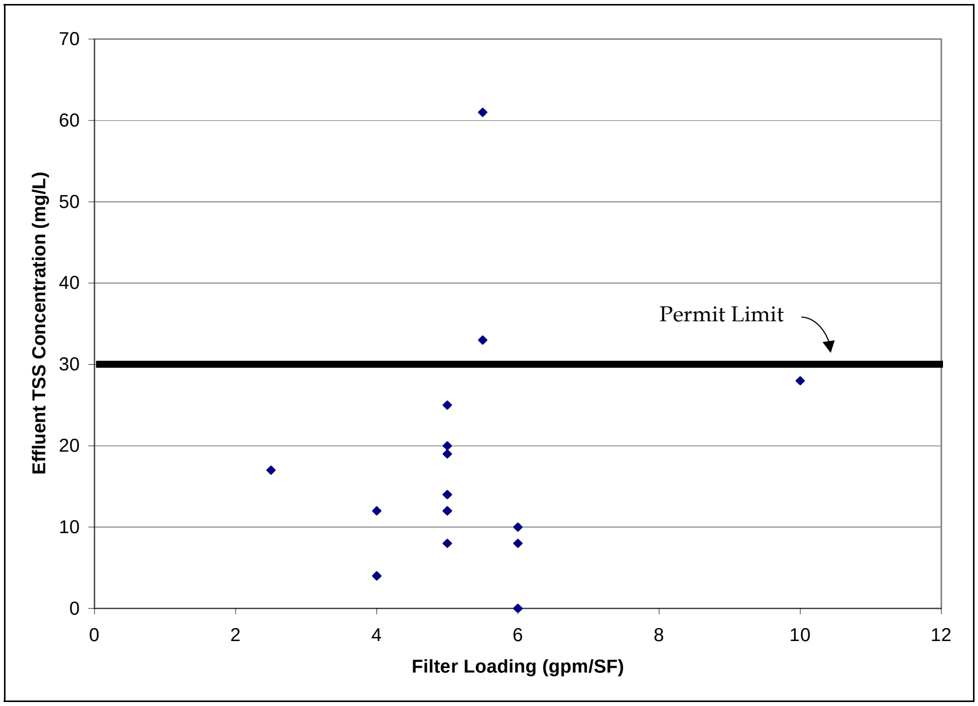
Table 5.5. CMF Removal of BOD and IBOD

Date	Sample Time	Influent BOD (mg/L)	Effluent BOD (mg/L)	BOD Removed (%)	Influent IBOD (mg/L)	Effluent IBOD (mg/L)	IBOD portion of influent BOD	IBOD portion of effluent TBOD	IBOD Removed (%)
11/24/04	11:17 AM	259	--	--	--	--	--	--	--
11/24/04	2:10 PM	250	--	--	--	--	--	--	--
12/01/04	1:30 AM	100	71	29.0%	71	40	71.0%	56.3%	43.7%
12/01/04	3:55 AM	72	30	58.3%	67	16	93.1%	53.3%	76.1%
12/01/04	6:00 AM	45	15	66.7%	2	2	4.4%	13.3%	0.0%
12/06/04	2:00 PM	290	24	91.7%	228	11	78.6%	45.8%	95.2%
12/07/04	12:07 PM	217	--	--	119	--	54.8%	--	--
12/08/04	3:04 PM	233	--	--	148	--	63.5%	--	--
12/09/04	11:23 AM	221	--	--	143	--	64.7%	--	--
12/09/04	1:40 PM	250	14	94.4%	141	4	56.4%	28.6%	97.2%
12/10/04	12:15 PM	99	43	56.6%	--	--	--	--	--
12/10/04	1:15 PM	83	34	59.0%	--	--	--	--	--
12/10/04	2:15 PM	100	17	83.0%	--	--	--	--	--
12/10/04	3:15 PM	120	27	77.5%	--	--	--	--	--
12/10/04	4:00 PM	120	16	86.7%	--	--	--	--	--
12/23/04	10:15 AM	200	73	63.5%	129	31	64.5%	42.5%	76.0%
12/23/04	11:11 AM	160	140	12.5%	102	46	63.8%	32.9%	54.9%
01/13/05	11:30 AM	55	35	36.4%	33	13	60.0%	37.1%	60.6%
01/13/05	1:45 PM	68	35	48.5%	41	10	60.3%	28.6%	75.6%

