City of St. Joseph, Missouri

Facilities Plan

Technical Memorandum No. TM-CSO-10

Wet Weather Treatment Facilities

By

BLACK & VEATCH
Building a world of difference.

Work Order No. 09-001
B&V Project 163509

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1.0 Executive Summary

The purpose of this assessment is to evaluate alternative high rate treatment technologies in treating wet weather flow in excess of the 27 mgd primary treatment capacity provided at the City of St. Joseph (City) Water Protection Facility (WPF). This additional treatment is needed to achieve the combined sewer overflow (CSO) Long Term Control Plan (LTCP) Phase IA objective, which is to attain an annual wet weather percent capture of 60 percent and treat the captured flow of 88 mgd. An additional 61 mgd of high rate treatment (HRT) capacity is required to treat this captured flow. A flow schematic representing this scenario is illustrated in Figure ES-1.

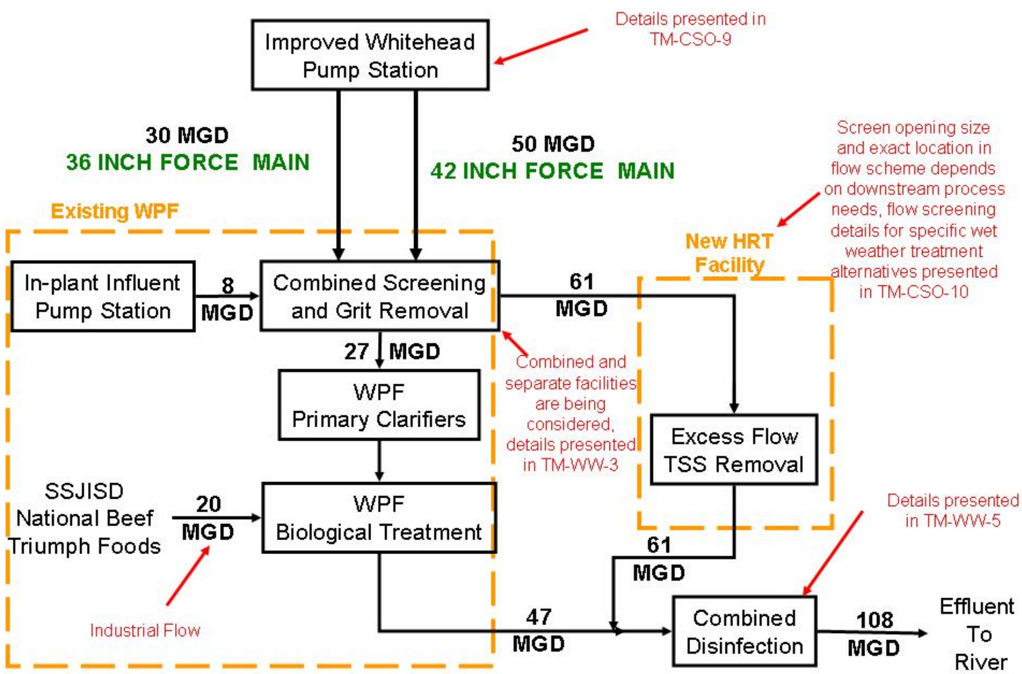

Figure ES-1 – Wet Weather Treatment Flow Schematic for Phase IA

Treatability tests were conducted to determine which HRT technologies were most applicable to the City's wet weather flow. The HRT technologies studied included: compressible media filtration (CMF), which is a specific type of high rate filtration

(HRF); chemically enhanced primary treatment (CEPT); and high rate clarification (HRC).

A workshop was conducted with City staff on April 29, 2009 to confirm the wet weather flow values to use for this evaluation; review wet weather treatment strategies, regulations, technologies, and treatability test results; and identify which technologies merited further consideration. Based on that workshop and subsequent discussions with City staff, the following HRT alternatives were selected:

- Alternative 1 –HRC Technologies
  - Alternative 1A – Ballasted Flocculation HRC
  - Alternative 1B – Sludge Recirculation HRC
- Alternative 2 – HRF based on CMF Technologies

The CEPT option was screened out because it performed poorly for ultraviolet (UV) disinfection.

Evaluation of these HRT technologies included developing capital, operations and maintenance (O&M), and net present worth costs and non-economic factors. Table ES-1 presents the capital costs and Table ES-2 presents the net present worth costs for the HRT alternatives evaluated and discussed in detail herein for the City.

Table ES-1
Summary of Opinion of Probable Project Costs [1]

Item	Alternative 1A Actiflo HRC, $	Alternative 1B DensaDeg HRC, $	Alternative 2 WWETCO CMF, $
Wet Weather Treatment Facility			
Structure, Valves, and Piping	3,521,000	4,078,000	5,864,000
Equipment	4,480,000	5,180,000	5,495,000
Chemical Storage/Blower Building			
Structure, Valves, and Piping	1,616,000	1,616,000	2,124,000
Equipment	203,000	203,000	1,092,000
Screening Building [2]			
Structure, Valves, and Piping	548,000	Base screening costs are presented in TM-CSO-12	Base screening costs are presented in TM-CSO-12
Equipment	1,353,000	Base screening costs are presented in TM-CSO-12	Base screening costs are presented in TM-CSO-12
Miscellaneous Yard Structures and Piping	1,310,000	1,310,000	1,310,000
Flood Protection/Fill (placeholder) [3]	202,000	263,000	332,000
Site Remediation (placeholder) [3]	1,211,000	1,577,000	1,993,000
Subtotal	*14,444,000*	*14,227,000*	*18,210,000*
Electrical, I&C, Sitework, Contractor General Requirements [4]	7,037,000	6,689,000	8,578,000
Subtotal	*21,481,000*	*20,916,000*	*26,788,000*
Contingency [5]	5,370,000	5,229,000	6,697,000
Land Acquisition (placeholder) [3, 6]	58,000	76,000	95,000
Opinion of Probable Construction Cost	**26,910,000**	**26,221,000**	**33,580,000**
Engineering, Legal, and Administration [7]	5,382,000	5,244,000	6,716,000
Opinion of Total Project Cost	**32,292,000**	**31,465,000**	**40,296,000**

Table ES-1
Summary of Opinion of Probable Project Costs [1]

Item	Alternative 1A Actiflo HRC, $	Alternative 1B DensaDeg HRC, $	Alternative 2 WWETCO CMF, $

1. All costs presented in May 2009 dollars (ENR BCI = 4773).
2. An Actiflo facility will require an additional fine screening facility not required by the other alternatives. The additional screening costs for Actiflo are presented herein. The base screening costs for the remaining wet weather alternatives are presented in TM-CSO-12/TM-WW-3 – Screening and Grit Removal Facilities.
3. Site related costs are placeholders and must be revised following final siting of the facilities. Site related costs are provided for the site area required for the HRT facilities.
4. Electrical and instrumentation and controls (I&C) projected at 25% of the total of all equipment and structure costs. The electrical and I&C cost does not include any new or back-up power feeds; these facilities will be evaluated in TM-WW-9 – Site Considerations, Utility Improvements, and Ancillary Facilities. Sitework projected at 10% of the total of equipment, structures, electrical, and I&C costs. Contractor general requirements projected at 12% of the total of equipment, structures, electrical, I&C, and sitework costs.
5. Project contingency is projected at 25% of the total of all equipment, structures, electrical, I&C, sitework, contractor general requirements, flood protection/fill, and site remediation costs.
6. Land acquisition cost is based on a projection provided by the City from a recent purchase of land directly south of the WPF.
7. Engineering, legal, and administration (ELA) costs are projected at 20% of the total of all equipment, structures, electrical, I&C, sitework, contractor general requirements, flood protection/fill, site remediation costs, contingency, and land acquisition.

Table ES-2
20-Year Net Present Worth Costs by Alternative [1]

	Alternative 1A Actiflo HRC, $	Alternative 1B DensaDeg HRC, $	Alternative 2 WWETCO CMF, $
Net Project Capital Present Worth [2]	26,145,000	25,311,000	32,130,000
O&M Present Worth [3]	6,454,000	6,246,000	479,000
Total Net Present Worth	**32,599,000**	**31,557,000**	**32,609,000**

1. Costs are in May 2009 dollars. Present worth calculated with 20-year life cycle costs at 5% interest.
2. Net project capital present worth represents the present worth of project costs less the remaining value of facilities at the end of the 20-year life cycle. Service life for determination of replacement frequency and salvage value was projected as follows: structures – 50 years; equipment, electrical, instrumentation and controls – 20 years.
3. O&M costs were assumed to escalate at 5% per year.

Capital costs for the two HRC options were found to be less expensive than the CMF technologies. However, the O&M costs for the CMF technologies are significantly less expensive than the HRC technologies due in large part to the high chemical use associated with HRC treatment. The net present worth value of the HRC and CMF technologies over a 20-year life cycle are within 5 percent of each other, which for planning level costs are essentially equal. Non-economic factors were also considered. While there are several non-economic considerations that differentiate the HRT alternatives, two of the more notable non-economic factors are process operation and process flexibility.

Wet weather events are inherently unpredictable from a storm frequency and intensity basis and will cause a wide variation in process operation requirements. In addition to normal tasks, plant operators may be faced with many unplanned tasks during a wet weather event (power losses, flooding, etc.). Therefore, having a wet weather treatment process that requires minimal operator interaction, especially at start-up, can be particularly advantageous. Starting up an HRC process requires that the operator visually observe the flocculation process and make any adjustments to the coagulant or polymer feed rates or other process adjustments such as flocculation mixer speed required to achieve effective treatment. Throughout operation of the Actiflo HRC process, the operator must take samples at the hydrocyclones to monitor the sand inventory and periodically add sand to the system. The DensaDeg HRC process may require the operator to monitor sludge thicknesses during the treatment event to optimize the process. On the other hand, filtration processes such as the CMF process are typically monitored and controlled by level instrumentation, requiring very little operator interaction. In summary, since the CMF technology is a physical process rather than a chemical process, it will require less hands-on control during unpredictable wet weather events.

Process flexibility refers to the ability to make adjustments to the process to handle different influent characteristics. Operations at other existing facilities have demonstrated that both the HRC and CMF processes can handle significant variations in influent flows and concentrations and still produce consistent effluent quality. Chemical types, doses, and flocculation mixing intensity can generally be adjusted somewhat to optimize the HRC process. CMF processes accommodate changes in influent solids loading by automatically adjusting filter backwash frequency based on the level of influent above the filter media.

Another process flexibility feature unique to wet weather HRT applications is the ability to use wet weather facilities to perform other functions when not being used for wet weather treatment. For example, the HRC processes could be designed to provide additional primary treatment redundancy or be designed to provide tertiary phosphorus removal during normal dry weather conditions. However, HRC use during dry weather would require chemical dosing that could have significant cost implications. The CMF process could be designed to provide tertiary filtration during dry weather as well. The CMF technology appears to be the only financially viable alternative that could perform dual use tertiary treatment.

In review of the economic and non-economic evaluation and current LTCP implementation schedule, a number of conclusions and recommendations can be made. Based on the current proposed implementation schedule of the LTCP, construction of the HRT facilities will not take place for approximately 15 years. Therefore, it is not imperative that a decision be made at this time. Alternative 1A, 1B, and Alternative 2 appear to be viable options for the new HRT facilities. Alternative 2 appears to have higher capital costs, but lower O&M costs and more non-economic benefits. It also appears that Alternative 2 may have the potential to more significantly lower its capital costs over time as the designs for the emerging CMF technologies are further refined and optimized.

Recommendations and conclusions of the HRT evaluation include the following points:

- Defer selecting the specific HRT technology until the actual time when wet weather treatment facilities must be implemented.
- Conduct long-term pilot testing of the CMF technology over multiple wet weather events to confirm process design criteria. During the pilot study, influent samples of wet weather event flows should also be sent to HRC manufacturers to conduct additional jar tests to further evaluate coagulants and polymers and help confirm the process design criteria for the HRC technologies.
- Different HRT alternatives require different equipment and different facility designs; therefore, the equipment should be pre-selected prior to detailed design of the facilities. During a pre-design phase (closer to the construction date), the information presented herein should be updated to select the HRT equipment. The designs for each alternative could be re-evaluated, taking advantage of any developments that may have taken place with each technology. At that time, vendor quotes could be requested again for each technology to update the life cycle costs and to select the HRT equipment prior to detailed design.

2.0 Purpose of Study

The purpose of this technical memorandum (TM) is to:

- Summarize the wet weather treatment objectives for the City of St. Joseph, Missouri.
- Discuss the wet weather bench-scale treatability testing performed during the summer of 2009.
- Identify high rate treatment alternatives for use in meeting the City's combined sewer overflow Long Term Control Plan objectives.
- Evaluate high rate treatment alternatives based on economic and non-economic factors.
- Present a recommended approach for implementing HRT facilities.

3.0 Background and Related Studies

Phase IA of the City's CSO LTCP is the initial phase of the City's intent to meet water quality control standards in accordance with the United States Environmental Protection Agency (USEPA) CSO Control Policy. The City has been working with USEPA and the Missouri Department of Natural Resources (MDNR) to finalize an implementation schedule for the City's LTCP which includes Phase IA as the initial program. A more detailed discussion regarding how the Phase IA improvements will help to achieve the overall CSO control program is included in TM-CSO-3a – Phase IA CSO Control Recommended Improvements Model. Screening and grit removal alternatives for the WPF and proposed HRT facilities are further evaluated in TM-CSO-12/TM-WW-3 – Screening and Grit Removal Facilities. Disinfection alternatives for the WPF and proposed HRT facilities are further evaluated in TM-CSO-11/TM-WW-5 – Disinfection Facilities.

One of the objectives of Phase IA of the City's CSO LTCP is to achieve an annual wet weather percent capture of approximately 60 percent which is projected to be 88 mgd. The existing WPF is rated to treat a maximum flow of 27 mgd through primary treatment; thus an additional 61 mgd of wet weather HRT capacity is needed to treat 88 mgd. A flow schematic representing this scenario is illustrated by Figure 1.

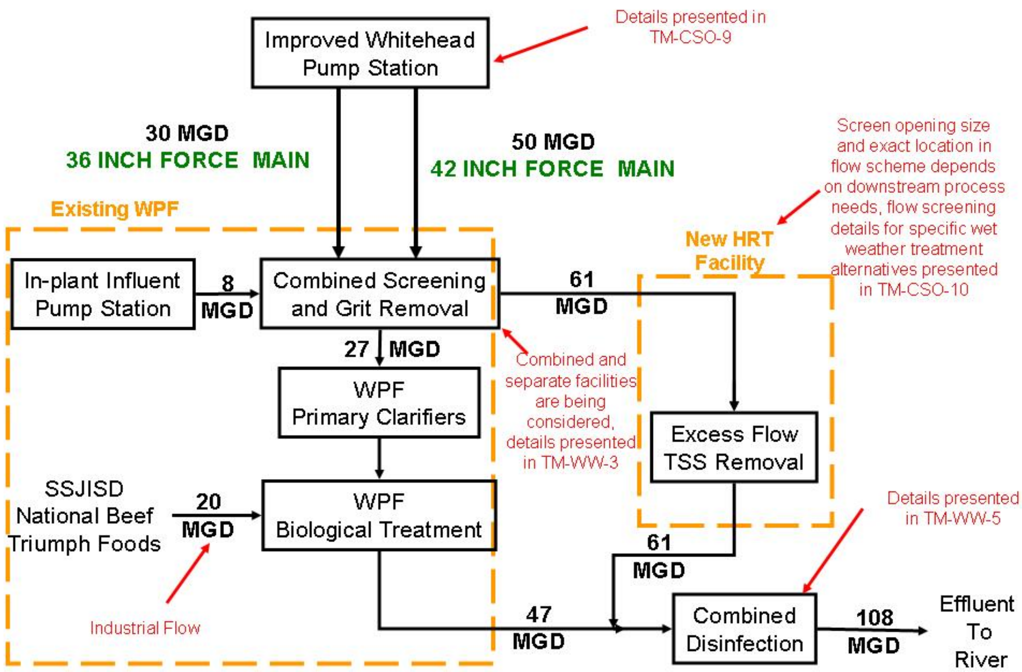

Figure 1 – Wet Weather Treatment Flow Schematic for Phase IA

4.0 Wet Weather Treatment Regulatory Considerations

To evaluate the relative performance of alternative technologies, it is important to determine what level of effluent quality must be achieved. Effluent limitations and performance standards for publicly owned treatment works (POTWs) during wet weather conditions are not completely quantified by the current suite of Clean Water Act (CWA) regulations. For combined sewers, the national CSO Control Policy (USEPA, 1994) provides some guidance with regards to wet weather treatment requirements. For separate sanitary sewers, various national policies have been proposed by the USEPA over the last several years, but none have been finalized thus far. Wet weather treatment requirements are currently a topic of considerable debate amongst all POTW stakeholders.

USEPA's CSO Control Policy states that a CSO community is presumed to meet water quality standards if one of the following conditions is met:

- The number of CSOs events per year is limited to an agreed upon frequency (typically four to six events per year).

- 85 percent of the wet weather combined sewage volume is captured and treated.
- 85 percent of the pollutant mass is reduced or eliminated from entering the receiving stream.

In addition, USEPA policy states that the nine minimum controls should be implemented. These controls are discussed in detail in the USEPA CSO guidance. One of the nine minimum controls in USEPA's CSO Control Policy is to optimize the peak flow capacity of existing treatment facilities. This scenario is depicted by Figure 2. In this strategy, flows exceeding the peak capacity of existing treatment facilities (designated as Q_{XS} on the figure or "Excess Flows") would be treated by auxiliary wet weather excess flow treatment facilities to help achieve the aforementioned CSO criteria. The Phase IA projects are initial steps in the City's adaptive management approach to improving water quality in the Missouri River and achieving the CSO LTCP goals and objectives.

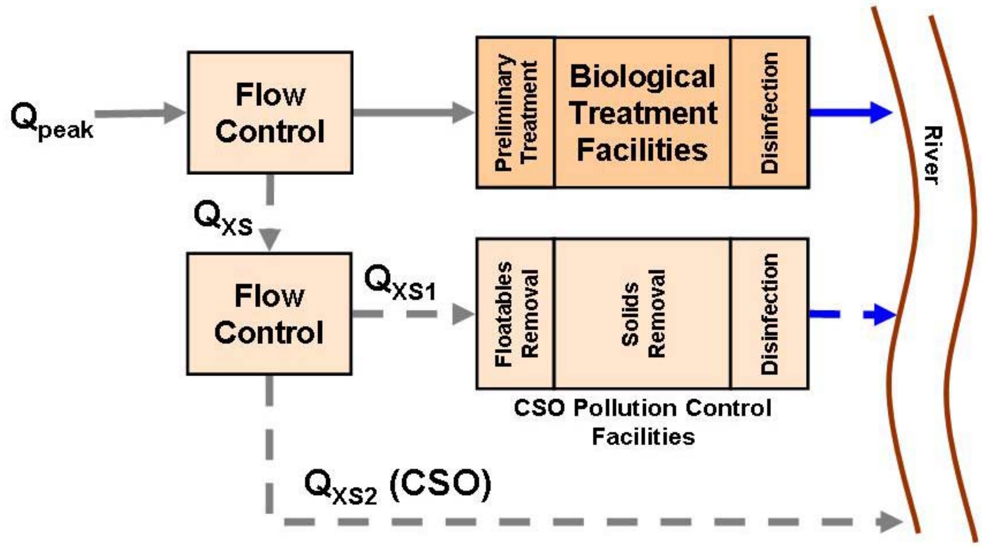

Figure 2 – Wet Weather Treatment Strategy Presumed by CSO Control Policy

Black & Veatch staff recently met with staff from USEPA's Office of Water to discuss potential regulatory issues with this wet weather treatment strategy. Black &

Veatch staff presented various design alternatives that are being considered in the LTCPs for various communities across the nation, including the City of St. Joseph. In many of these cases, integrating various process units of the CSO control facilities with existing treatment facilities leads to a superior design alternative with respect to event responsiveness, operability, maintainability, and system redundancy, any one of which may result in superior water quality protection. Furthermore, integration of certain facilities may also be more cost effective than a stand-alone design. An integrated wet weather treatment concept being considered for use by the City is presented in Figure 3.

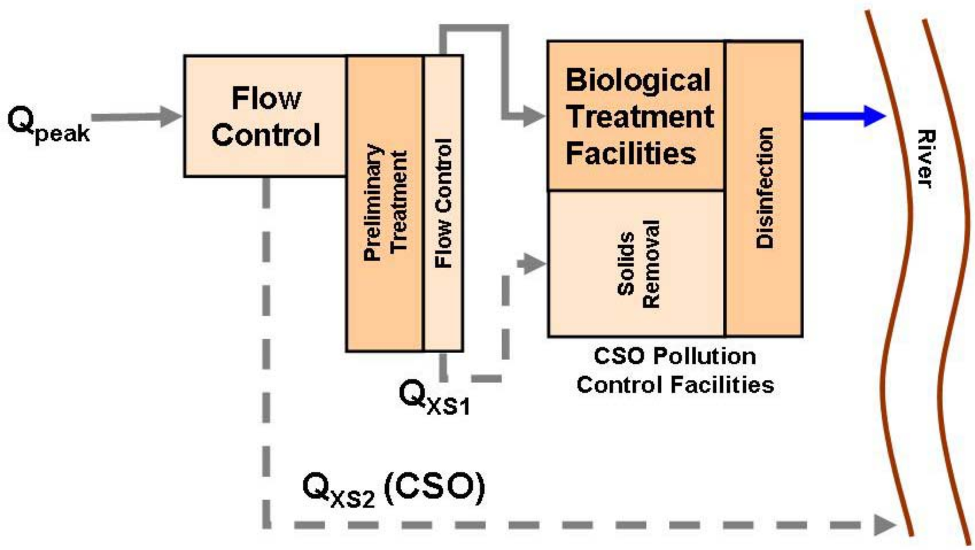

Figure 3 – Wet Weather Treatment Strategy with Integrated Facility Design

5.0 Wet Weather Influent Characteristics

Plant operating data from April 1, 2006 through November 30, 2008 were evaluated to predict influent characteristics that would likely occur during future wet weather events. These data are summarized on Figure 4 through Figure 6. Evaluations of these data are summarized on Figure 7 through Figure 10. Observations from these evaluations include the following:

- Figure 8 indicates that as flows increased, the influent total suspended solids (TSS) concentrations became much more variable. Figure 9 indicates that as flows increased, the biochemical oxygen demand (BOD_5) concentrations generally decreased. These trends are consistent with typical wet weather first-flush dynamics observed at other facilities serving combined sewers.