Effect of Loading Rate

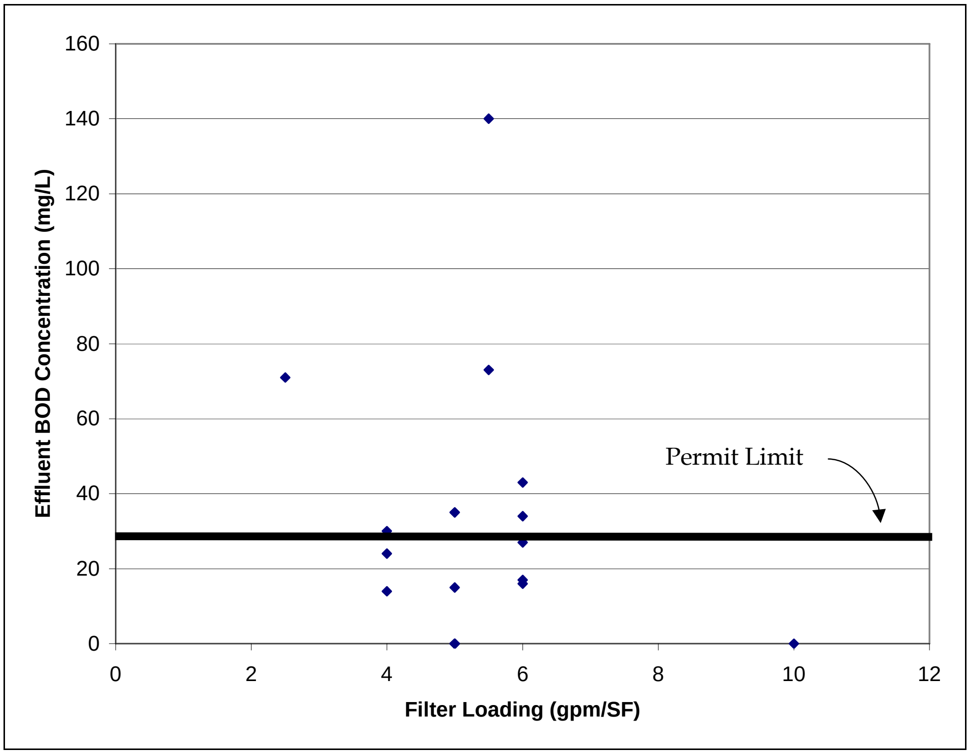
According to the manufacturer (Severn Trent, 2004), CMF units are designed to filter at rates between 4 gpm/SF and 10 gpm/SF. During the study, the effect of filter loading rate on effluent TSS concentration was evaluated over the range of 2.5 gpm/SF to 10 gpm/SF with 15 of the 17 tests conducted between 4 gpm/SF to 6 gpm/SF. Tests were limited to the lower end of the recommended range due to operational difficulties as discussed in Section 5.2. As shown in Figure 5.5, filtration rate had little effect on effluent TSS concentration, and TSS concentrations were generally compliant with both the 7-day and 30-day discharge limitations over the range evaluated. Two excursions were noted, both occurred at a filtration rate of 5.5 gpm/SF. A third effluent sample (December 7, 2004, 09:02) contained 28 mg/L TSS which is approaching the discharge limitation. This test was performed at a filtration rate of 10 mg/L. Since only one test was conducted at this rate, it cannot be determined if the effluent concentration is high because of the higher filtration rate or for another reason.

Figure 5.5. Effect of Filter Loading Rate on Effluent TSS Concentration



The effect of filtration rate on effluent BOD concentration was tested over the range of 2.5 gpm/SF to 6 gpm/SF. As shown in Figure 5.6, filtration rate has little effect on effluent concentration. Of the 14 tests conducted, 7 effluent samples (50%) were compliant with the 30-day discharge limitation. This lower compliance ratio was expected since only the IBOD fraction is effectively removed by filtration.

Figure 5.6. Effect of Filter Loading Rate on Effluent BOD Concentration



SOLIDS LOADING

Solids loading is a measure of the amount of solids that a filter can process between backwashes. It is more representative of operational efficiency than filter run time because it is not dependent on filter surface area. During the pilot study, solids loadings ranged from 0.14 lbs/SF of filter surface area to 0.68 lbs/SF with an average of about 0.39 lbs/SF. This is approximately 40% of the manufacturer-projected solids loading of 1 lb/SF. The lower than expected solids loading is an indication that solids present in the influent are prematurely blinding the media. This could be caused by a media grain size that is too small for the particle size being removed (i.e. larger particles will blind the media interstitial spaces more rapidly), the presence of a media coating such as biogrowth, oil, or grease, or inefficient backwashes. Since this problem was apparent immediately after startup and oil and grease were not observed in the influent, the likely cause is the disparity between media and particle size. This is further supported by the results of the particle size distribution analysis (Section 5.2.2) which showed that between 4% and 20% of the influent particles exceeded the manufacturer recommended maximum influent particle size.

6. PROJECTED FULL-SCALE CMF IMPLEMENTATION

The proposed full-scale CMF would treat excess flow to the Treatment Plant received during wet weather. The Plant would provide full secondary treatment to 4 MGD as it currently does, and any flows above 4.0 MGD would be sent to the CMF system for treatment. The treated flows would then be blended, disinfected, and discharged.

A previous feasibility study performed by CRA for the City regarding proposed CMF was completed in July 2004. CRA worked with STS to develop physical system parameters based on a hydraulic capacity of 10.5 MGD. STS recommended installing three filters, each 9’ 5” x 48’ 0”. These would operate with an average filter loading rate of 4.0 gpm/ft^2 and a maximum flow of 8.0 gpm/ft^2 when one filter is out of service for backwashing.

Based on the performance of CMF during the pilot study, it is unlikely that the filter loading rate could be sustained at 8.0 gpm/ft^2. Adding a fourth filter to the system would keep the maximum loading rate below 5.5 gpm/ft^2 when one filter is out of service for backwashing. This loading rate is likely to produce somewhat longer run times, however during times of extended high flow, it may not be enough. Average filter run times during the pilot study were approximately 90 minutes. With a full backwash lasting 30 minutes, it is possible that one filter will be in backwash at all time. This leaves no room for emergency backwashes should one filter become upset.

STS has found success with treating storm events at the Village Creek Plant with a slightly modified operating procedure. Rather than tie any filter up for a full 30-minute backwash during the peak, “speed wash” was employed. This is a short reverse flow of water with air scour to remove the solids from the top and first foot or two of media. While not cleaning the filter entirely, it will remove a good portion of the solids and extend the filter run. The Village Creek Plant has been able to consistently achieve 4-hour filter run times with this method which has proven to be sufficient to carry it through the heaviest of wet weather events.

Using the experience at Village Creek and the results of this pilot study, STS recommends installing five filters, each 9’ 5” x 48” 0”. It suggests the addition of the fifth filter so that some overlap in speed washes may occur. That is to say that the next speed wash may begin as the previous filter is being rinsed. The maximum flow rate with two filters out of service would remain at 5.5 gpm/ft^2, however using the speed wash method during times of high flow should eliminate the risk previously discussed.