- As increased amounts of combined wet weather flows are collected and treated, the raw influent TSS loading pictured on Figure 8 is expected to level off in a fashion similar to the raw influent BOD_5 loading shown on Figure 9. Some of the differences observed between these correlations can be explained by the fact that BOD_5 measures both soluble and particulate constituents, while TSS only measures particulate constituents.
- Based on experience at other facilities, it is anticipated that as the WPF and high rate treatment facilities increase their amount of CSO capture, it will continue to receive these first-flush loads, but will receive greater amounts of influent with increasingly lower pollutant concentrations.
- As suggested by Figure 10, it is anticipated that the wet weather influent flows will have a relatively low fraction of soluble pollutants in general. Therefore, solids and pathogens are expected to be the primary pollutants of concern, which is consistent with observations from similar wet weather treatment studies at other facilities and consistent with the treatment requirements presumed by USEPA's CSO Control Policy.
- In summary, suspended solids removal and disinfection of wet weather flows should be the focus of wet weather treatment in St. Joseph.

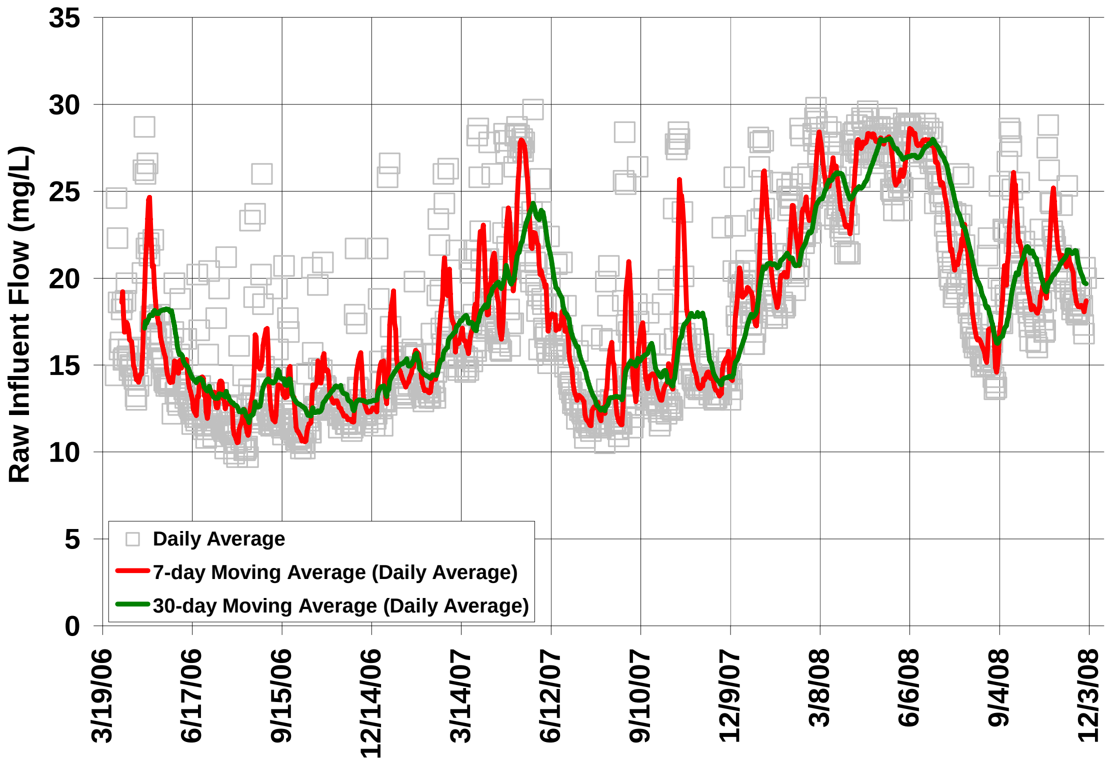

Figure 4 – Raw Influent Flow Data

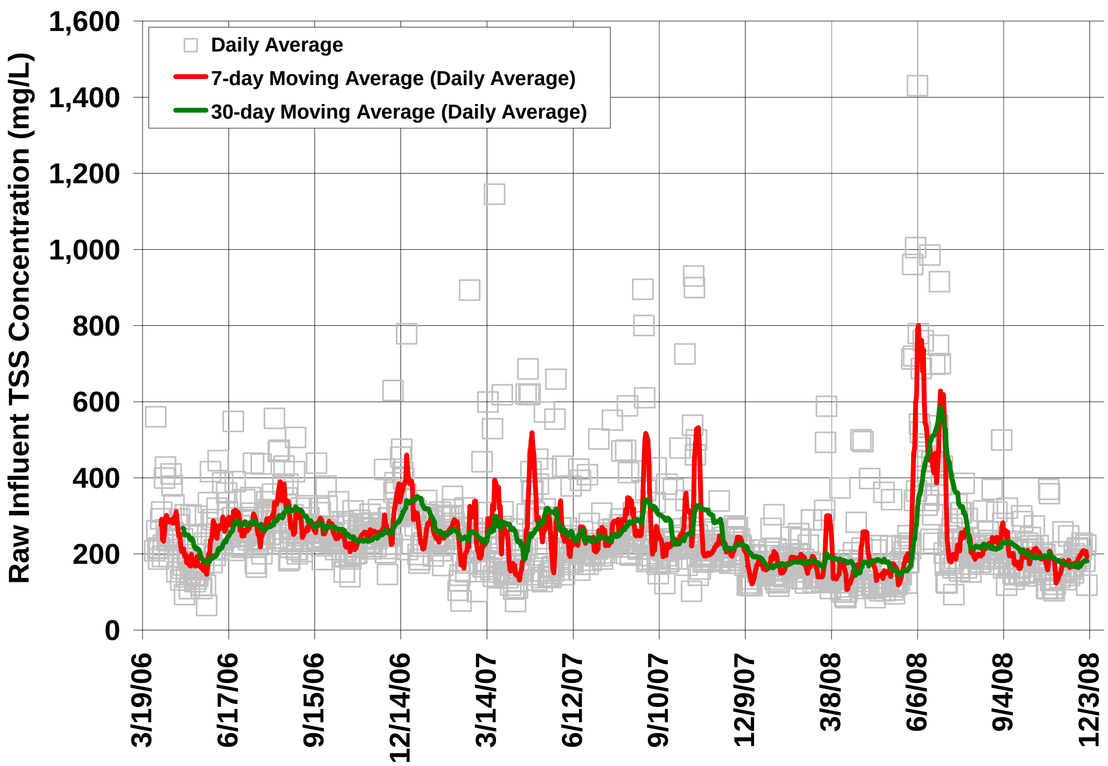

Figure 5 – Raw Influent TSS Data

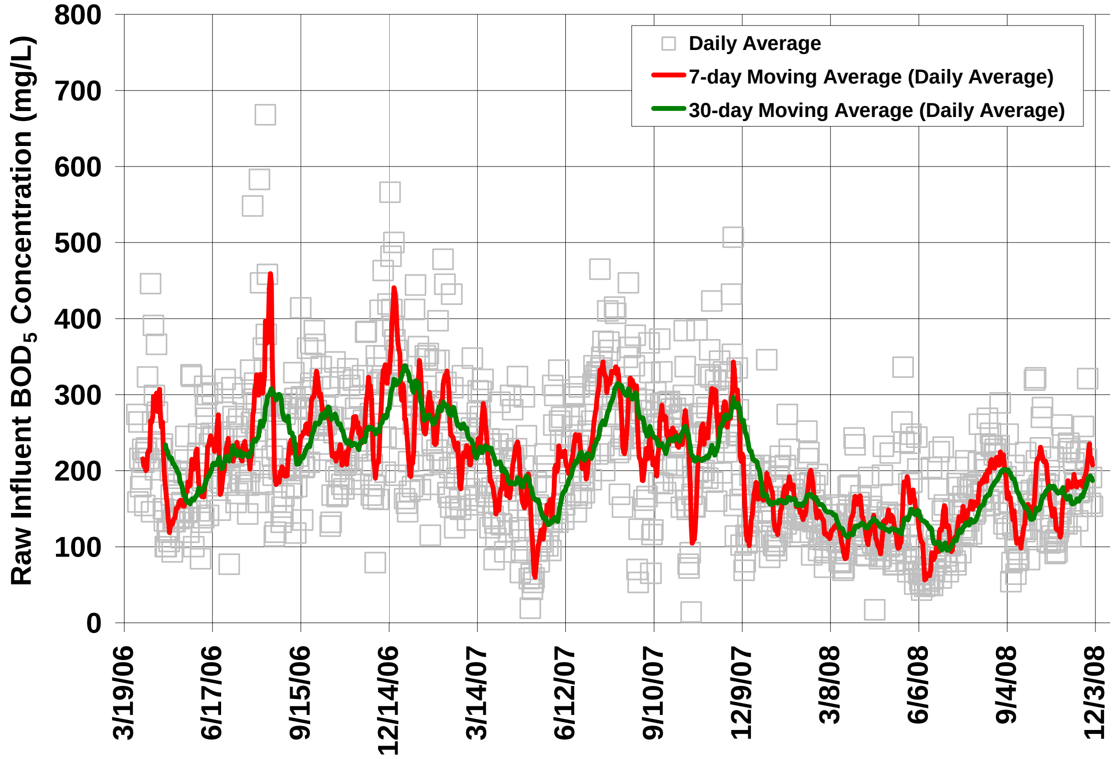

Figure 6 – Raw Influent BOD_5 Data

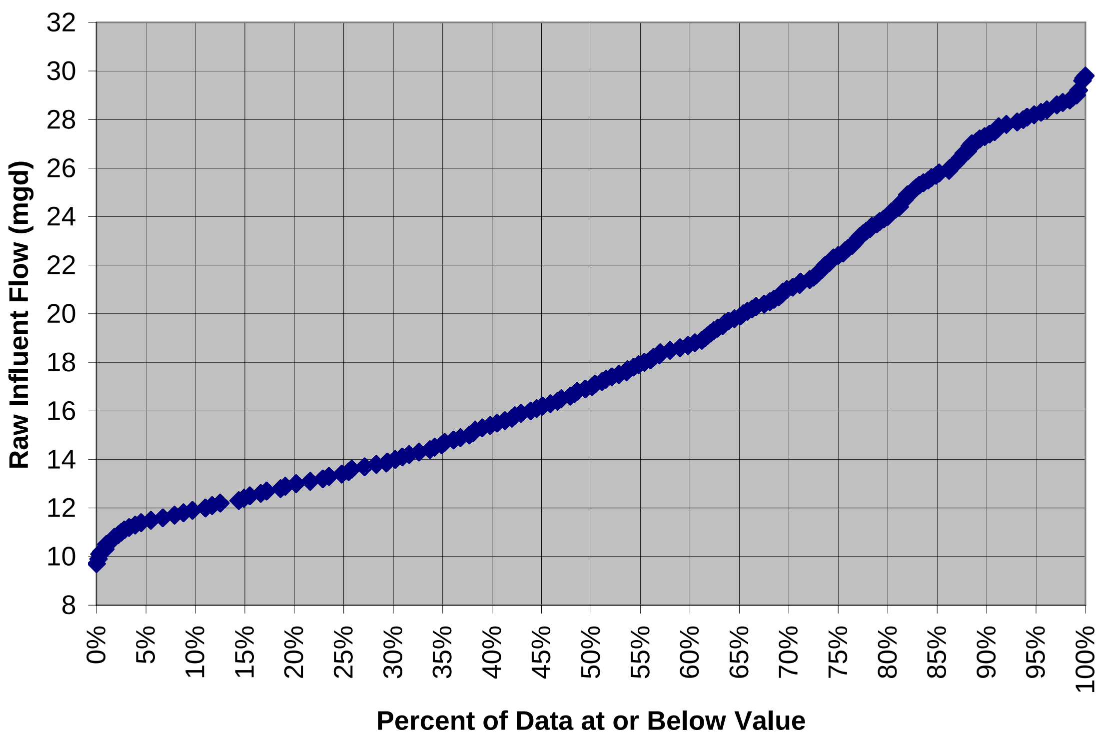

Figure 7 – Raw Influent Data Probability Curve

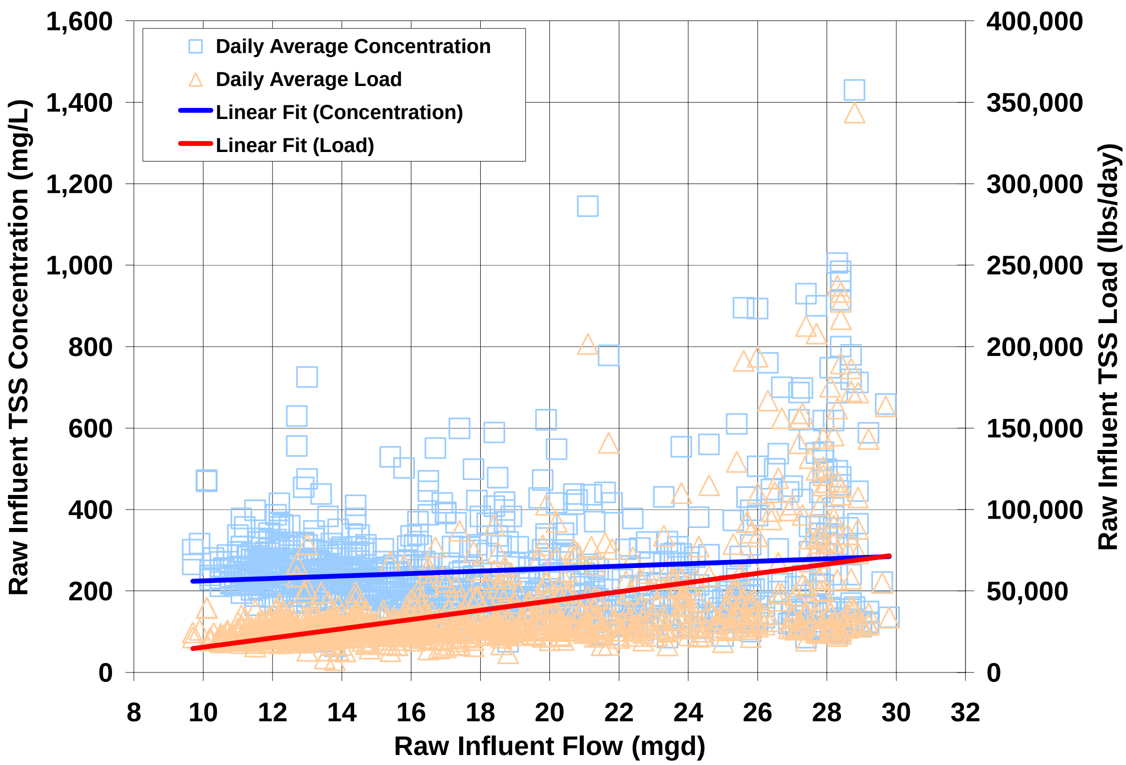

Figure 8 – Raw Influent TSS Correlated to Flow

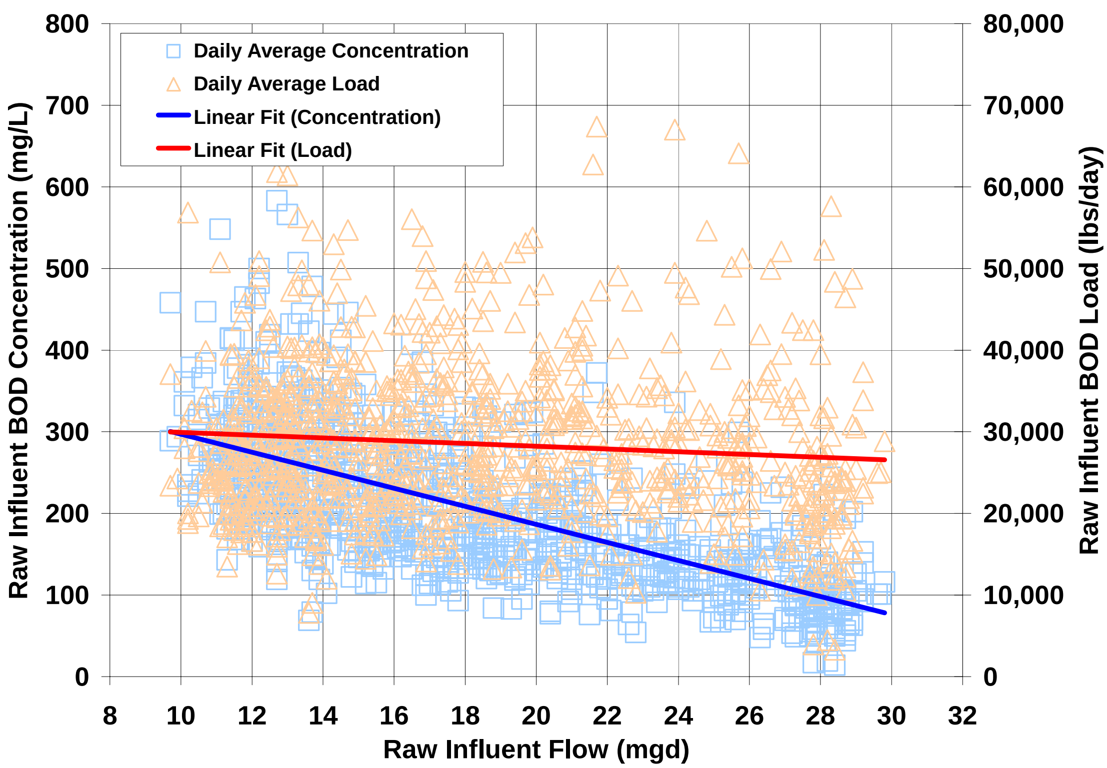

Figure 9 – Raw Influent BOD_5 Correlated to Flow

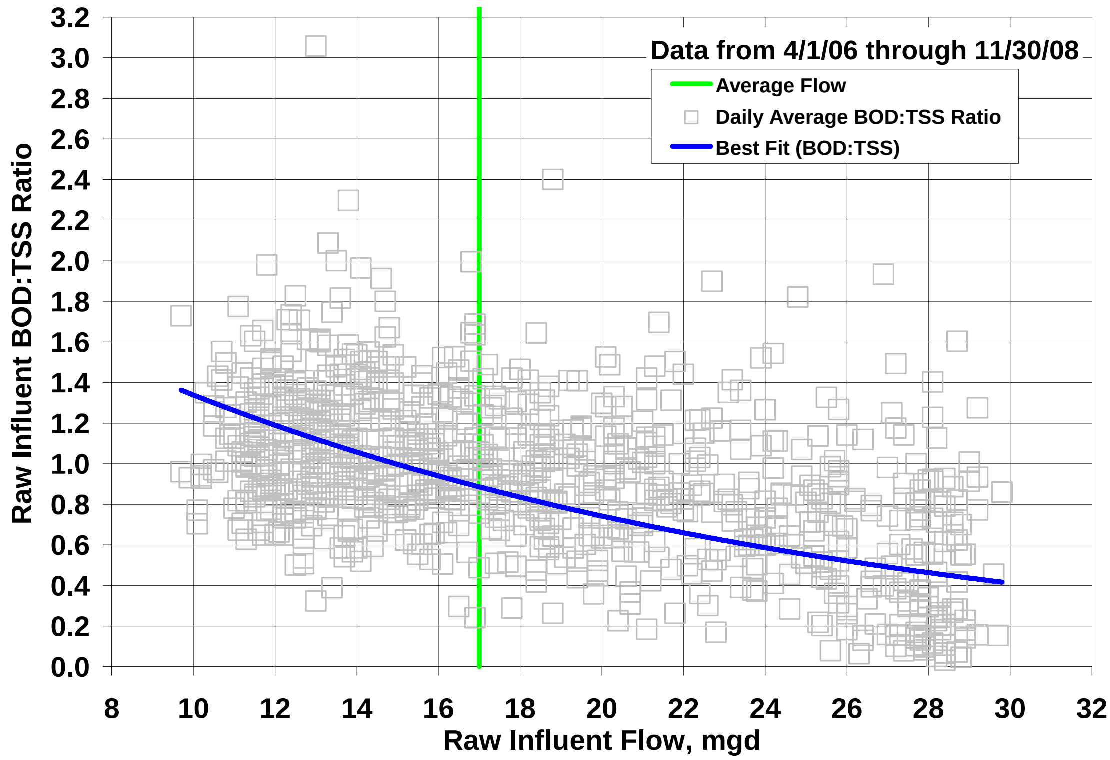

Figure 10 – Raw Influent BOD:TSS Ratio Correlated to Flow

6.0 Excess Flow Treatment Technology Overview and Test Results

This section presents the various HRT technologies evaluated to meet the future wet weather excess flow treatment needs of the City of St. Joseph. Excess flow HRT facilities generally consist of one or more of the following process units:

- Screening and grit removal
- Suspended solids removal
- Disinfection

Various technology alternatives for these process units were discussed with City staff in a workshop held on April 29, 2009.

6.1 Screening and Grit Removal

Screening selection is largely dictated by the requirements of the downstream suspended solids removal process (refer to Section 6.2). For example, Kruger recommends a perforated plate media with ¼ inch (6 mm) holes ahead of their Actiflo

HRC process, whereas a bar media with ½ inch (12 mm) bar spacing would be sufficient for either the DensaDeg HRC process or the CMF processes.

The level of grit removal is essentially the same for the various HRT technologies considered. The HRT technologies themselves are not particularly sensitive to grit and would not dictate choosing one grit technology over another. Grit loading at the WPF has been relatively high from the combined sewers and could be higher when the HRT facilities are provided to treat more flows.

Wet weather screening and grit removal alternatives are evaluated further in TM-CSO-12/TM-WW-3 – Screening and Grit Removal Facilities.