The most likely layout for implementing a full-scale CMF on Gulvin Park Pump Station property is shown in Appendix F. Each of the five proposed filter units would consist of a concrete basin with common walls between them, necessary filter piping and valving, and system controls. The filter units would be housed in a 75 by 80-foot pre-engineered steel building with a 25 by 40-foot annex for the backwash pumps, air blowers, and controls. The concrete mudwell would be located adjacent to the filter building. The existing chlorine contact chamber would serve as clearwell.

Any flow above the capacity of the biological treatment at the Marsh Creek plant would be diverted to the filters at the exit of the Gulvin Park Pump Station. Flow metering and valving would be installed in the existing 24-inch discharge line as well as on the new filter influent line. Flow would enter the new filter building and be split among the five filters. Effluent from the CMF system would travel by gravity through new pipe to the existing chlorine contact chamber for disinfection prior to blending with the Marsh Creek effluent, dechlorination and discharge. Spent backwash water would be collected in the mudwell and slowly fed back to the head of the plant by gravity through new piping, into the pump station wet well.

BLENDED EFFLUENT QUALITY

An analysis of the projected TSS and BOD concentrations in the blended effluent was performed to ensure that they would meet permit requirements. This was done by performing a series of mass balances on the flow from full treatment and the potential flow through CMF, using the following equation:

$$\text{Blended Concentration} = \frac{(\text{Plant Flow})(\text{Plant Effluent Concentration}) + (\text{CMF Flow})(\text{CMF Effluent Concentration})}{\text{Blended Flow}}$$

The mass balances were performed using flows increasing in increments of 1 MGD. The first 4 MGD were attributed to the treatment plant flow, and anything above that was attributed to CMF flow. For all scenarios examined, the average plant effluents were used, 13 mg/L of TSS and 15 mg/L of BOD. Two different scenarios for both TSS and BOD, the CMF effluent, were examined. Average and maximum effluent concentrations seen during the pilot study were used, 19 mg/L and 61 mg/L of TSS and 41 mg/L and 140 mg/L of BOD.

As previously stated, the City must meet a 30-day average discharge level of 30 mg/L for both TSS and BOD and a 7-day average discharge level of 45 mg/L for both TSS and BOD. The results of this projection can be seen in Figures 6.1 and 6.2.

Figure 6.1. Projected TSS Concentration in Blended Effluent

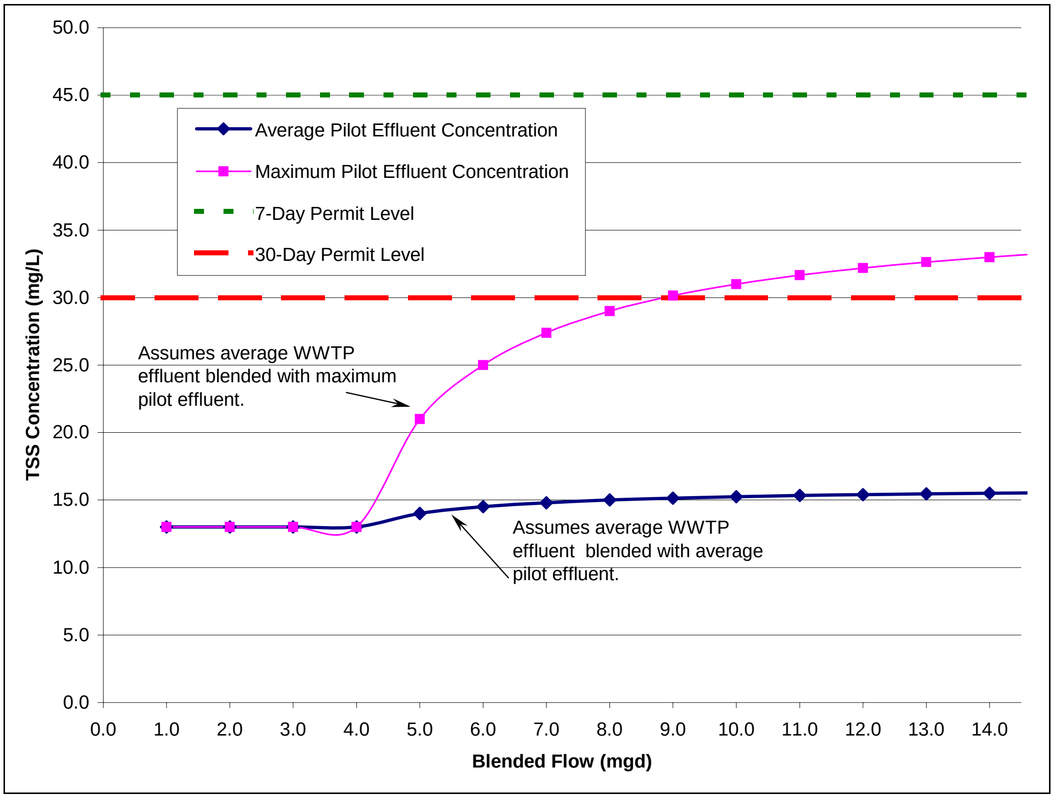
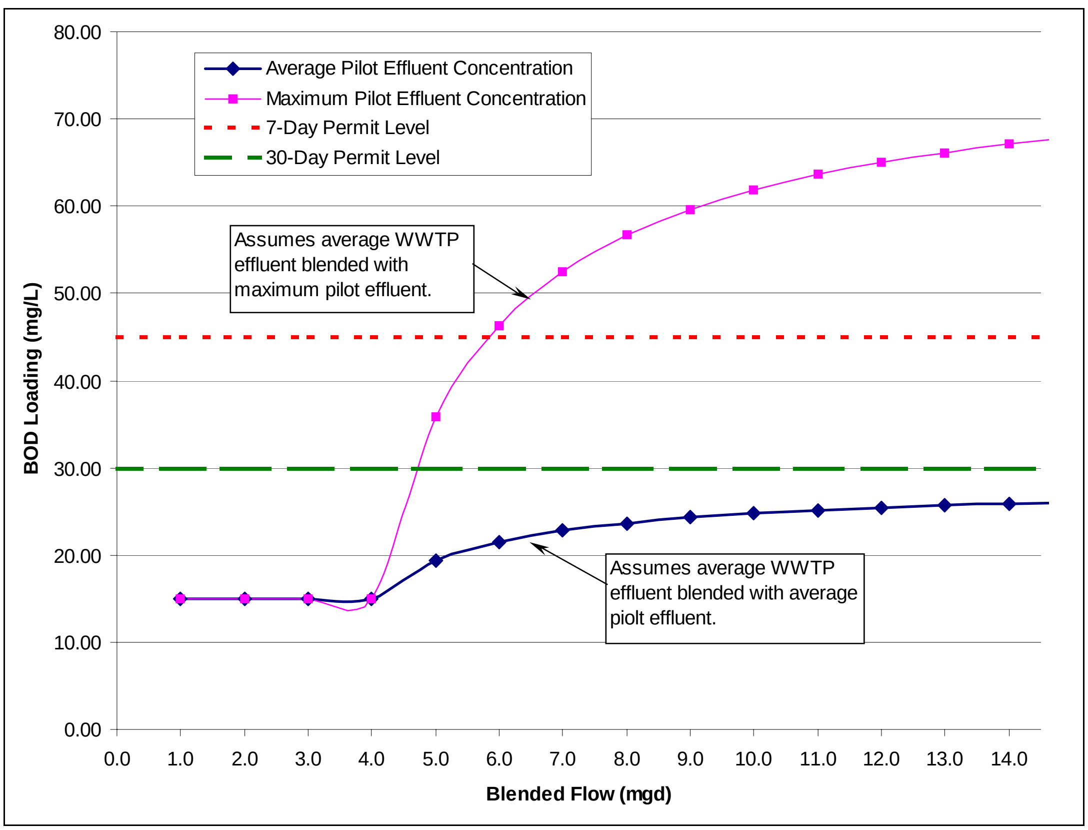