6.2 Suspended Solids Removal

Currently most operating wet weather HRT facilities generally rely on either HRF processes or chemically enhanced HRC processes for suspended solids removal. CMF is the HRF process most often used for wet weather treatment at the scale being considered for the City of St. Joseph, with competing technologies commercially available from Schreiber (Fuzzy Filter) and Wet Weather Engineering and Technology (WWETCO Filter). The most often used HRC technologies are the Actiflo system by Kruger and the DensaDeg system by Infilco Degremont (IDI).

6.2.1 High Rate Filtration

CMF uses a bed of synthetic fiber balls to capture influent suspended solids. As illustrated on Figure 11, the Fuzzy Filter is most commonly configured as an up-flow filter with influent flowing up through the media bed. While in filtration mode, a perforated plate compresses the media from the top. The filter remains in the filtration mode until the captured solids accumulate to the point that the media must be cleaned. At that point a wash cycle is initiated and the top perforated plate is moved upward to allow the bed to expand. An air scouring method is used to clean the media and the solids are carried away in the wash water stream. At the end of the wash cycle, the media is recompressed and the unit is returned to service once the remaining solids are flushed from the system.

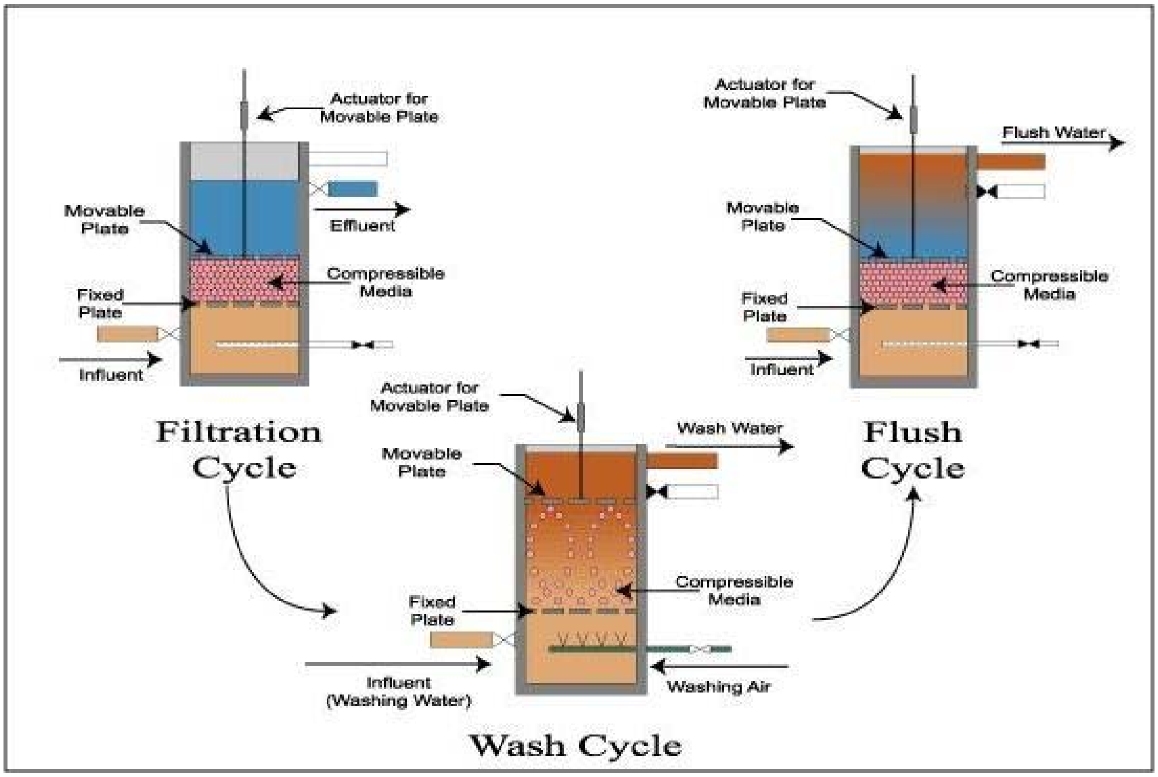

Figure 11 – Fuzzy Filter Process Schematic

For continuous-flow applications, multiple CMF cells must be provided so that individual cells can be cleaned using a backwash system while the remaining cells continue operating in the filtration mode. The CMF system is usually operated as a constant-rate filter system (i.e., flow rate relatively constant until a backwash cycle is initiated). The effective duration of the filtration cycle is a function of the solids loading rate and the beginning of the wash cycle is usually automated either through the use of timers or by pressure or level instrumentation monitoring the differential pressure across the filter bed.

The WWETCO Filter also uses synthetic fiber balls in its media bed and has an operating cycle similar to the Fuzzy Filter. However, it uses a down-flow configuration (as opposed to an up-flow configuration used by the Fuzzy Filter), a flexible rubber membrane to compress the media (versus a mechanically activated perforated plate used by the Fuzzy Filter) and a different air scouring method. As illustrated on Figure 12, the lower portions of the WWETCO filter housing are made from a flexible reinforced membrane material. As influent fills the basin around the perimeter of the filter housing, the membrane flexes inward and compresses the media. Influent rises until it overtops the housing and spills onto the media bed. The media bed filters solids from the water as it passes through the media. As solids accumulate, flow through the media bed becomes restrictive to the point that water levels rise and signal a backwash cycle. The basin is then drained to release the compression and the media is backwashed. An air scour pipe along the centerline of the filter housing cleans the media and the solids are carried away in the backwash stream.

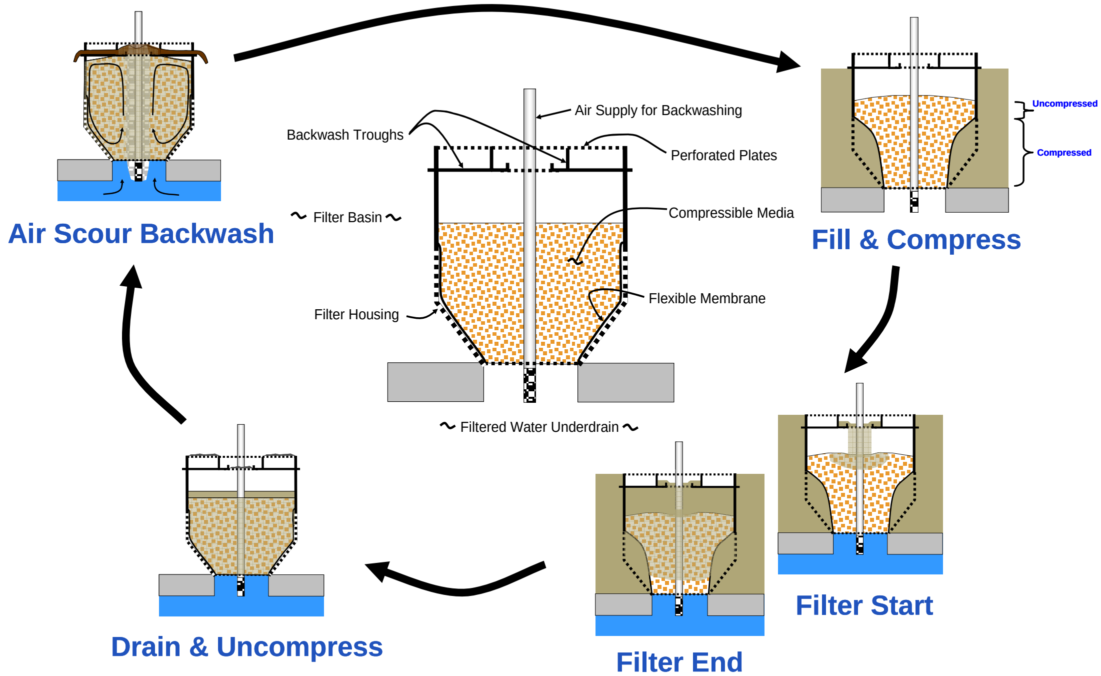

Figure 12 – WWETCO Filter Process Schematic

Other high rate filtration technologies are available in the wastewater market. Cloth media filters (manufacturers include Aqua-Aerobic, Kruger, Parkson, and Siemens) are becoming fairly common for tertiary filtration applications, but not for CSO applications. Black & Veatch recently conducted side-by-side wet-weather trials of representative CMF and cloth media filter technologies. The CMF technology appeared to consistently produce effluent with lower TSS concentrations and appeared to be less sensitive to influent hydraulic and solids loading rates than the cloth media technology.

6.2.2 High Rate Clarification

Both the Actiflo and DensaDeg HRC systems rely on chemical coagulation and flocculation to increase the capture of suspended solids in wet-weather influent. They rely on lamella plate settlers to greatly decrease the required surface area of the settling tank. However, each system uses a different mechanism to increase the density of the flocculated solids. The similarities and differences between Actiflo and DensaDeg HRC processes are described in the following section.

The Actiflo system uses a ballasted flocculation process as illustrated in Figure 13. This process consists of the following basic steps:

1. A coagulant is added and thoroughly dispersed into the wastewater.
2. A flocculant (generally anionic polymer) is then added and thoroughly dispersed in the wastewater along with a ballasting agent (microsand).
3. The mixture of wastewater, chemicals, and microsand is then gently mixed to promote flocculation of the coagulated suspended solids, chemical precipitates, and microsand. The microsand creates a floc with a density substantially greater than normal wastewater solids making it more readily settleable.
4. The mixture overflows to the settling tank, where the ballasted flocs settle rapidly and the clarified water is collected by a number of effluent launders situated above a set of lamella settling plates.

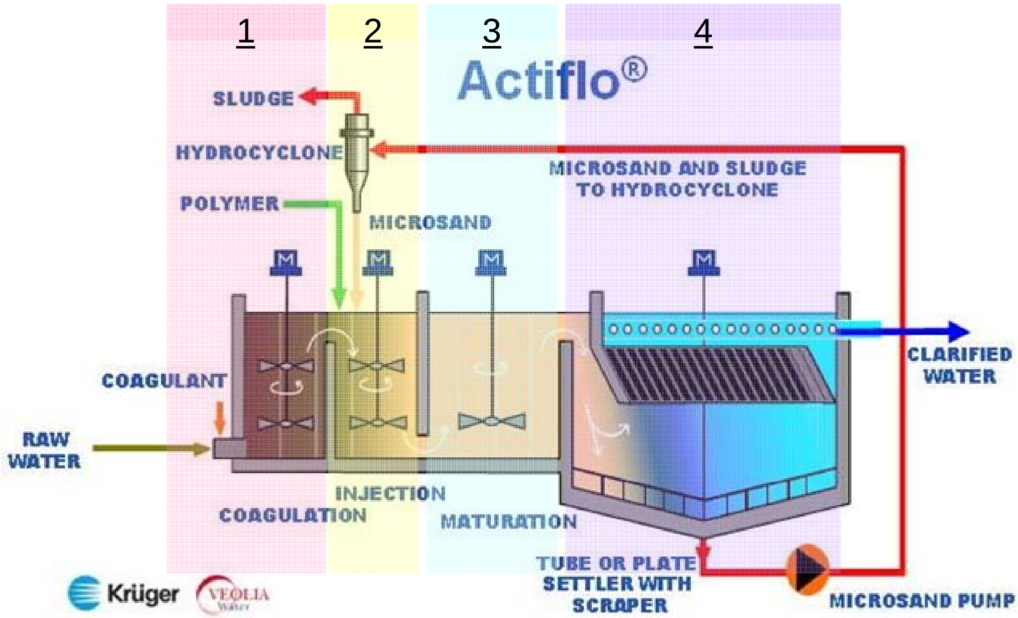

Figure 13 – Actiflo Process Schematic

In the Actiflo system, the settled sludge is removed by sand slurry pumps and pumped to hydrocyclones to separate the microsand from the captured suspended solids and chemical precipitates. The recovered microsand underflows from the hydrocyclones back to the injection tank for reuse in the process. Sludge overflow from the hydrocyclones typically is routed to the headworks of a conventional wastewater treatment plant to be cosettled and thickened in conventional clarifiers (separate thickening facilities can also be provided if necessary). There are some losses (approximately 3 percent on average) of microsand in the hydrocyclone separation process that require the addition of microsand as part of the system operations.

Other ballasted flocculation systems on the market include CoMag by Cambridge Water Technology and MagSep by Advanced Water Treatment Solutions, which is illustrated in Figure 14. Both processes use magnetic ballast (magnetite) and magnetic ballast separation and recovery technologies in place of the microsand and hydrocyclones used in the Actiflo process. Both processes have proven to be successful, but at a much smaller scale than being considered for the St. Joseph WPF. These systems have been used mostly for tertiary phosphorus removal or metals removal from industrial wastewater instead of CSO applications.

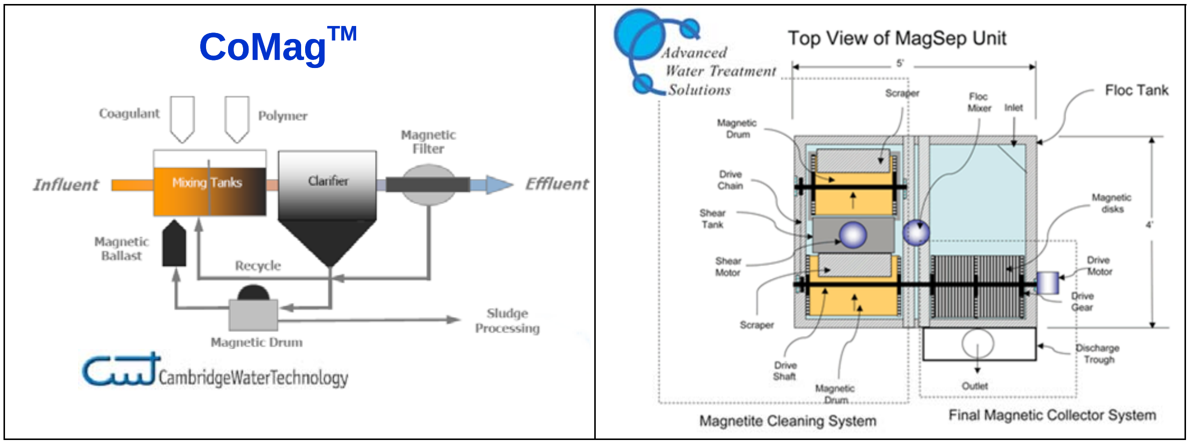

Figure 14 – Other Ballasted Flocculation Systems

The DensaDeg process illustrated on Figure 15 uses similar steps as the Actiflo process, but instead of microsand ballast, uses a different mechanism to increase floc density. The settling tank on the DensaDeg system is somewhat deeper than the settling tank on the Actiflo system to provide a thickening section at the bottom. Thickened sludge is recycled from the bottom of the settling tank and recirculated within the reactor zone. The reactor zone is equipped with a turbine mixer and draft tube designed to provide high internal recirculation rates and promote solids contact. Polymer is also injected in the reactor zone to further enhance flocculation.

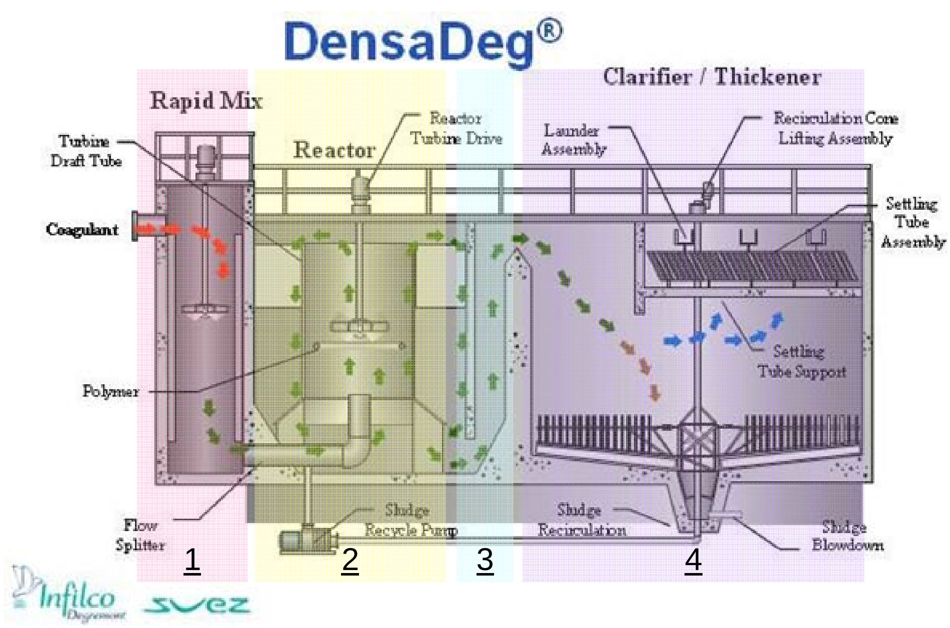

Figure 15 – DensaDeg Process Schematic

Suspended solids captured and chemical precipitates formed by the process are periodically removed from the system as a sludge blowdown stream. This sludge is generally thick enough to be routed to conventional treatment plant stabilization or dewatering processes without additional thickening.

Other chemically enhanced clarification systems, both with and without lamella settlers, are being used in the wastewater industry; however, Actiflo and DensaDeg appear to currently be the most viable HRC choices for this wet weather application, for reasons including the following: (1) both DensaDeg and Actiflo HRC are proven technologies in wet weather applications with over a decade of operational experience in CSO applications worldwide and (2) recent guidance documents from USEPA and the Water Environment Federation (WEF) mention both DensaDeg and Actiflo HRC as viable technologies for CSO control.

CEPT is also a form of HRC but involves the addition of chemicals to existing primary clarifiers to enhance settling. This option was also evaluated for use by the City and is discussed in the following sections.

6.2.3 Treatability Testing of Suspended Solids Removal Technologies

Treatability tests were conducted on wastewater samples from the WPF to assess performance of CMF, CEPT, and HRC technologies on the City's wastewater and wet weather flows. A small flow-through filtration unit pictured in Figure 16 was used for CMF testing, while a series of batch jar tests were used for CEPT and HRC testing. The arrangement illustrated in Figure 17 was used to ensure that the influent samples being treated by the three different technologies were as identical as practically possible. As mentioned on the figure, this arrangement would also allow a blend of primary influent and secondary effluent to be used as a synthetic wet weather influent in cases where actual wet weather influent was not available.

Figure 16 – Treatability Testing Units

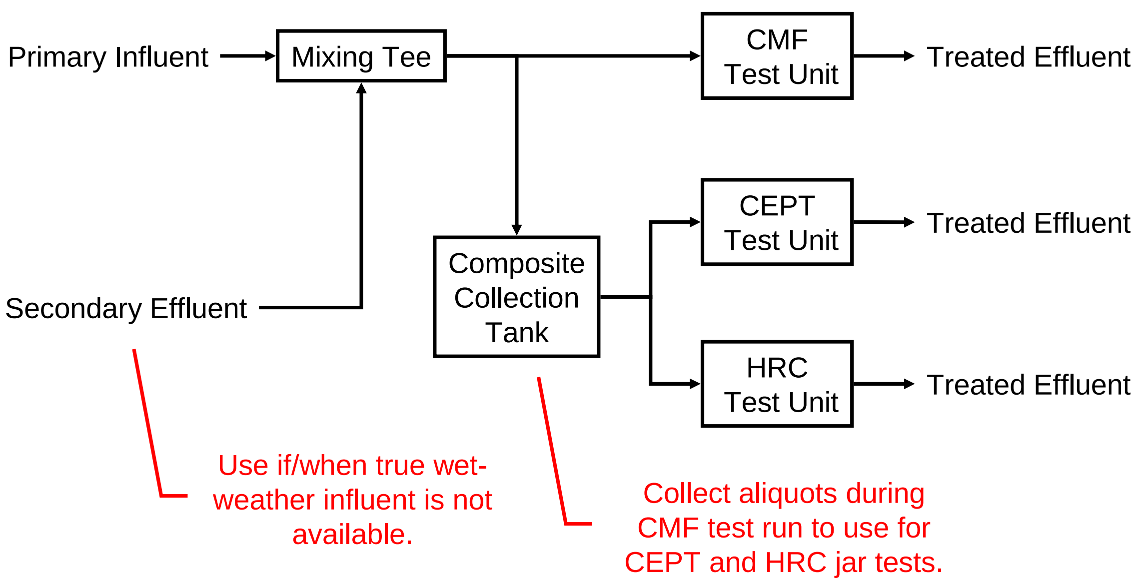

Figure 17 – Treatability Testing Schematic

On Friday, April 10, 2009, a rainstorm moved through the City which significantly increased flows to the WPF. Wet weather treatability testing began at approximately 8:00 a.m. and was completed at approximately 6:00 p.m. that evening. Since actual wet weather influent was available, no secondary effluent was blended with the primary influent. The CMF unit was tested first. During the CMF test run, the level of water above the filter bed and the influent and effluent turbidity were measured. These data were used to calculate the differential head (pressure) across the filter bed and the turbidity removal percentage values that are shown in Figure 18. Influent and effluent composite samples were collected during the CMF test run for laboratory analyses.