Figure 6.2. Projected BOD Concentration in Blended Effluent



From Figure 6.1, it can be seen that the TSS concentrations in the projected blended effluent would generally meet permit levels. In all cases, the TSS concentrations would comply with the 7-day requirement of 45 mg/L. In the worst case scenario (maximum TSS out of the filter at peak flow), the projected blended effluent would exceed the 30-day permit level, however the 30-day average is based on a composite of multiple results and the likelihood of the average being compliant is high.

The projected BOD levels in the blended effluent should meet the permit requirements for the majority of the time. With the average pilot effluent BOD levels, the blended effluent would comply with the permit requirements at all times. In the worst case scenario of the maximum BOD concentration in the CMF effluent, the blended effluent does have the potential to exceed the permit levels. Again, the 30-day average is based on multiple samples, and it is likely that the average would be compliant. It is possible, though that the blended effluent would exceed the 7-day average requirement of 45 mg/L. During times of high flow, however, the influent BOD concentration is generally lower. In addition, the effluent sample with the highest BOD concentration used for this analysis had a relatively low percentage of IBOD. Since the filter can not effectively remove soluble BOD, the overall BOD removal was often low. This is a worst case scenario and would occur infrequently.

FULL SCALE OPERATION AND MAINTENANCE

The only component of the CMF system that routinely requires significant energy and maintenance is the backwash system. Since the speed wash method requires trial and error to optimize and the pilot test was not conducted with one, the following energy evaluation is performed based on typical backwashes only.

The system uses a 30 HP backwash pump and a 100 HP backwash blower. A typical backwash consists of a 30-second air scour, 15 minutes of air and water, and finally 5 minutes of water alone. This requires approximately 26.75 kWh per backwash. With the backwash water rate at 6 gpm per ft^2, the volume of spent backwash water that needs to be sent back to the head of the plant is 55,000 gallons per backwash.

From the 2004 Feasibility Study, it is estimated that Geneva will experience 48 days per year when the Plant flow is in excess of 4 MGD. Four of these days are considered high flow days with 10.5 MGD to the CMF system. The remainder are average flow days with 1.5 MGD going to the CMF system.

Based on the filter loading rates, influent TSS concentrations, and corresponding filter run times encountered during the pilot study, it has been calculated that the filter can handle approximately 0.4 lbs of TSS/ft^2 before a backwash is needed. Using the average influent TSS concentration seen during the pilot study of 94 mg/L, the filter run times under various scenarios can be calculated and are presented below in Table 6.1.

Table 6.1. Estimated Backwash Parameters

Scenario	Flow to CMF System (MGD)	Filter Run Time (hr)	System Backwashes per Day	Energy Required per Day (kWh)	Water Required for Backwashes per Day (MG)	Spent Backwash Water as a % of Total Plant Flow
Average Wet Weather	1.5	14.9	2	53.5	0.11	2%
Peak Wet Weather	10.5	2.1	57	1525	3.1	21.4%

Under the peak-flow conditions, the ratio of spent backwash water to total plant flow is excessive. Recommended Standards for Wastewater Facilities, 2004, requires that the spent backwash water is returned to the head of the plant at a rate of 15% of the design flow rate (Chapter 110, Paragraph 112.43). Since the design rate of the treatment plant is 4.0 MGD, only 0.6 MGD of spent backwash water can be returned. The remainder should be stored until the wet weather subsides. Historical records show that the peak-flow will last at most 1.5 days. Therefore, to meet these standards, a mudwell storage capacity of at least 3.75 MG would be required.

CAPITAL CONSTRUCTION COST ESTIMATE FOR IMPLEMENTING A FULL-SCALE CMF SYSTEM AT GENEVA

The capital cost of designing and constructing the proposed full-scale CMF is based on the cost estimate done for the feasibility study. The building has been resized to accommodate five filters. The cost estimate for the filtration equipment has been scaled up from three to five filters. From this, the project has been estimated at $5,000,000. A breakdown of these costs is contained in Appendix G.

7. COMPARISON OF CMF WITH ALTERNATIVE TREATMENT TECHNOLOGIES

CMF was compared with ACTIFLO, a type of high rate sedimentation, which reportedly achieves an effluent quality within the range established for CMF in this study. CMF was not compared with the other alternative treatment technologies listed on Table 3.1, because these technologies either do not achieve effluent qualities that are within the ranges established, or they require significant process additions and modifications.

ACTIFLO is a three stage process using physiochemical means to remove suspended solids. The first stage is a coagulation stage where a chemical coagulant is added to the wastewater in the coagulation tank. This is followed by the flocculation stage. Microsand is added in the injection tank and forms flocs with the suspended solids through induced collisions. The floc passes to the maturation tank to thicken and mature. Both tanks are equipped with dynamic mixers. Finally, the floc enters the decantation stage with a counter current lamella settler. The treated water is drawn off at the top of the lamella while the sludge and microsand are precipitated at the bottom of the tank. These are collected by a scraper and pumped to the hydrocyclones to separate the sludge from the microsand. The microsand is recirculated to the flocculation stage.

Krüger, the manufacturer of ACTIFLO, provided information regarding the design of high rate sedimentation at Geneva. Krüger has proposed one train, 34.5 feet by 12.1 feet to treat 6 MGD. Total power requirements for operating the equipment have been estimated at 37.75 HP. The estimated capital cost for the ACTIFLO equipment as provided by Krüger is $770,000. Estimated daily operating costs, including chemical and energy costs, are approximately $790.

The proposed CMF system was based on a design flow of 10.5 MGD. The ACTIFLO quote provides for only 6 MGD based on the assumption other potential upgrades at the Plant will take place and reduce the required capacity. In order to accurately compare the two systems, the ACTIFLO information provided by Krüger has been scaled up to accommodate the full 10.5 MGD. Pumps, piping, etc. would also be needed and have been added to the estimate. The capital cost for this system has been estimated at $3,300,000 (see Appendix G).

Energy and chemical costs have also been scaled to accommodate the average and peak wet weather events. These costs, as well as a comparison between the CMF and the ACTIFLO systems are presented below in Tables 7.1, 7.2 and 7.3.

Table 7.1. Comparison of CMF and ACTIFLO Operating Costs for an Average[1] Wet Weather Day

	CMF	ACTIFLO
Daily Energy Required (kWh)	53.5	169
Daily Energy Cost[2]	$4	$13
Additional Daily O&M Costs	N/A	$186
Total Daily Operating Costs	**$4**	**$199**

[1]Average wet weather day = 1.5 MGD excess flow to be treated by CMF or ACTIFLO
[2]Based on $0.075/kWh

Table 7.2. Comparison of CMF and ACTIFLO Operating Costs for a Peak[1] Wet Weather Day

	CMF	ACTIFLO
Daily Energy Required (kWh)	1525	1182
Daily Energy Cost[2]	$115	$90
Additional Daily O&M Costs	N/A	$1,300
Total Daily Operating Costs	**$115**	**$1,390**

[1]Peak Wet Weather Day = 10.5 MGD excess flow to be treated by CMF or ACTIFLO
[2]Based on $0.075/kWh

Table 7.3. Comparison of CMF and ACTIFLO Total Costs

	CMF	ACTIFLO
Capital Cost	$5,000,000	$3,300,000
Annual Operating Cost	$636	$14,316
Net Present Worth*	**$5,012,500**	**$3,580,600**

***** Based on 30 years and 3% inflation. Does not include labor or routine maintenance, as those costs are expected to be similar for both systems.