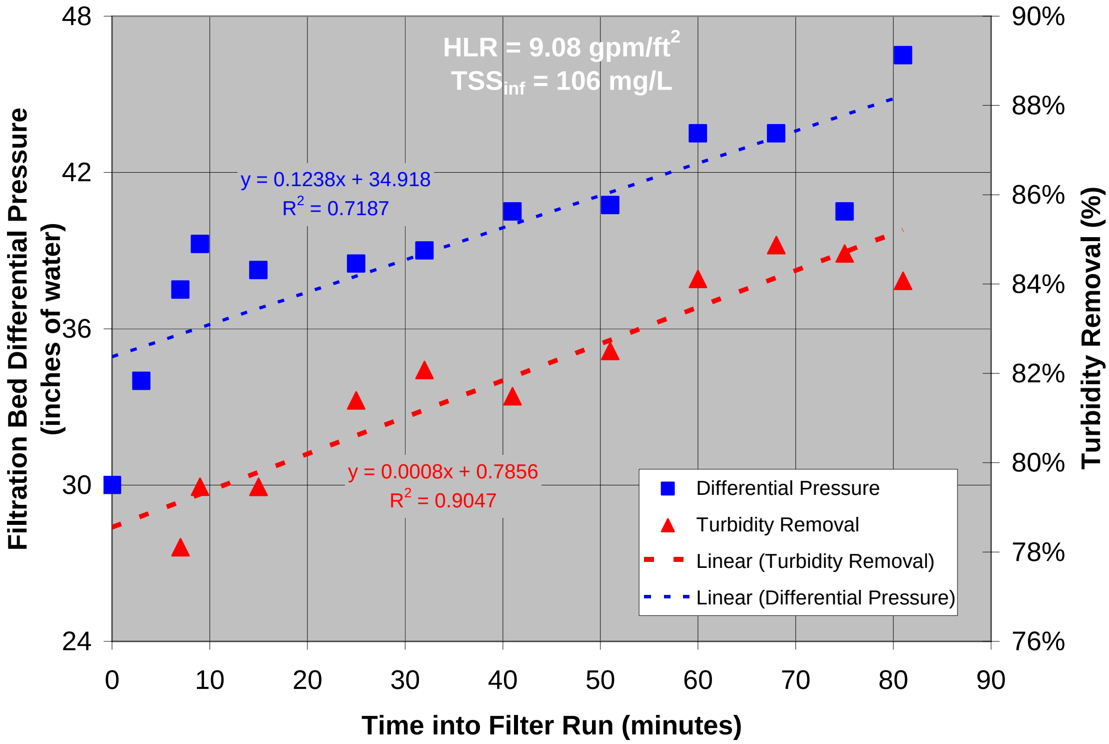

Figure 18 – Operational Data Collected During CMF Test Run

Parallel with the CMF testing, influent aliquots were collected and composited throughout the test run for CEPT and HRC jar testing that was conducted later that day. This was done to ensure that testing for all technologies were performed with like samples. CEPT and HRC tests were conducted on the CMF influent composite sample in accordance with test protocols developed for this evaluation. The jar testing consisted of the following steps:

- Adding microsand ballast addition (HRC only)
- Adding coagulant addition and rapid mixing
- Adding flocculant addition and rapid mixing

- Gentle mixing to promote flocculation
- Settling
- Decanting

To compare the effectiveness of different coagulants on the St. Joseph wet weather flows, ferric chloride ($FeCl_3$ or ferric) and aluminum sulfate [$Al_2(SO_4)_3 \cdot 14H_2O$ or alum] were tested separately as coagulants, while an anionic polymer (Ciba MAGNAFLOC 155 or M155) was used as the flocculant in all the jar tests. The ferric chloride solution used in these tests was a sample from the ferric chloride solution being used by the City for odor control at the Faraon Street Pump Station. The alum solution used in these tests was prepared from dry granules. The polymer solution was also prepared from dry granules.

HRC jar tests were conducted first, starting with a series of jars to optimize effluent turbidity and pH using ferric as the coagulant, followed by a series for flocculant optimization and then a series for alum optimization. A similar series of jar tests were conducted for CEPT using the same coagulants and flocculants as used in the HRC jar tests. The results of these optimization jar tests are summarized in Figure 19 through Figure 28. Observations from these data include the following:

- The optimal ferric chloride dose for both HRC and CEPT appeared to be approximately 14 mg/L, while the optimal alum dose for both HRC and CEPT appeared to be approximately 30 mg/L.
- The optimal polymer dose for HRC appeared to be approximately 0.25 mg/L (as 100 percent active Ciba MAGNAFLOC 155), while the optimal polymer dose for CEPT appeared to be approximately 0.5 mg/L.
- The influent appeared to have relatively little buffering capacity, as the effluent pH was significantly depressed as the coagulant dose was increased. For example, during the HRC jar tests, the effluent pH dropped below 6.5 at ferric chloride doses above approximately 15 mg/L and alum doses above approximately 31 mg/L. Buffering capacity of the influent is

an important factor for HRC processes because many of the co-precipitation reactions require alkalinity.

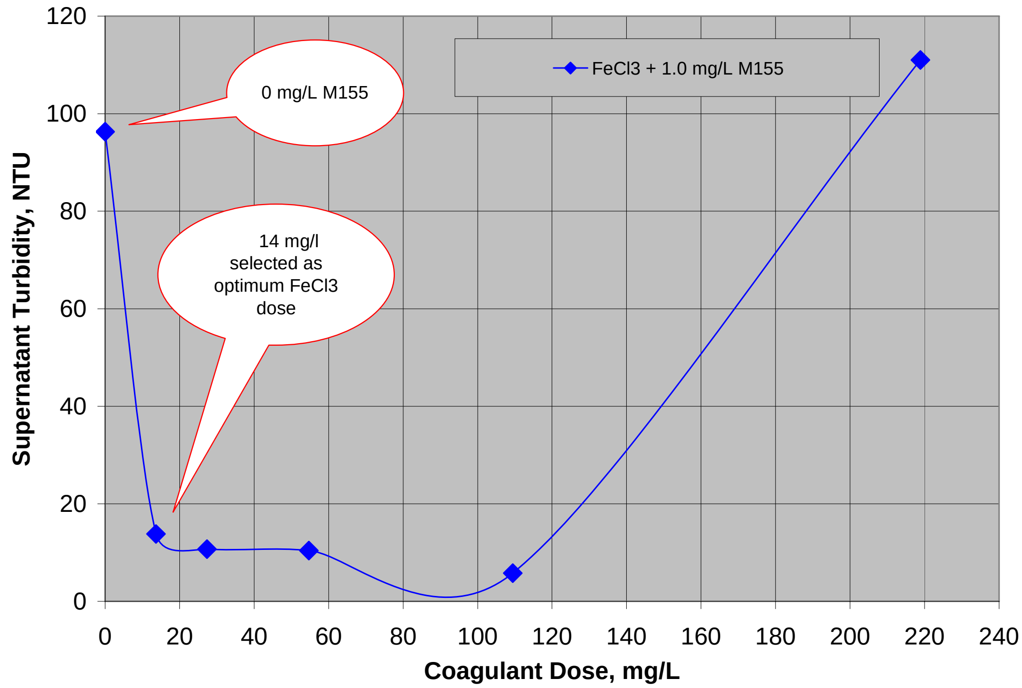

Figure 19 – Ferric Chloride Turbidity Optimization for HRC

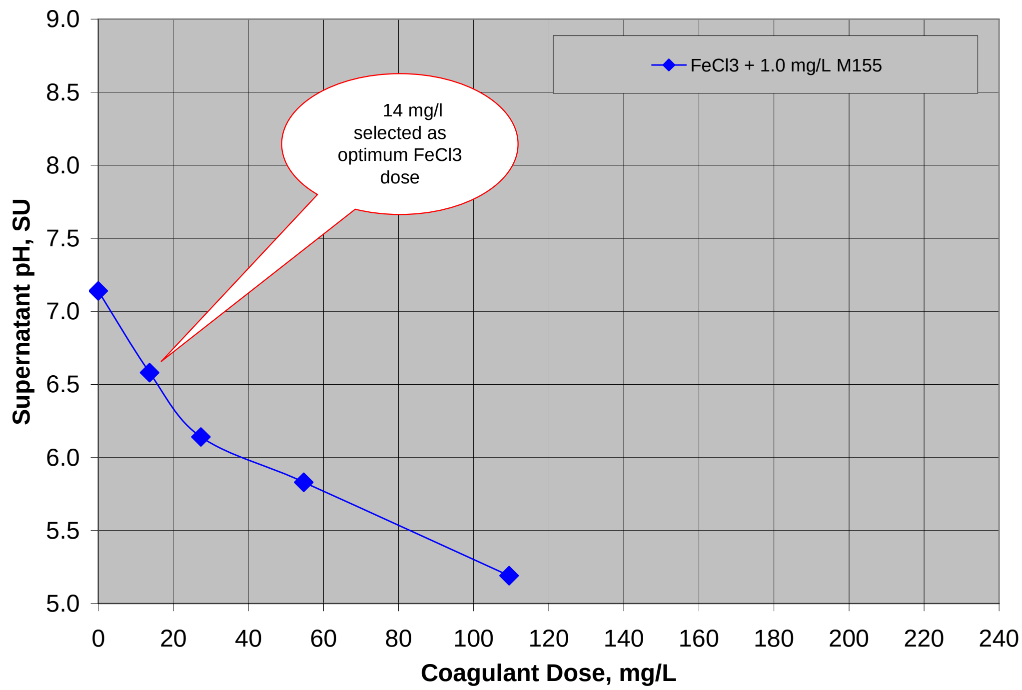

Figure 20 – Ferric Chloride pH Optimization for HRC

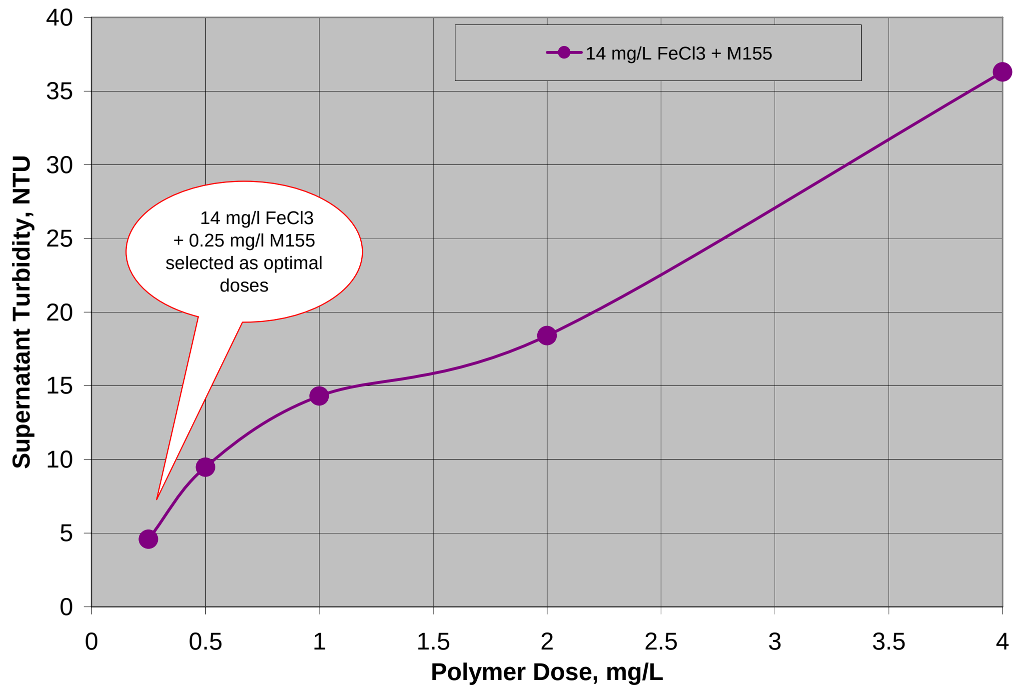

Figure 21 – Polymer Optimization for HRC

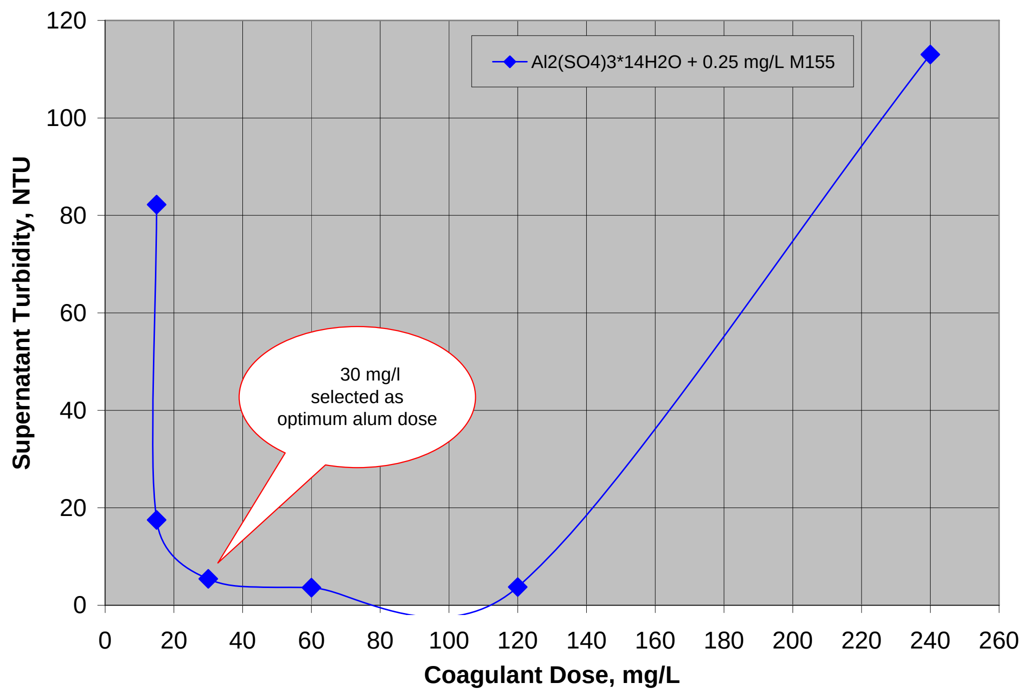

Figure 22 – Alum Turbidity Optimization for HRC

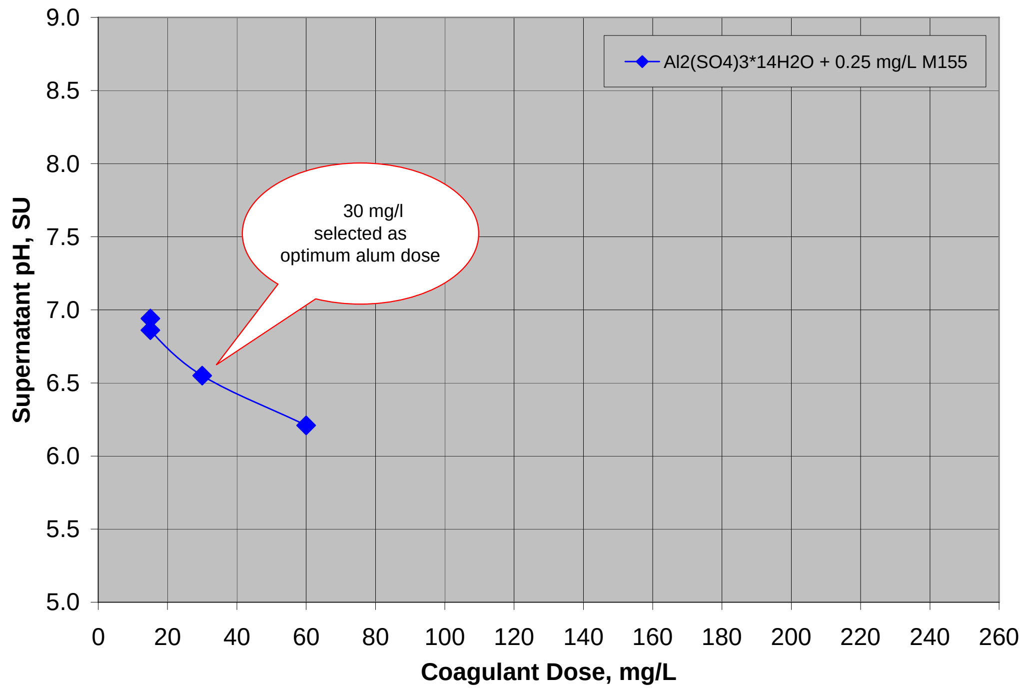

Figure 23 – Alum pH Optimization for HRC

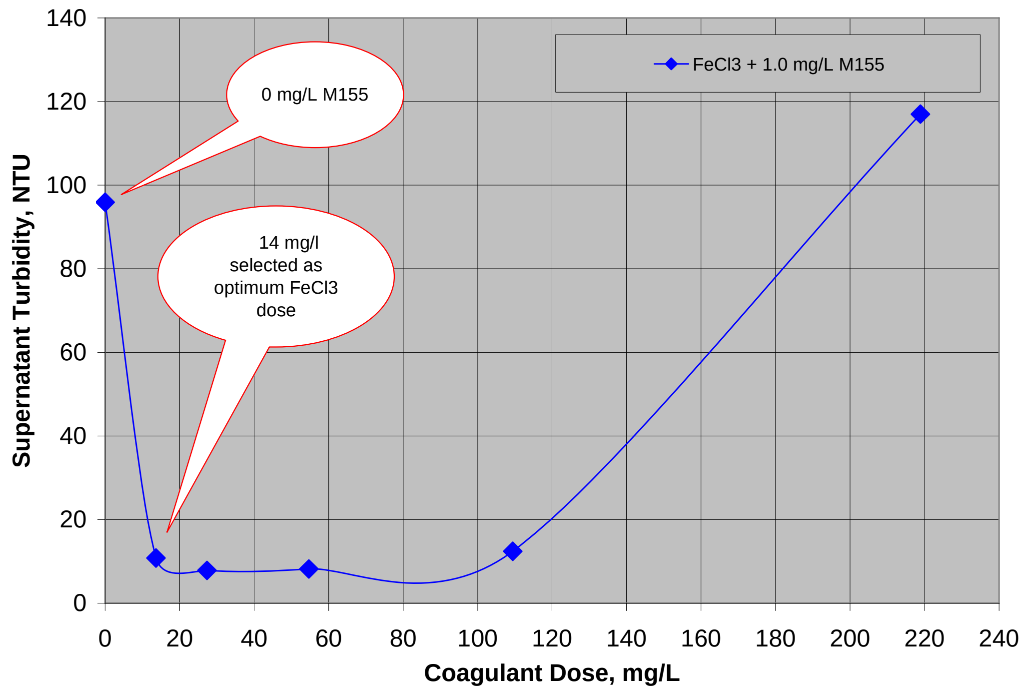

Figure 24 – Ferric Chloride Turbidity Optimization for CEPT

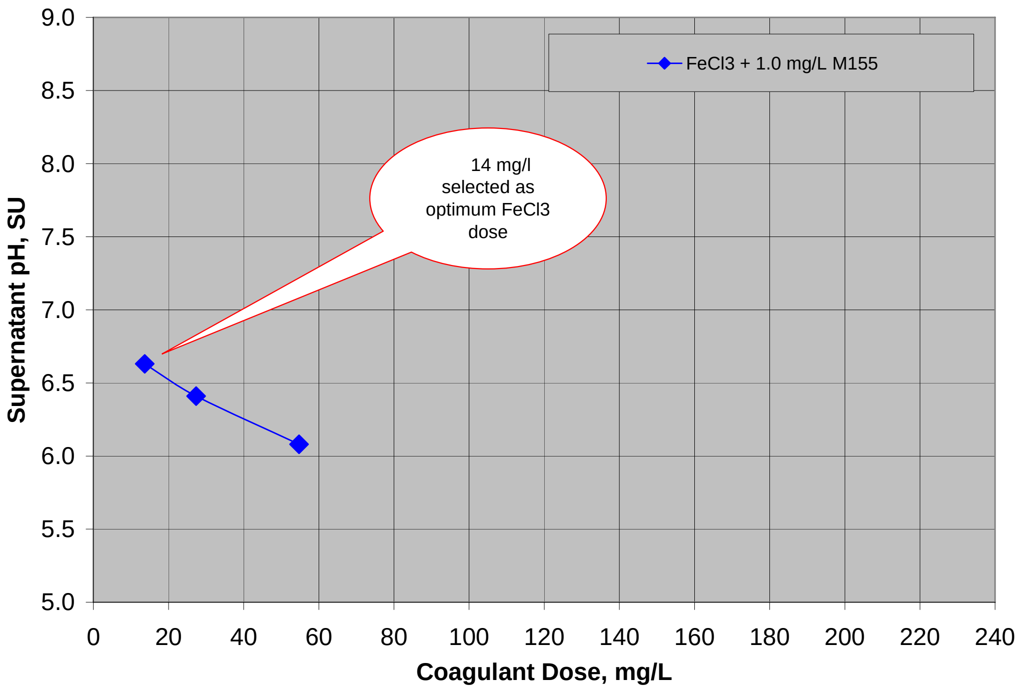

Figure 25 – Ferric Chloride pH Optimization for CEPT

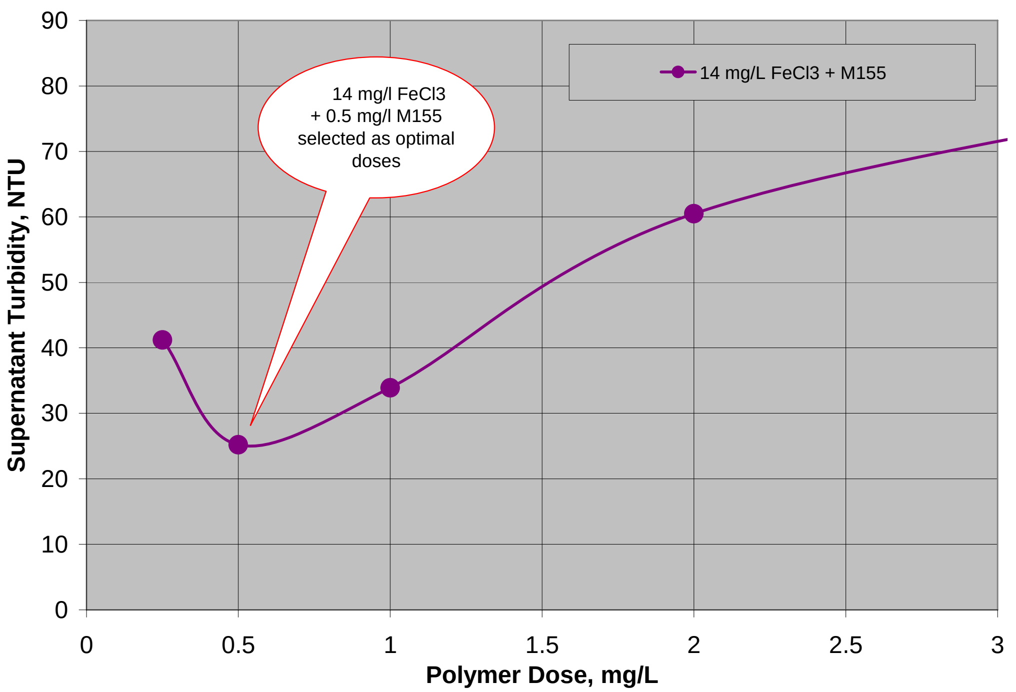

Figure 26 – Polymer Optimization for CEPT

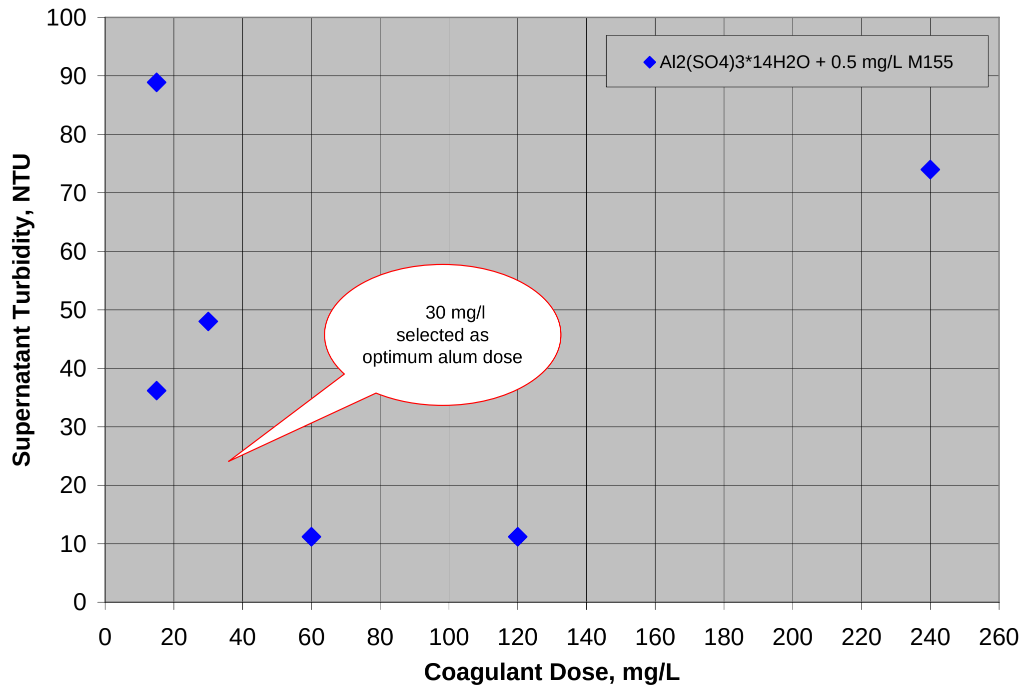

Figure 27 – Alum Turbidity Optimization for CEPT

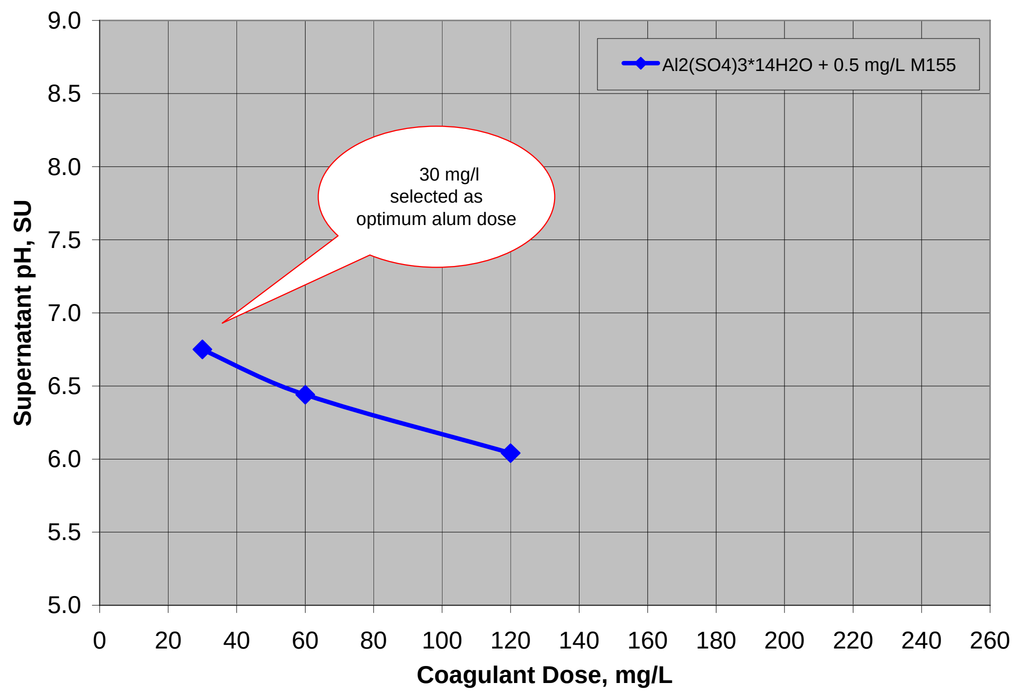

Figure 28 – Alum pH Optimization for CEPT

After optimizing the chemical doses, a series of jars were treated using the optimal chemical doses to produce enough decant to allow for laboratory analyses of all parameters of interest. These laboratory results for the HRC and CEPT tests along with corresponding results for the composite samples collected during the CMF test run are shown on Figure 29 through Figure 35. Observations from these data include the following:

- While the effluent from CMF appeared to be somewhat more turbid than that from HRC or CEPT (Figure 29), the TSS results (Figure 30) indicate that CMF produced the lowest effluent TSS concentrations.
- HRC using alum appears to provide the best improvement in UV transmittance (Figure 31); however, the collimated beam results (Figure 32) suggest that the effluent from CMF was the most amenable to UV disinfection. Although particle size was not measured in these tests, it was visibly evident that the solids in the CMF effluent sample were very small and colloidal. By contrast, the solids in the HRC and CEPT effluent samples were relatively large and tended to flocculate and settle to the bottom of the sample container. This difference in the nature of the effluent solids might explain the seemingly discrepant results between the UV transmittance testing and the collimated beam testing. Refer to TM-CSO-11/TM-WW-5 for further evaluation of wet weather disinfection alternatives.
- The results on Figure 33 indicate that influent total iron was removed by all three technologies. Effluent iron concentrations are sometimes a concern in downstream disinfection processes. For example, soluble ferrous iron (Fe^{2+}) in the effluent will generally contribute a chlorine demand and contribute to effluent TSS when chlorine reactions convert soluble ferrous iron to a ferric (Fe^{3+}) precipitate. Colloidal iron is known to absorb UV, inhibiting the UV disinfection process. Although effluent iron speciation was not conducted, the total iron results indicate that HRC and CEPT with alum as a coagulant generated similar effluent total iron results as CMF. HRC and CEPT with ferric as a coagulant generated somewhat higher effluent total iron results.

- The results on Figure 34 indicate that both the HRC and CEPT technologies consumed a similar amount of alkalinity, causing similar depressions of the effluent pH. On the other hand, CMF appeared to consume much less alkalinity and caused no detectable impacts to the effluent pH.
- The dose response results on Figure 35 indicate that the effluent from all three technologies was amenable to chlorination. The effluent from HRC and CMF appeared to require slightly less contact time than the effluent from CEPT. TM-CSO-11/TM-WW-5 provides further discussion about the wet weather disinfection alternatives evaluation.