ENVIRONMENTAL COMPARISON

As previously stated, ACTIFLO is reported to be capable of achieving similar effluent characteristics as CMF. Previous pilot studies by Krüger, have shown TSS removals to be around 80 to 95% and BOD removals to be around 40 to 80%. During the pilot study, CMF had an average TSS removal of 79% and an average BOD removal of 62%.

Both technologies also have the ability to be used either as a wet weather bypass or as a final polishing step for normal treatment plant flow. Other wet weather technologies, such as an ORF are used for wet weather flows only. While Geneva is more than able to meet its permit limits under normal dry weather flow, this could be a desirable option of other treatment plants facing similar situations.

8. CONCLUSIONS

Based on the above evaluation, the following conclusions have been made:

Validity of Data

- Pilot influent water quality conforms to generally accepted trends and is considered representative of actual water quality conditions at the Gulvin Park Pump Station.

Operational Challenges

- Due to the high insoluble fraction of BOD in the influent, CMF may be an appropriate technology for Geneva. However, because the influent contains up to 20% particles that exceed manufacturer's recommendations, some additional equipment will be needed or operational challenges may be encountered.
- Pilot study filter run times were shorter than the manufacturer projected run time of one lb TSS/SF. The shorter run times are likely caused by the larger particle sizes in the influent.

Effluent Water Quality

- CMF generally achieves TSS discharge limitations.
  - 94% of the tests were compliant with the seven-day discharge limitation.
  - 83% of the tests were compliant with the 30-day discharge limitation.
  - 39% of the tests were compliant with minimum removal requirement.
- CMF has limited affect on Gulvin Park Pump Station BOD.
  - 79% of the tests were compliant with the seven-day discharge limitation.
  - 50% of the tests were compliant with the 30-day discharge limitation.
  - 21% of the tests were compliant with the minimum removal requirements.
- To consistently remain compliant with the discharge permit, CMF effluent must be blended with treatment plant effluent.
- Effluent TSS concentration generally increases as influent TSS concentration increases.
- There is no correlation between influent and effluent BOD concentrations.
- CMF removes up to 97% of the IBOD with an average value of 65%.
- CMF is equally effective across the entire range of influent TSS and BOD concentrations evaluated.

- Treatment plant flow rate has little effect on effluent TSS of BOD concentrations and TSS and BOD removals.
- Effluent water quality is independent of filter loading rate in the range of 4 to 6 gpm/SF. The effect of filter loading rate in excess of 6 gpm/SF could not be determined because of limited data.

9. RECOMMENDATIONS

It is clear from the results of this pilot study that CMF is an effective, energy-efficient method for treating raw wastewater during wet weather events. The pilot unit was able to achieve an average TSS removal of 79% and an average BOD removal of 62%. Estimated energy costs range from $4 to $115 per day for average to maximum wet weather flows, respectively. However, the operational challenges faced during the study show that CMF may not be a practical method for wet weather treatment without additional equipment.

Since the most likely cause of the operational challenges was the large particle size, it is possible that CMF may work well for wet weather treatment when particles 150 microns or greater are first removed. Potential technologies for doing this include rotary screens or coarse dual media filters.

In the absence of a separate technology for removing large particles, CMF is not the best option for wet weather treatment at the City of Geneva. ACTIFLO is able to achieve a comparable effluent quality for a lower life cycle cost and will likely be able to handle the large particle size more efficiently.

Appendix A

CMF Pilot Test Layout
and Process Flow Diagram

Appendix B

Treatment Plant Flow Data

Appendix C

Precipitation Data

Appendix D

Pilot Test Data

Appendix E

Particle Size Data

Appendix F

Proposed Full Scale
Coarse Monomedia Filtration Layout

Appendix G

Full Scale Coarse Monomedia Filtration
Capital Cost Estimate

Appendix H

ACTIFLO Capital Cost Estimate