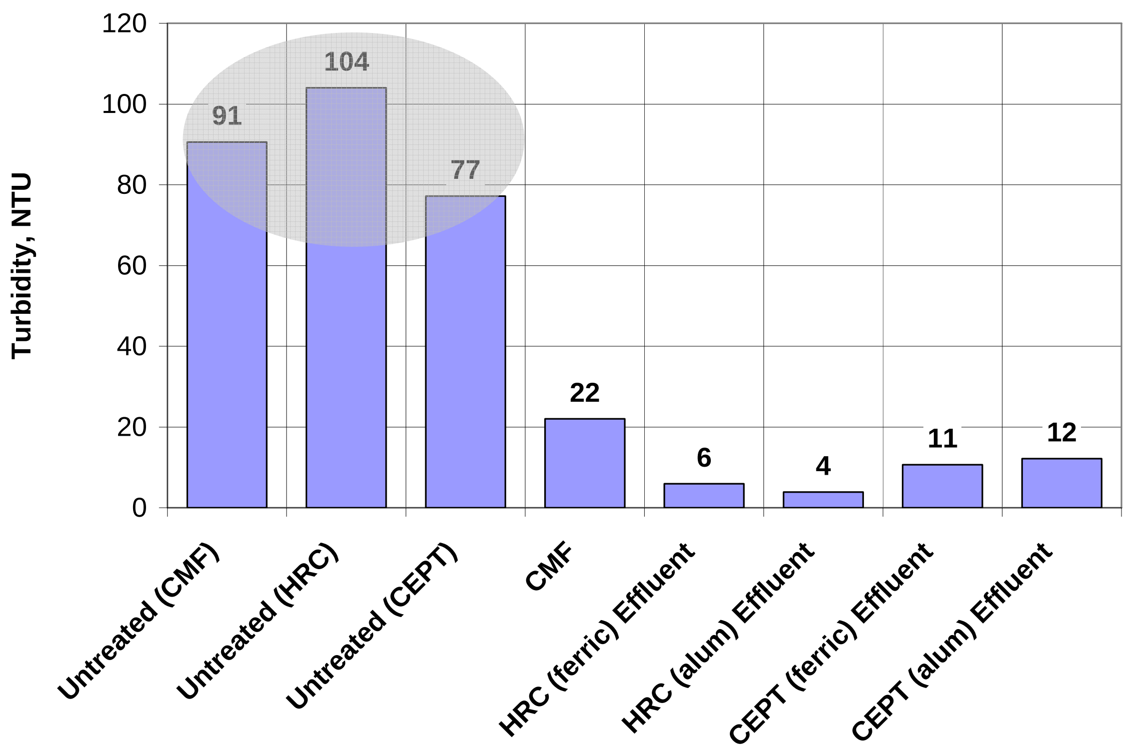

Figure 29 – Comparison of Turbidity Results

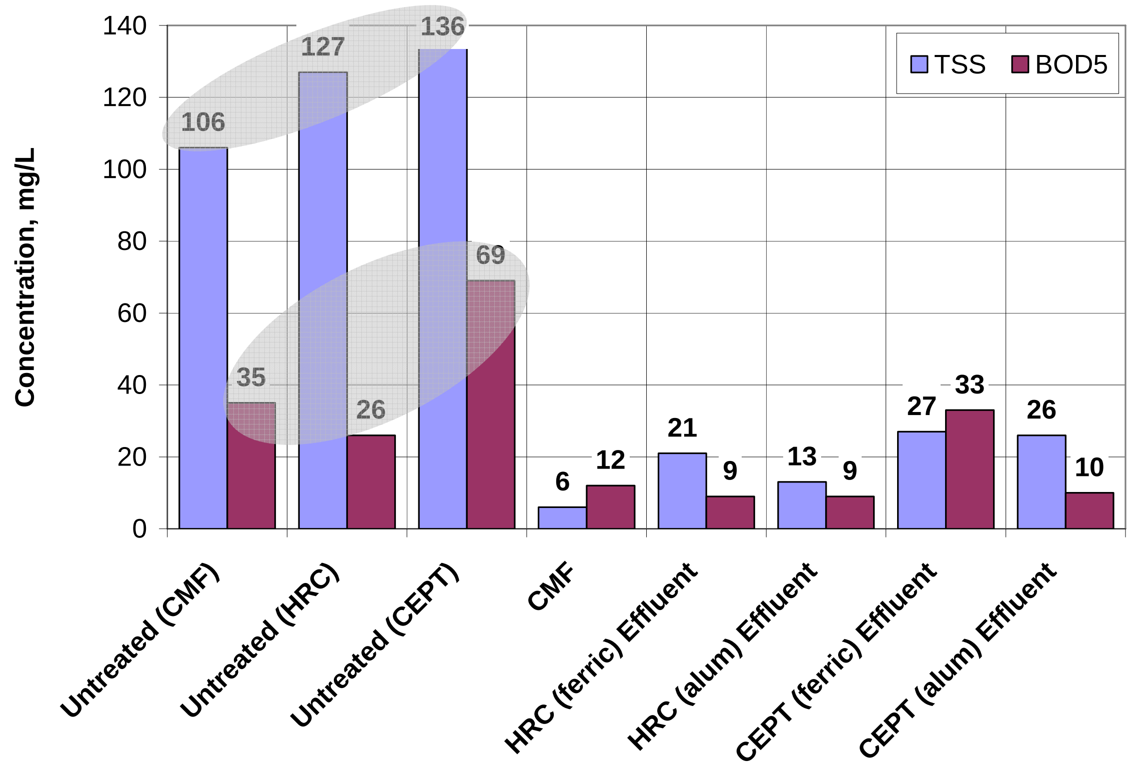

Figure 30 – Comparison of TSS and BOD Results

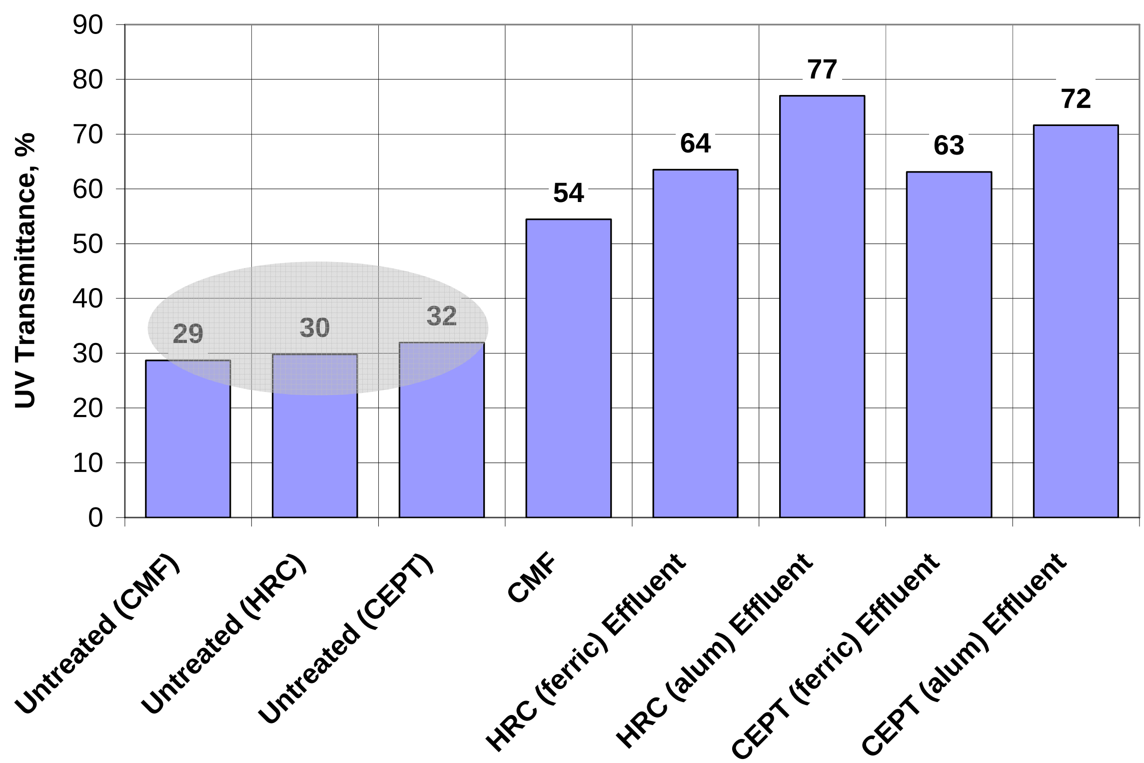

Figure 31 – Comparison of UV Transmittance Results

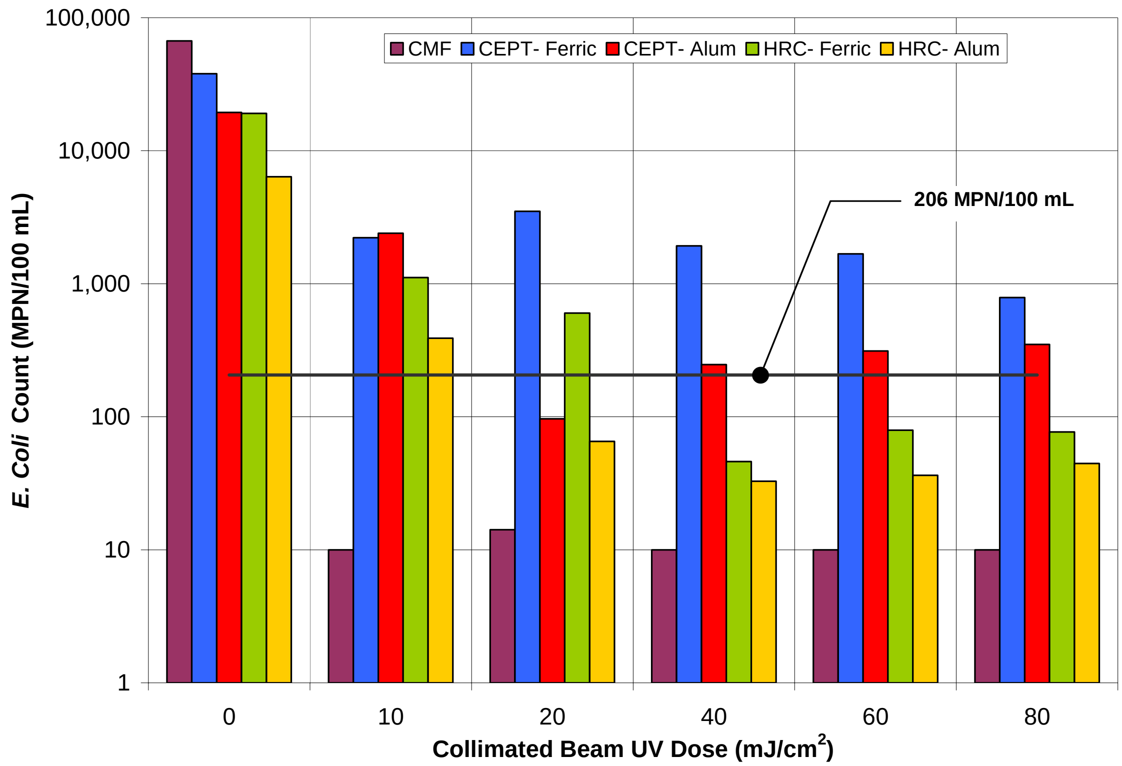

Figure 32 – Comparison of Effluent *E. coli* Response to UV Irradiation

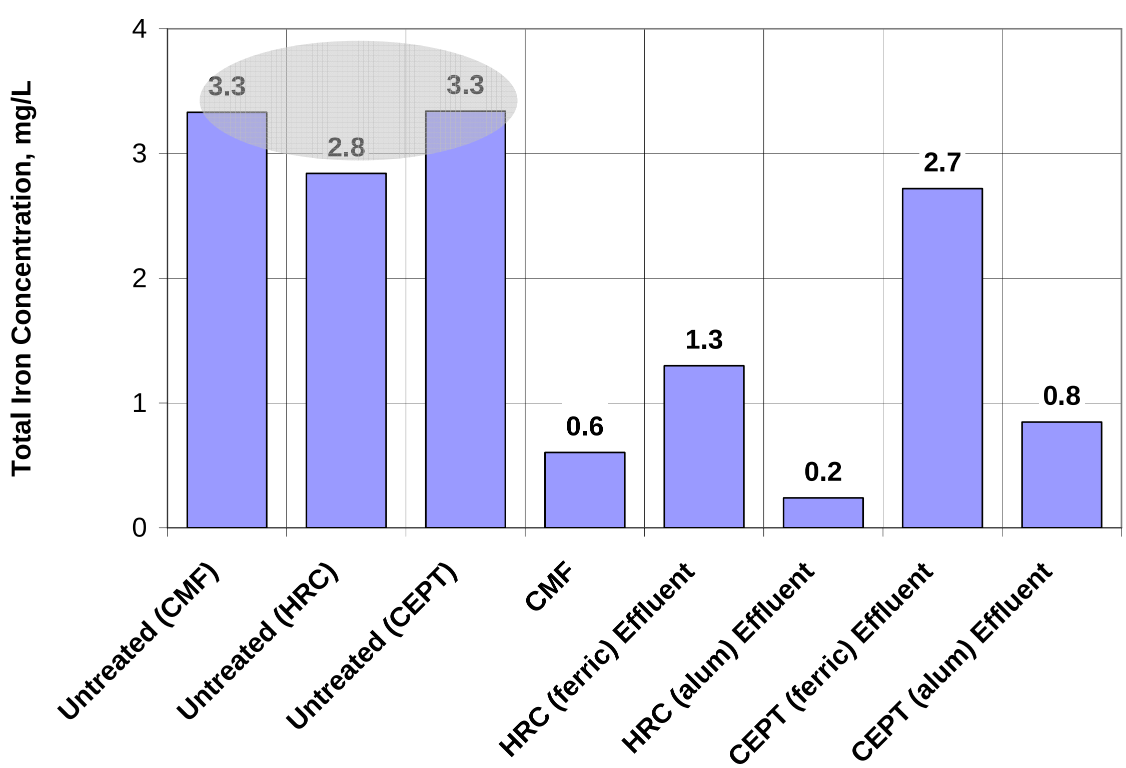

Figure 33 – Comparison of Iron Results

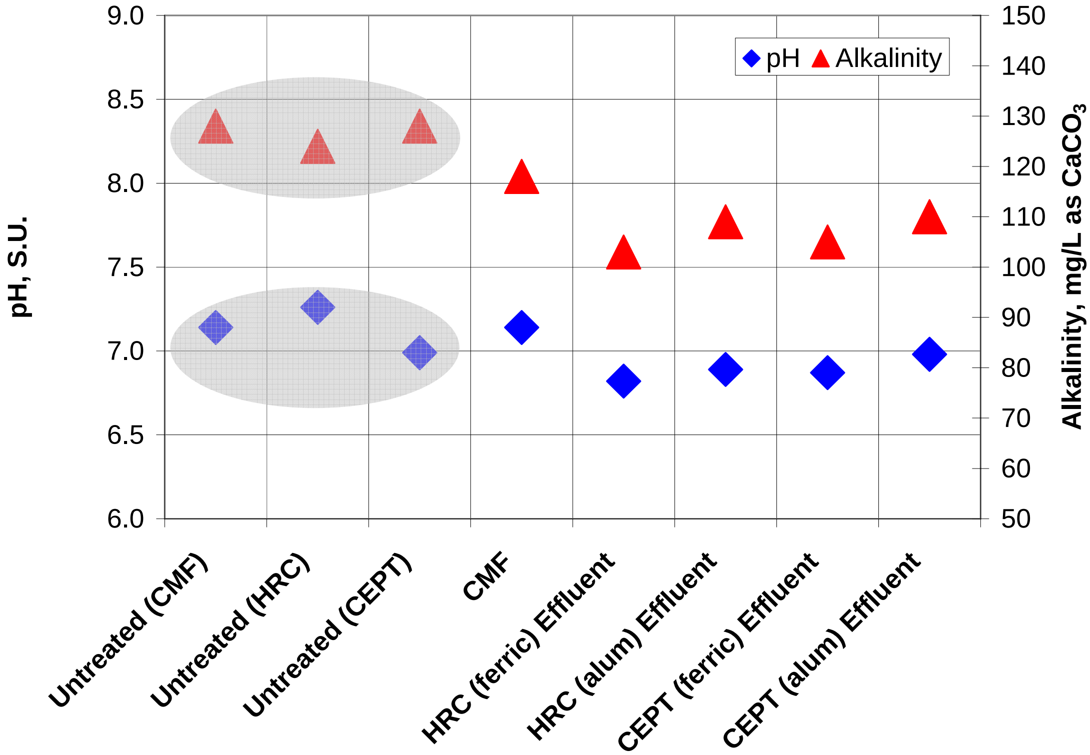

Figure 34 – Comparison of pH and Alkalinity Results

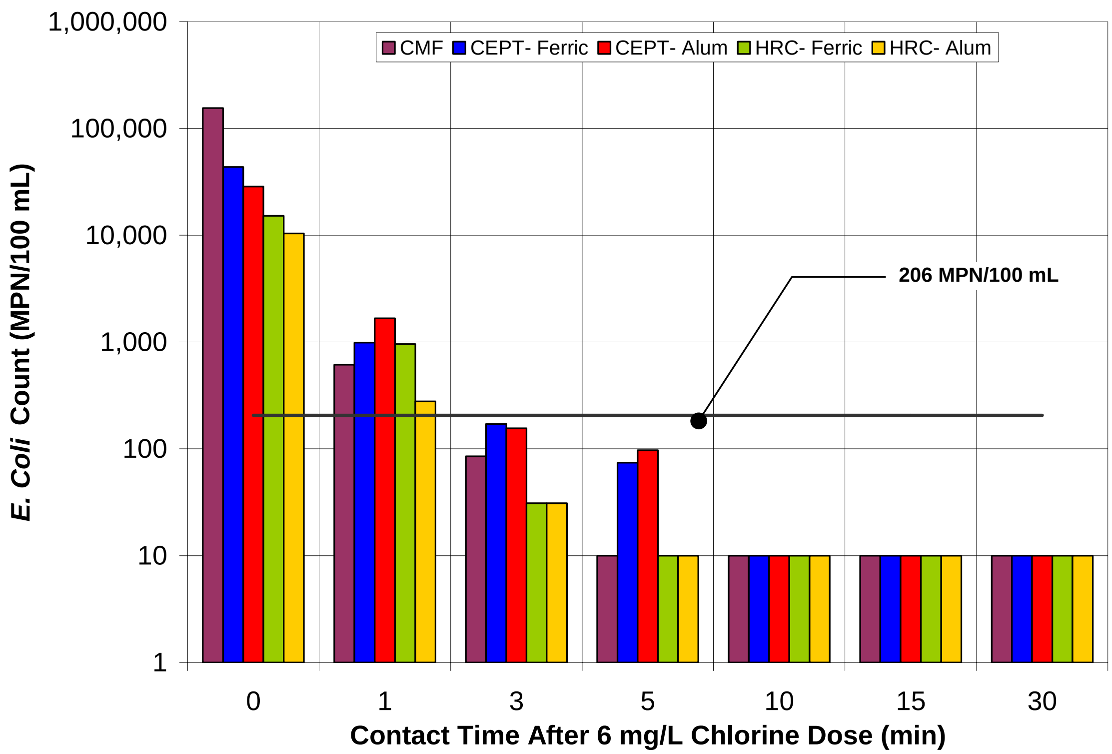

Figure 35 – Comparison of Effluent *E. coli* Response to Hypochlorination

6.3 Disinfection

Consideration was given to combining disinfection facilities to treat both dry weather and wet weather flows at the WPF. TM-CSO-11/TM-WW-5 presents the results from a dry weather and wet weather treatment facilities evaluation that considered both combined and separate disinfection alternatives.

7.0 Wet Weather Treatment Alternatives Development

A workshop was conducted with City staff on April 29, 2009 to review preliminary evaluations of wet weather treatment strategies, regulations, results of treatability testing, and treatment technology alternatives. Based on that workshop and subsequent discussions with City staff, the following HRT alternatives were selected for further evaluation:

- Alternative 1 –HRC Technologies
    - Alternative 1A – Ballasted Flocculation HRC
    - Alternative 1B – Sludge Recirculation HRC
- Alternative 2 – HRF based on CMF Technologies

The CEPT option was screened out because it performed poorly for UV disinfection.

As mentioned previously, a complete HRT facility would consist of preliminary treatment process units (screenings and grit removal) upstream of the core suspended solids removal process units along with downstream disinfection process units.

Unless noted otherwise, Table 1 summarizes the influent characteristics and design criteria that were used in the development of all the alternatives, based in part on the wet weather treatability testing described in Section 6.2.3.

Table 1 Preliminary Wet Weather HRT Design Criteria	
Parameter	**Value**
Total Peak Flow Capacity, mgd	61
Influent Concentrations (Event Average)	
TSS, mg/L	120
BOD_5, mg/L	45
Effluent Concentration Goal (Event Average)	
TSS, mg/L	<30
BOD_5, mg/L	<30
Chemical Dosages [1, 2]	
Alum (as $Al_2(SO_4)_3 \bullet 14H_2O$), mg/L	30
Anionic Polymer (as dry Ciba Magnafloc 155), mg/L	0.25

Notes:
1. Chemical dosing only considered for alternatives using HRC technologies as CMF technologies do not require chemicals.
2. Preliminary estimate. Additional testing and evaluations recommended to optimize chemical dosage.

7.1 Alternative 1A – High Rate Clarification (Ballasted Flocculation)

Alternative 1A is based on two trains of ballasted flocculation HRC. Kruger's Actiflo process was chosen as the basis of design for this alternative. Each train would be sized to treat screened and degritted flows up to 30.5 mgd for a total capacity of 61 mgd. Since this facility is a wet weather facility and would therefore only operate intermittently, no process train redundancies were considered.

7.1.1 Design Criteria

Table 2 presents the preliminary design criteria used for the proposed ballasted flocculation facility. Chemical storage and feed system sizing was based on a 7 day storm event consisting of 61 mgd of flow the first day and 30.5 mgd the last 6 days. Kruger recommends that the upstream screening for this alternative be a perforated plate type screen with ¼ inch (6 mm) holes. Bar-type screens with ½ inch (12 mm) bar spacing would be sufficient for the other HRT alternatives considered. Upstream grit removal for this alternative can be the same technology as the other HRT alternatives. The grit facilities are discussed in detail within TM-CSO-12/TM-WW-3. Downstream disinfection facilities for this alternative are anticipated to be the same as for the other HRT alternatives and are presented in TM-CSO-11/TM-WW-5.

Table 2
Alternative 1A – Actiflo HRC Preliminary Design Criteria

Parameter	Value
Total Peak Flow Capacity, mgd	61
Peak Flow Capacity per Train, mgd	30.5
Hydraulic Residence Times	
Coagulation Tank, minutes	1.0
Injection Tank, minutes	1.0
Maturation Tank, minutes	3.0
Settling Tank Rise Rate at Design Capacity, gpm/ft^2	60
Estimated Sludge Production at Design Capacity	
Captured Influent TSS, lbs/day	55,000
Captured Chemical Precipitates, lbs/day	6,700
Sand Loss, lbs/day	300
Total, lbs/day	62,000
Estimated Sludge Solids Concentration, % TS	0.2 to 0.5
Sludge Discharge at Design Capacity, mgd	1.5 to 3.7

7.1.2 Facility Sizing

The ballasted flocculation facilities, consisting of two parallel 30.5 mgd trains, would be housed in a structure approximately 110 feet by 55 feet. The facility footprint incorporates the area for the basins, sand recirculation pumps, sand storage, and an electrical/control room. The depth of the basins would be approximately 20 feet below the operating floor elevation. All basin dimensions are based on recommendations from Kruger Inc. for their standard Actiflo equipment. The building dimensions were based on previous projects where Actiflo was designed for similar flow conditions. A brick and block building was assumed to cover the entire facility with grating and concrete walkways for access. Table 3 presents the preliminary process dimensions and equipment sizing for this alternative. The basins for the new ballasted flocculation system would be located indoors along with the basin mixers, sludge scraper assembly, and hydrocyclones. A separate electrical and control equipment room would be located adjacent to the process room and would house the sand slurry pumps located in the basement. A layout of the facility is shown in Figure 36.

Table 3
Alternative 1A – Preliminary Process Dimensions and Equipment Sizing

Parameter	Value
Number of Trains	2
Coagulation Tank (1 per train)	
Length, ft	14
Width, ft	12
Injection Tank (1 per train)	
Length, ft	14
Width, ft	12
Maturation Tank (1 per train)	
Length, ft	20
Width, ft	25
Settling Tank (1 per train)	
Length, ft	25
Width, ft	25
Sand Recirculation Pumps (each train)	2 duty + 1 standby
Capacity (each), gpm	660
Motor (each), hp	60
Number of Hydrocyclones per Pump	1
Alum Storage and Feed Equipment	
Number of Tanks	1
Diameter, ft	12
Height, ft	15
Number of Metering Pumps	4
Capacity (each), gph	130
Polymer Storage and Feed Equipment	
Number of Tanks	1
Diameter, ft	9
Height, ft	13
Number of Feeder Blenders	4

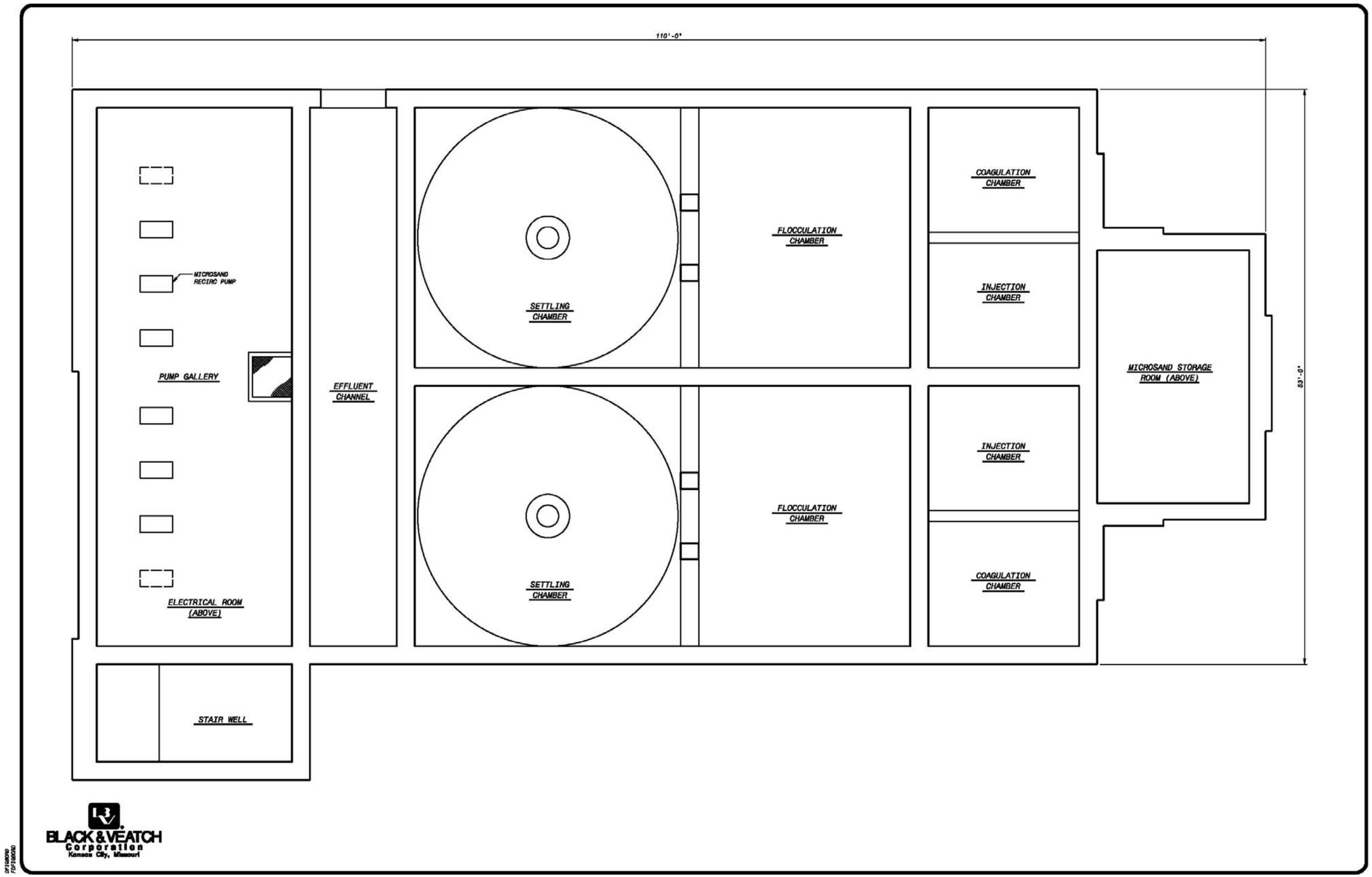

Figure 36 – Preliminary Layout of Ballasted Flocculation HRC Facility

Figure 37 shows the layout of the chemical feed and storage building which would house the coagulant and polymer feed and storage systems. For 61 mgd, the building would be approximately 60 feet by 55 feet (3,300 square feet). The size of the building is based on using an emulsion polymer and alum as a coagulant. The polymer feed system proposed herein consists of one 6,000 gallon polymer tank and four polymer feeder blenders. Smaller polymer totes could be used instead of the larger bulk storage option. However, for planning and budgeting purposes, the more expensive option of using a bulk storage tank was used. Using polymer totes to minimize the size and cost of this facility can be evaluated during design. The coagulant system proposed herein consists of one 12,000 gallon alum tank with two duty and two standby diaphragm type metering pumps.

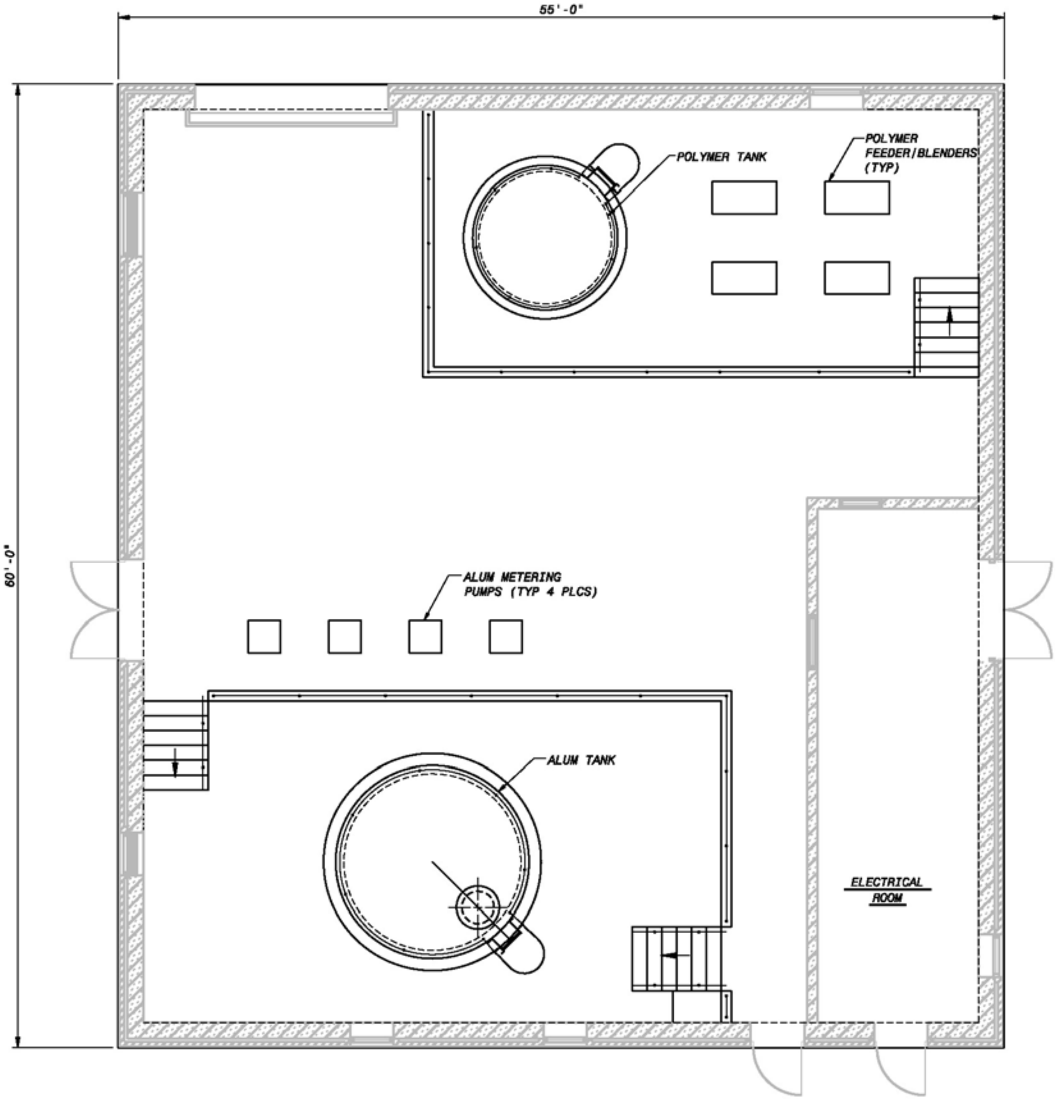

Figure 37 – Preliminary Layout of Chemical Feed Facility

7.1.3 Proposed Improvements

New structures would be constructed to house the components of the HRT system. Fine screen facilities will be required upstream of the Actiflo facility. Kruger recommends perforated plate screen technology with ¼ inch openings to better capture straw shaped particles (cigarette butts, soda straws, etc.) that could pass a bar type screening system and interfere with the hydrocyclones, which are critical to the Actiflo process. The Actiflo option is the only HRT process discussed herein requiring ¼ inch screening. For all other HRT alternatives, ½ inch bar screening is adequate. The additional cost of perforated plate screening has been included in the Actiflo alternative (Alternative 1A). TM-CSO-12/TM-WW-3 provides further evaluation of wet weather screening and grit removal alternatives. TM-CSO-11/TM-WW-5 provides further evaluation of disinfection alternatives downstream of the ballasted flocculation system.

Figure 38 provides a general layout of the proposed ballasted flocculation HRC facilities. The proposed Actiflo facilities are shown in red. Figure 38 also shows in yellow other new facilities (i.e., Effluent Pump Station and UV Disinfection Facilities) related to the HRC and WPF improvements to demonstrate how the two systems might interface. This arrangement should be considered preliminary. Final location of these facilities will be determined once all land acquisition needs have been identified and final design is performed.

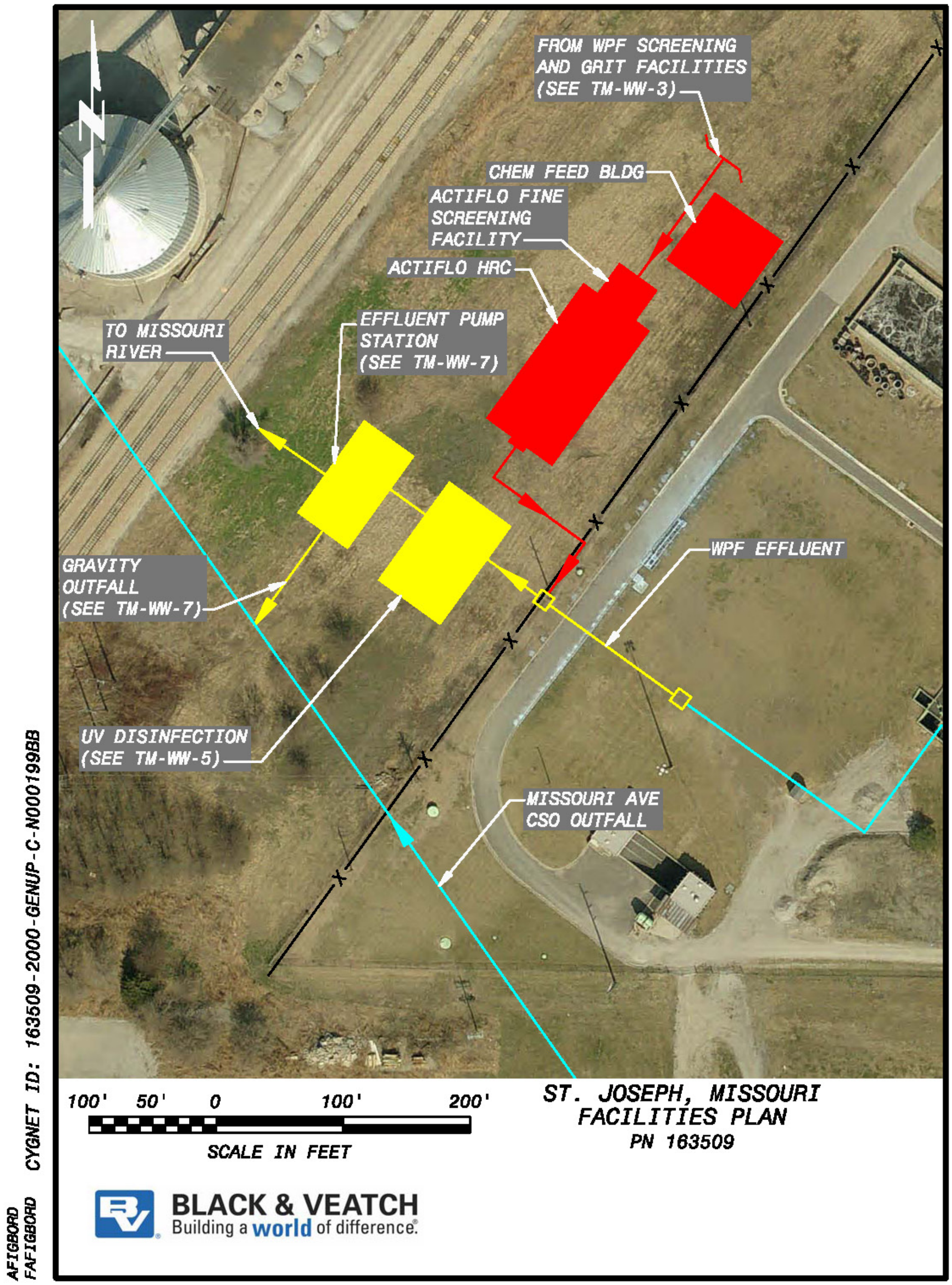

Figure 38 – Preliminary Site Layout for Alternative 1A: HRC Ballasted Flocculation

7.2 Alternative 1B – High Rate Clarification (Sludge Recirculation)

Alternative 1B is based on two trains of sludge recirculation HRC. Infilco Degremont's DensaDeg process was chosen as the basis of design for this alternative. Each train would be sized to treat screened and degritted flows up to 30.5 mgd for a total capacity of 61 mgd. Since this facility is a wet weather facility and would therefore only operate intermittently, no process train redundancies were considered.

7.2.1 Design Criteria

Table 4 summarizes the preliminary design criteria for the proposed HRC facility. Upstream bar screening for this alternative would have a maximum bar spacing of ½ inch (12 mm) which is different than for the Actiflo system. Upstream grit removal needs for this alternative should be the same as for the other HRT alternatives. Downstream disinfection facilities for this alternative are expected to be the same as for the other HRT alternatives. The chemical storage building dimensions as well as the proposed chemical storage tanks and feed equipment will be identical to those proposed as part of Alternative 1A.

Table 4
Alternative 1B – Preliminary Design Criteria

Parameter	Value
Total Peak Flow Capacity, mgd	61
Peak Flow Capacity per Train, mgd	30.5
Settling Tank Rise Rate at Design Capacity, gpm/ft^2	40
Estimated Sludge Production at Design Capacity	
Captured Influent TSS, lbs/day	55,000
Captured Chemical Precipitates, lbs/day	6,700
Sand Loss, lbs/day	n/a
Total, lbs/day	61,700
Estimated Sludge Solids Concentration, % TS	2 to 5
Sludge Discharge at Design Capacity, mgd	0.15 to 0.37

7.2.2 Facility Sizing

The sludge recirculation HRC system facilities will consist of two 30.5 mgd parallel trains housed in a structure approximately 105 feet by 70 feet. The basins for the new HRC system would be located indoors along with the basin mixers and sludge scraper assemblies. The sludge pumps and electrical and control equipment would be located in a room adjacent to the process room. The facility footprint incorporates the area for the basins, an influent piping and pump room consisting of five progressing cavity sludge recirculation pumps and two progressing cavity sludge blow down pumps, an effluent channel, and an electrical room. The depth of the basins will be approximately 28 feet below the operating floor elevation. All basin dimensions were based on recommendations from Infilco Degremont for their standard equipment. Table 5 summarizes the preliminary process dimensions and equipment for this alternative.

Table 5
Alternative 1B – Preliminary Process Dimensions and Equipment Sizing

Parameter	Value
Number of Trains	2
Nominal Dimensions of Each Train	
Length, ft	70
Width, ft	35
Rapid Mixer Tank	
Number per Train	2
Top Entry Mixer (1 per tank), hp	10
Reactor Tank	
Number per Train	2
Top Entry Mixer (1 per tank), hp	15
Clarifier/Thickener Tank (1 per train)	
Number per Train	1
Sludge Recycle Pumps	
Number of Pumps	5 (2 duty per train + 1 shared standby)
Capacity (each), gpm	635
Motor (each), hp	15
Sludge Blowdown Pumps	
Number of Pumps	2 (1 duty per train)
Capacity (each), gpm	635
Motor (each), hp	15
Alum Storage and Feed Equipment	Same as Alternative 1A (Table 3)

The building dimensions were based on previous projects where DensaDeg was constructed to treat similar flow rates. A brick and block building is proposed to cover the entire facility with grating and concrete walkways for access. A layout of the facility is shown on Figure 39.

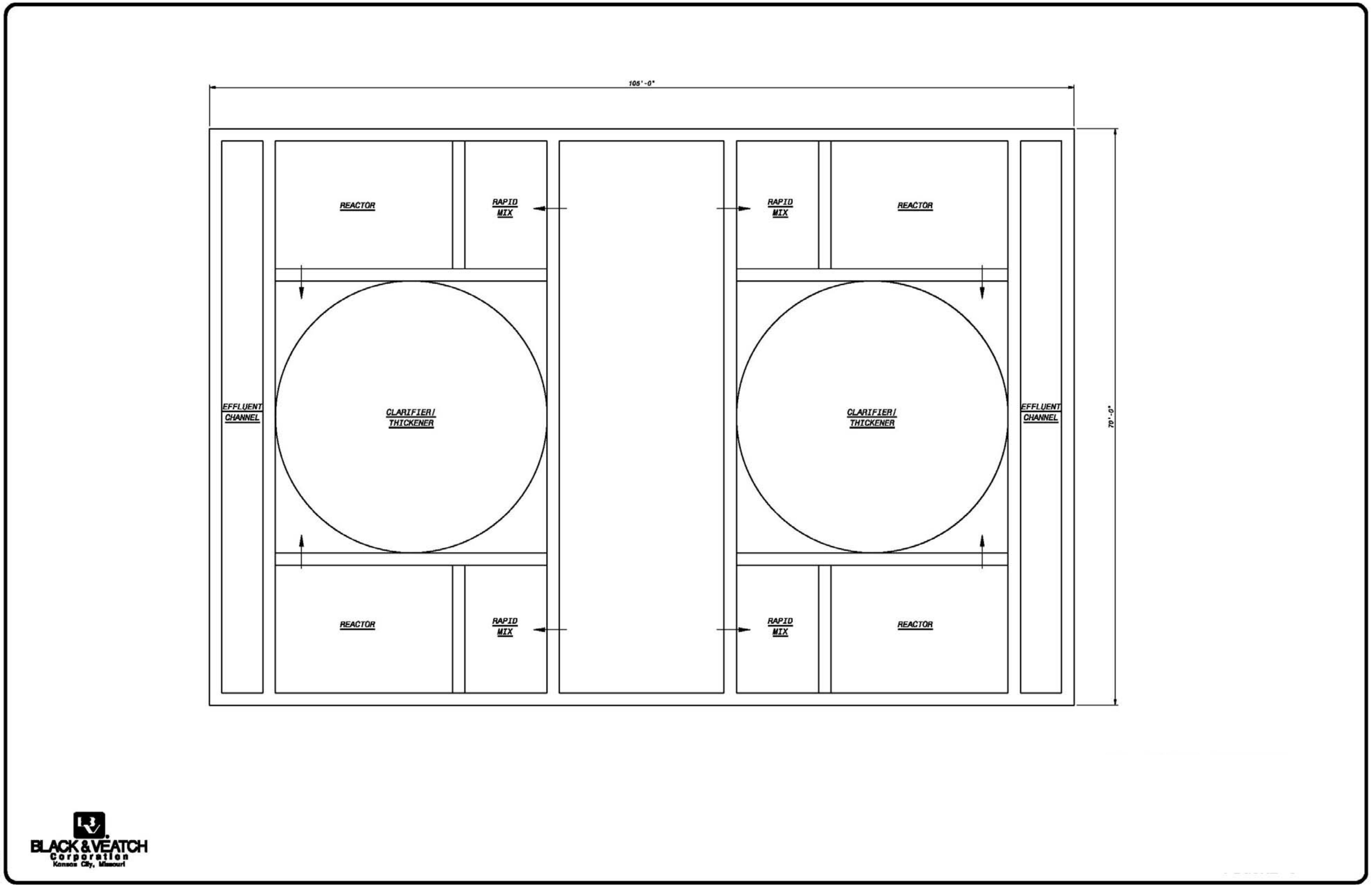

Figure 39 – Preliminary Layout of Sludge Recirculation HRC Facility

Figure 40 shows the layout of the chemical feed and storage building which would house the coagulant and polymer feed and storage systems. This facility is identical to the chemical and feed building proposed for Alternative 1A as the chemical dosing for Alterative 1B is expected to be similar to that of Alternative 1A. Determining optimal chemical dosages for either HRC technology will require additional testing which can be conducted during preliminary design.

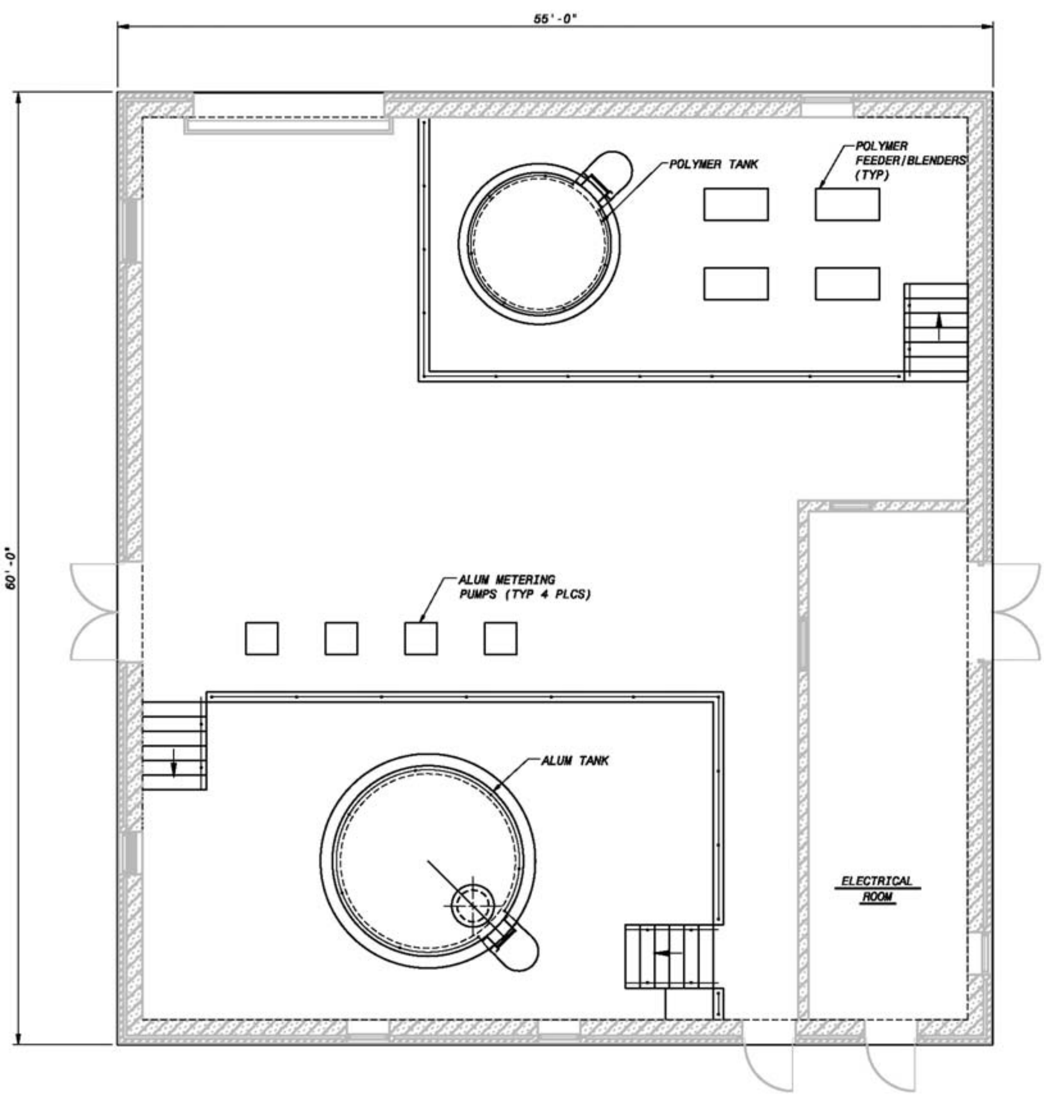

Figure 40 – Preliminary Layout of Chemical Feed Facility

7.2.3 Proposed Improvements

New structures would be constructed to house the components of the HRT system. As mentioned previously, fine screen facilities will be required upstream of the DensaDeg facility. The DensaDeg system, though, has less stringent screening requirements than the Actiflo system and ½ inch bar screen media is recommended. Furthermore, since the entire WPF will likely be fitted with ½ inch screens in the future, there are no specific screening requirements that should be associated with Alternative 1B. Therefore, costs for additional screening and grit removal have not been added to this alternative's project cost presented later within this technical memorandum. All flow reaching the proposed HRT facilities will have already been screened to ½ inch by the proposed WPF improvements. Only the Actiflo facility would require additional ¼ inch screening. Refer to TM-CSO-12/TM-WW-3 for further evaluation of wet weather screening and grit removal alternatives. Refer to TM-CSO-11/TM-WW-5 for further evaluation of disinfection alternatives downstream of the sludge recirculation HRC system.

Figure 41 provides a general layout of the proposed sludge recirculation HRC facilities. The proposed HRC facilities are shown in red. Figure 41 also shows in yellow other new facilities (i.e., Effluent Pump Station and UV Disinfection Facilities) related to the HRC and WPF improvements to demonstrate how the two systems might interface. This arrangement should be considered preliminary. Final location of these facilities will be determined once all land acquisition needs have been identified and final design is performed.

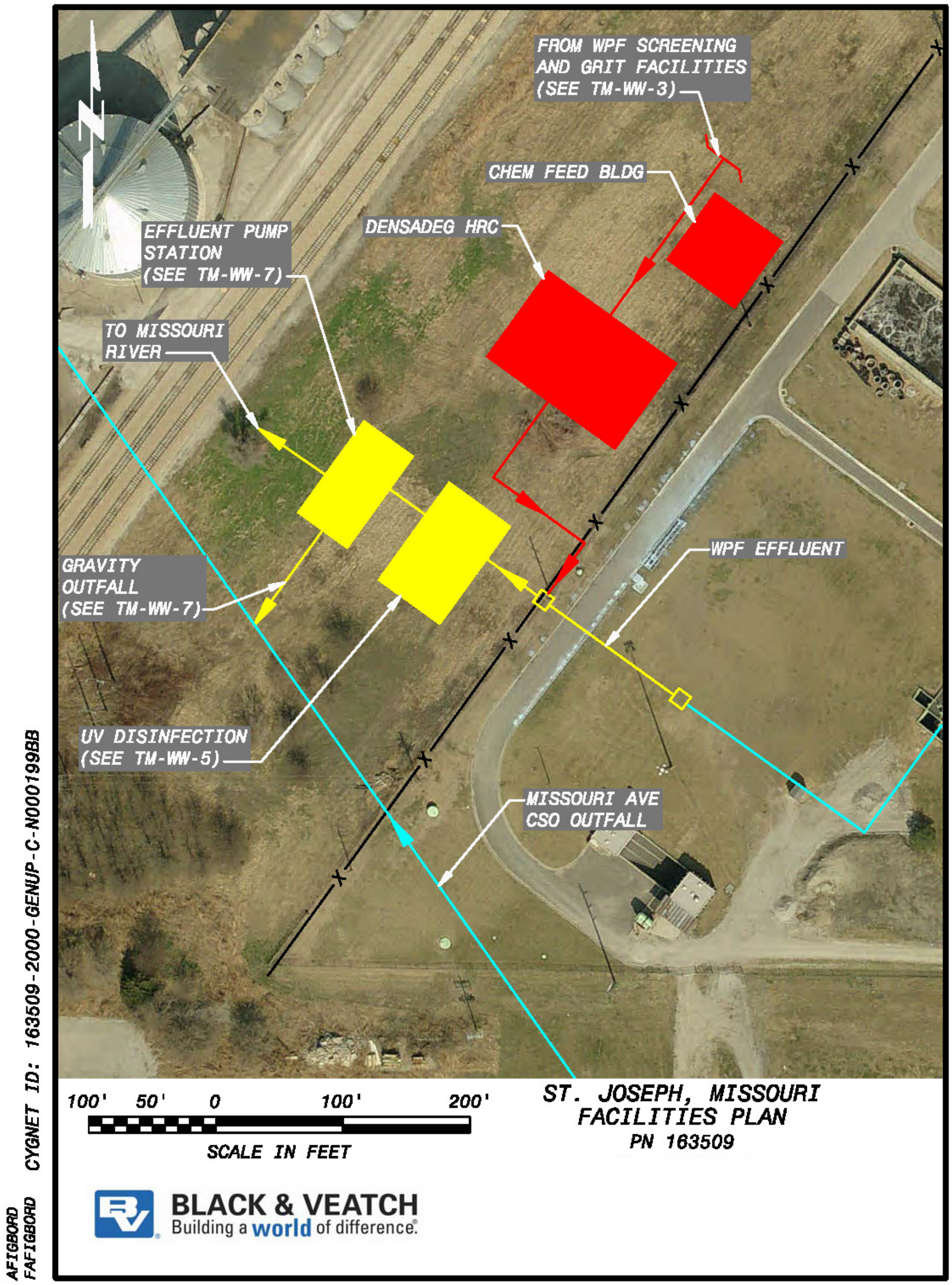

Figure 41 – Preliminary Site Layout for Alternative 1B: Sludge Recirculation

7.3 Alternative 2 – Compressible Media Filtration

Alternative 2 is based on providing multiple compressible media filter cells. Wet Weather Engineering and Technology's WWETCO Filter was chosen as the preliminary basis of design for this evaluation, although Schreiber's Fuzzy Filter could also be a viable technology option that could be considered as design progresses. The preliminary design consists of eight filter cells. During the peak solids loading at 61 mgd, it is anticipated that six of the filter cells would be in filtration mode, while two of the cells would be in backwash mode. Lower solids loading rates during extended wet weather events (i.e. lower flow rates and/or lower TSS concentrations) would result in less backwash volume through longer filter service runs.

7.3.1 Design Criteria

Table 6 summarizes the preliminary design criteria for the proposed CMF facility. Upstream bar screening for this alternative is recommended to have a maximum bar spacing of ½ inch (12 mm). Upstream grit removal needs for this alternative are recommended to be the same as for the other HRT alternatives. Downstream disinfection facilities for this alternative are anticipated to be the same as for the other HRT alternatives. No chemicals are anticipated to be required with this alternative.

Table 6
Alternative 2 – Preliminary Design Criteria

Parameter	Value
Total Peak Flow Capacity, mgd	61
Hydraulic Loading at Peak Flow, gpm/ft^2	10
Solids Loading at Peak Flow, ppd/ft^2	30
Estimated Sludge Production at Design Capacity	
Captured Influent TSS, lbs/day	55,000
Captured Chemical Precipitates, lbs/day	n/a
Sand Loss, lbs/day	n/a
Total, lbs/day	55,000
Estimated Backwash Solids Concentration, % TS	0.2 to 0.5
Backwash Discharge at Design Capacity, mgd	1.2 to 3.1

7.3.2 Facility Sizing

The CMF system filter cells would be housed in a structure approximately 120 feet by 110 feet for two parallel trains of 30.5 mgd each. The filter basins for the new CMF system would be located outdoors along with the system valves and piping. The depth of the basins will be approximately 14 feet below the operating floor elevation. All basin dimensions were based on recommendations from WWETCO for their standard equipment. The backwash blowers and electrical and control equipment would be located indoors in a building adjacent to the basins. The blower and electrical building dimensions would be approximately 65 feet by 60 feet by 20 feet high. Table 7 summarizes the preliminary process dimensions and equipment sizing for this alternative.

Table 7
Alternative 2 – Preliminary Dimensions and Equipment Sizing

Parameter	Value
Number of Trains	2
Nominal Dimensions of Each Train	
Length, ft	120
Width, ft	55
Number of Cells	8
Nominal Dimensions of Each Cell	
Length, ft	30
Width, ft	27
Number of Strip Filters per Cell	4
Nominal Dimensions of Each Filter	
Length, ft	30
Width, ft	6
Total Filtration Area, ft^2	5,760
Depth of Filter Media, inches	30
Backwash Air Scour Blowers	
Number of Blowers	4
Capacity (each), scfm	7,200
Motor (each), hp	300

A layout of the CMF basins is shown on Figure 42 while Figure 43 shows the layout of the blower building which would also house the electrical and control equipment.

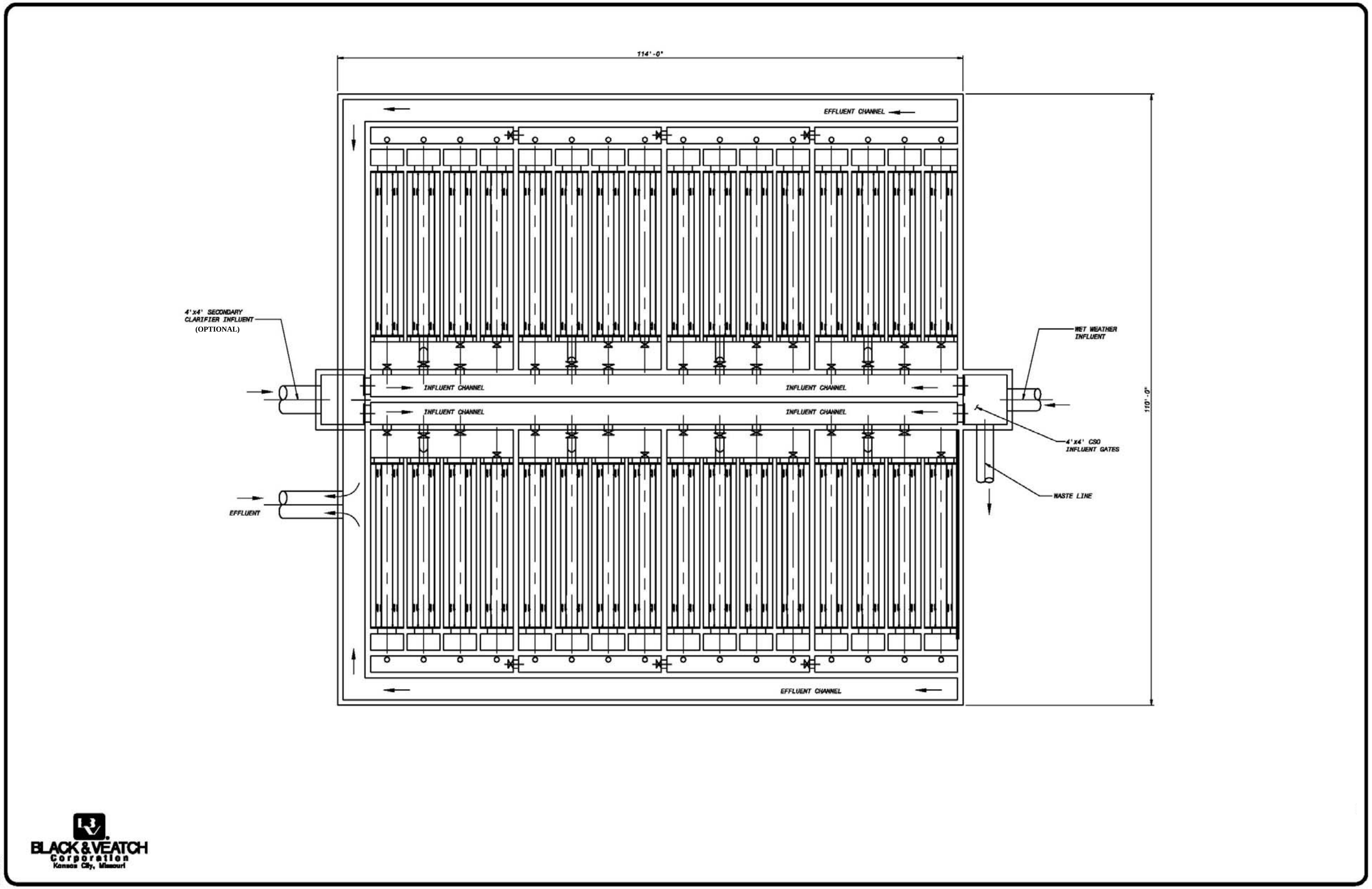

Figure 42 – Preliminary Layout of CMF Building

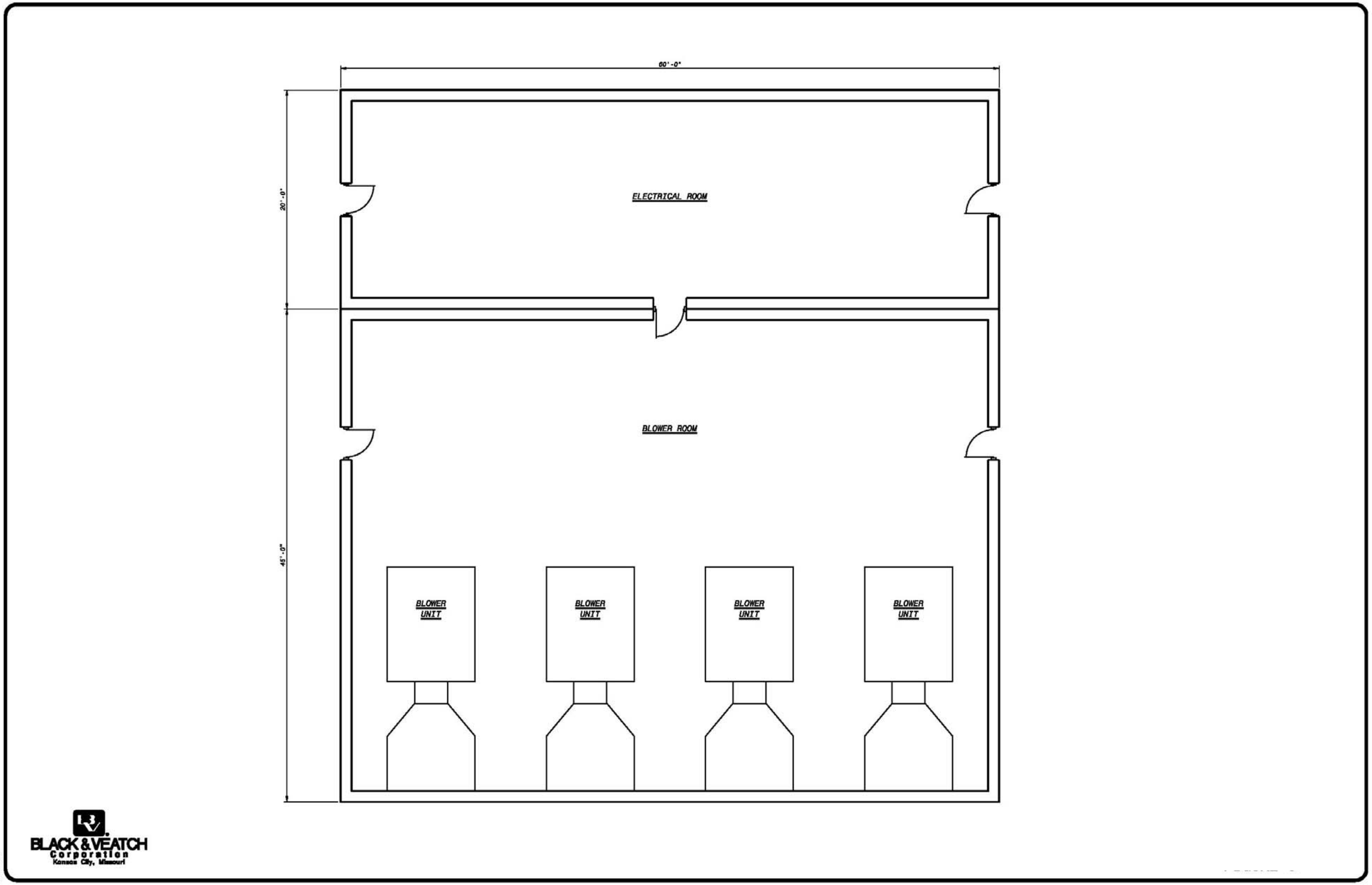

Figure 43 – Preliminary Layout of CMF Blower Building

7.3.3 Proposed Improvements

New structures would be constructed to house the components of the HRF system. As mentioned previously, fine screen facilities will be required upstream of the HRF facility. The compressible media system, though, has less stringent screening requirements than the Actiflo system and ½ inch bar screen media is recommended. Furthermore, since the entire WPF will likely be fitted with ½ inch screens in the future, there are no specific screening requirements that should be associated with Alternative 2. Therefore, costs for additional screening and grit removal have not been added to this alternative's project cost presented later within this technical memorandum. All flow reaching the proposed HRF facilities will have already been screened to ½ inch by the proposed WPF improvements. Only the Actiflo facility would require additional ¼ inch screening. Refer to TM-CSO-12/TM-WW-3 for further evaluation of wet weather screening and grit removal alternatives. Refer to TM-CSO-11/TM-WW-5 for further evaluation of disinfection alternatives downstream of the compressible media HRF system.

Figure 44 provides a general layout of the proposed compressible media HRF facilities. The proposed HRF facilities are shown in red. Figure 44 also shows in yellow other new facilities (i.e., Effluent Pump Station and UV Disinfection Facilities) related to the HRF and WPF improvements to demonstrate how the two systems might interface. This arrangement should be considered preliminary. Final location of these facilities will be determined once all land acquisition needs have been identified and final design is performed.

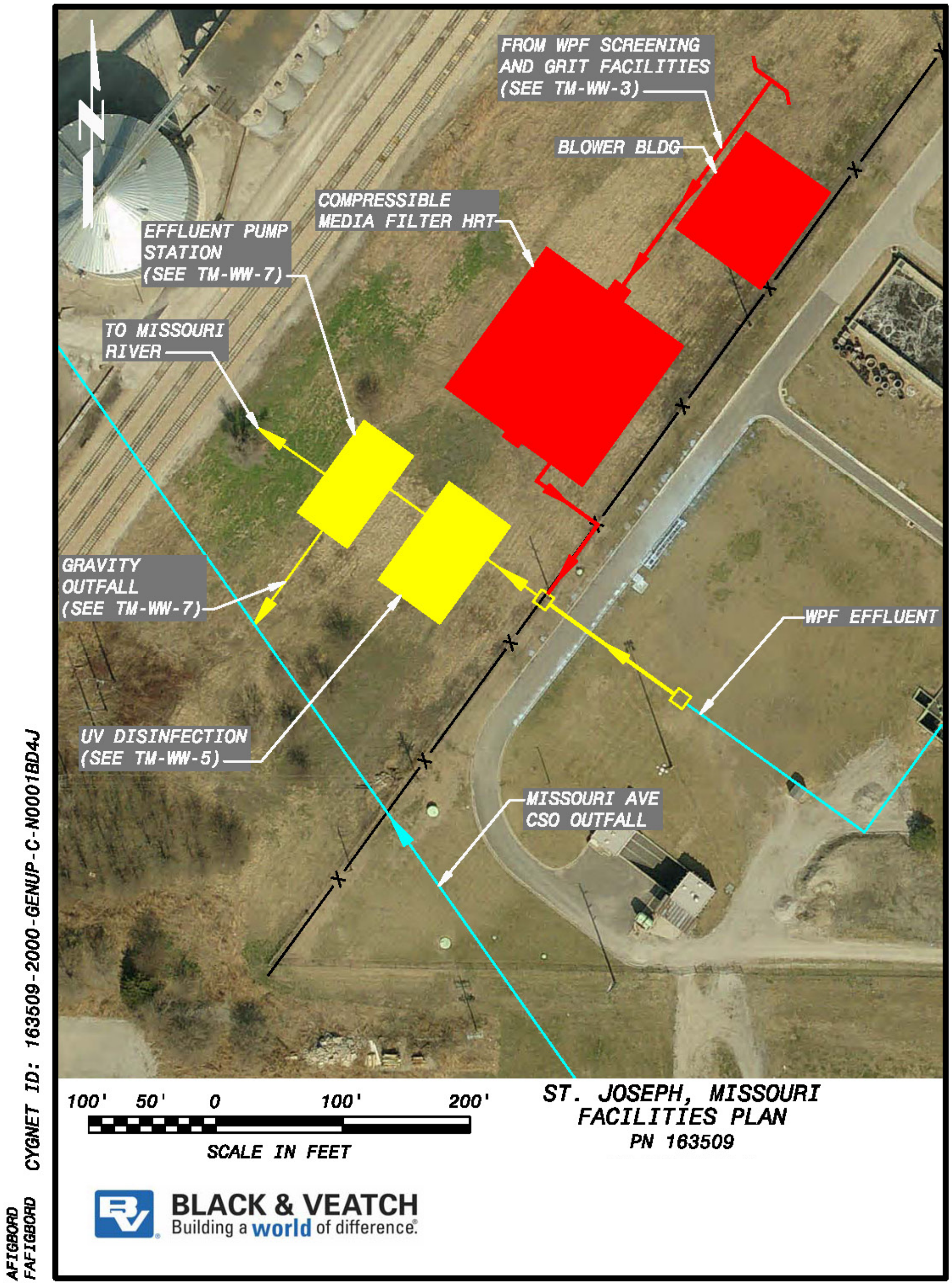

Figure 44 – Preliminary Site Layout of Alternative 2: Compressible Media Filter

7.3.4 Optional Dual Dry Weather Use

Alternative 2 can be modified by adding another influent line from the secondary clarifiers to provide tertiary filtration during dry weather. During times when not used for wet weather conditions, the filter system could receive effluent from the WPF secondary clarifiers. The lower solids loading rates during dry weather operations would result in significantly less backwash volume through longer filter service runs than during wet weather operations. During wet weather operations, the effluent from the secondary clarifiers would not be filtered.

Wet weather conditions would establish the worst-case design criteria for this facility. Therefore, the design criteria presented for Alternative 2 would still apply. In tertiary filtration mode, filter cell run times are anticipated to be at least 24 hours as opposed to the 2 to 5 hour run times (depending upon solids loading) anticipated during wet weather operations. This should result in tertiary backwash volumes of approximately 0.5 percent of the treated volume as opposed to the 2 to 5 percent backwash volumes anticipated during wet weather operations. This is an important consideration for estimating O&M costs if dry weather filtration is to be used.

Using the CMF for dual purposes would require two inlet boxes and gates, one set for secondary clarifier effluent during dry weather and one set for wet weather influent. Also, additional head losses would result from having this filter in-line with the rest of the WPF processes. Further discussions about the anticipated head losses will be presented in TM-WW-7 – Hydraulic Analysis and Effluent Pump Station. A preliminary layout of the tertiary treatment option is shown on Figure 45. Final location of these facilities will be determined once all land acquisition needs have been identified and final design is performed.

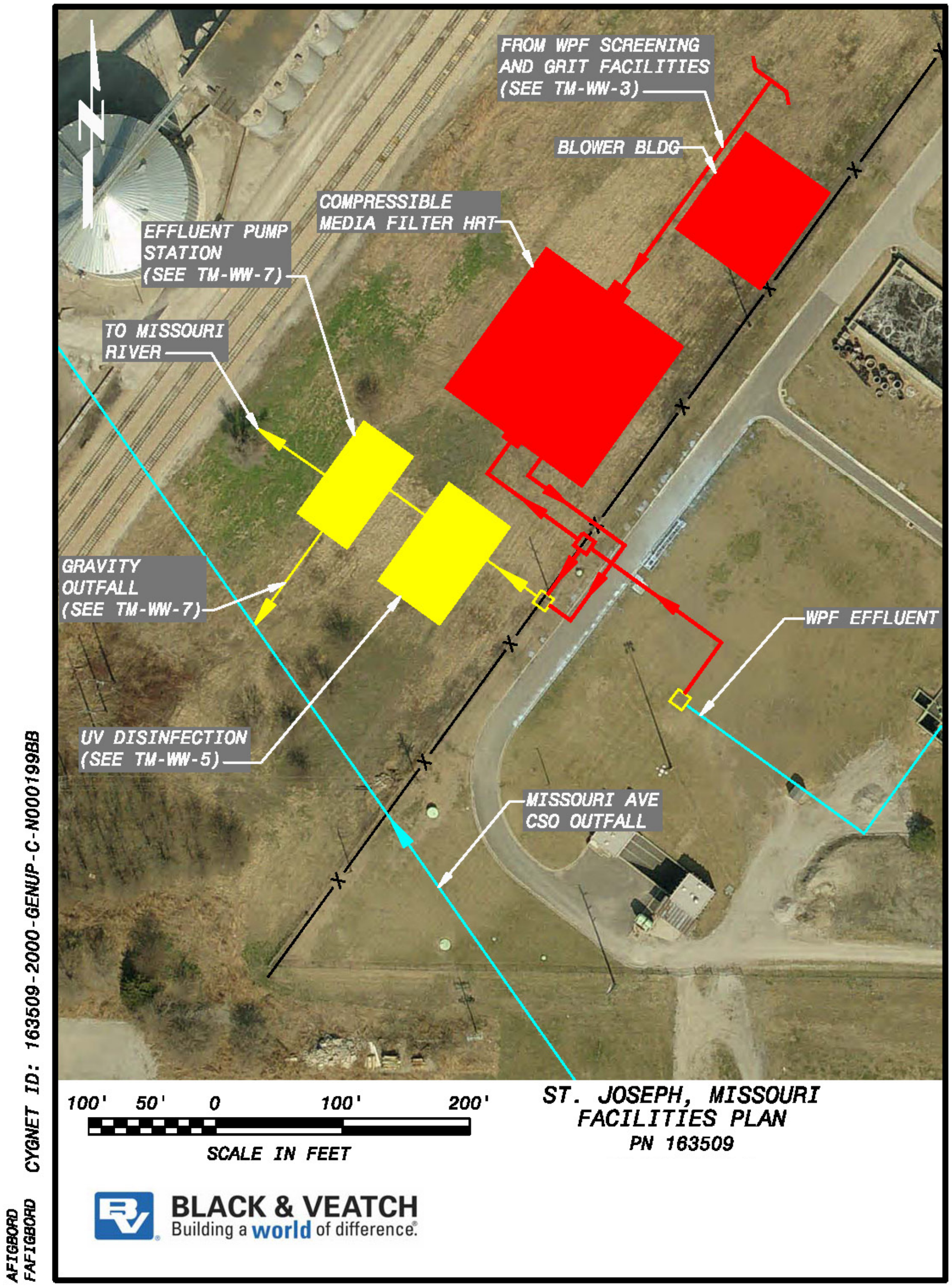

Figure 45 – Preliminary Site Layout of Alternative 2: Compressible Media Filter with Optional Tertiary Treatment

8.0 Evaluation of Alternatives

The three HRT alternatives (Alternative 1A – Ballasted Flocculation HRC, Alternative 1B – Sludge Recirculation HRC, and Alternative 2 – Compressible Media HRF) were evaluated based on economic and non-economic criteria. This section describes the results of this analysis.

8.1 Economic Factors and Considerations

The economic evaluation of the three HRT alternatives was based on life cycle costs using a 20-year present worth basis. The following sections present the capital and O&M costs developed for each alternative.

8.1.1 Opinion of Probable Project Costs

A conceptual cost estimating methodology was employed to develop capital project costs for the proposed high rate treatment processes. All project costs are given in May 2009 dollars (Engineering News Record (ENR) Building Cost Index (BCI) equal to 4773).

The building costs were developed based on brick and block wall construction. It is anticipated that these facilities must be founded on piles approximately 75 feet below grade based on past construction at the WPF. Equipment costs were based on vendor quotes, and equipment installation was projected at 40 percent of the equipment cost for all equipment.

In addition to building, structure, and equipment costs projected directly, other construction costs were projected by applying a percentage to appropriate project costs as indicated in Footnotes 4 and 5 of Table 8. The cost for electrical and instrumentation and controls (I&C) was projected at 25 percent of the cost of equipment, installation, and structures. This electrical and I&C cost does not include any new or back-up power feeds; these facilities will be evaluated in TM-WW-9 – Site Considerations, Utility Improvements, and Ancillary Facilities. An allowance of 10 percent was applied for project sitework. Contractor general requirements were projected at 12 percent and contingency was set at 25 percent. Costs related to engineering, legal, and administration are reflected in a 20 percent multiplier applied to all construction costs.

Additional site related costs are also reflected in the capital costs given in Table 8. The costs reflected in the table are shown as placeholders as the final site location for the facilities must be known in order to provide a more accurate projection of the site associated costs. Site area for each alternative was projected as the footprint of any building or structures required for the alternative plus an approximate 50-foot buffer around the facility. The flood protection line item projects the amount of fill soil required to bring the future facility site up to the approximate elevation of the WPF (approximate El 816). It was projected that five feet of fill would be required. As most of the potential locations for siting the facilities are located on industrial land with unknown environmental history, a placeholder for site remediation was also included. A unit cost of $150 per cubic yard of soil removed, considering a five foot depth over the area of the site. In addition, five feet of fill dirt would be utilized to replace the five feet of contaminated soil removed. This number should be considered as only a placeholder as site remediation costs are very specific to the site location and type of contamination encountered. Likewise, land acquisition costs were projected at $1.33 per square foot based on preliminary guidance from the City; this value was based on the purchase price of the property located to the south of the WPF. Actual land costs may vary significantly based on the site chosen. Determination of site related costs must be revisited once the actual site selection(s) have been finalized.

Based on the current schedule of the LTCP, construction of the HRT facilities will not take place for approximately 15 years. Given the recent volatility in the costs of construction materials for these alternatives as well as the costs of operating chemicals for the HRC alternatives, it is recommended that the costs for each alternative be reevaluated in a pre-design phase closer to the planned construction date.

The total opinion of probable project cost for Alternative 1A and 1B is approximately $32.3 million and $31.5 million, respectively. A summary of the project costs for this option is presented in Table 8. The costs include the HRC facility, the chemical feed and storage building, miscellaneous yard structures, and upstream and downstream piping to connect to other facilities. The Actiflo facility (Alternative 1A) would require an additional screening facility that would not be required by the DensaDeg facility (Alternative 1B). The project costs for Alternative 1A presented herein accounts for the additional ¼ inch fine screening required for this process. Basic screening requirements for the remaining HRT options and WPF are presented in TM-CSO-12/TM-WW-3.

Although the preliminary layouts on Figure 44 are based upon the WWETCO compressible media filter, the Schreiber Fuzzy Filter is another viable compressible media filter technology. For budgetary planning purposes, the total opinion of probable project cost for Alternative 2 is based on the WWETCO technology which is approximately $40.3 million. A summary of the project costs for this option is presented in Table 8. The costs include the compressible media filter facility, blower building, miscellaneous yard structures, and upstream and downstream piping to connect to other facilities.

Appendix A presents additional details of the development of the conceptual capital costs.

Table 8
Summary of Opinion of Probable Project Costs [1]

Item	Alternative 1A Actiflo HRC, $	Alternative 1B DensaDeg HRC, $	Alternative 2 WWETCO CMF, $
Wet Weather Treatment Facility			
Structure, Valves, and Piping	3,521,000	4,078,000	5,864,000
Equipment	4,480,000	5,180,000	5,495,000
Chemical Storage/Blower Building			
Structure, Valves, and Piping	1,616,000	1,616,000	2,124,000
Equipment	203,000	203,000	1,092,000
Screening Building [2]			
Structure, Valves, and Piping	548,000	Base screening costs are presented in TM-CSO-12	Base screening costs are presented in TM-CSO-12
Equipment	1,353,000	Base screening costs are presented in TM-CSO-12	Base screening costs are presented in TM-CSO-12
Miscellaneous Yard Structures and Piping	1,310,000	1,310,000	1,310,000
Flood Protection/Fill (placeholder) [3]	202,000	263,000	332,000
Site Remediation (placeholder) [3]	1,211,000	1,577,000	1,993,000
Subtotal	*14,444,000*	*14,227,000*	*18,210,000*
Electrical, I&C, Sitework, Contractor General Requirements [4]	7,037,000	6,689,000	8,578,000
Subtotal	*21,481,000*	*20,916,000*	*26,788,000*
Contingency [5]	5,370,000	5,229,000	6,697,000
Land Acquisition (placeholder) [3, 6]	58,000	76,000	95,000
Opinion of Probable Construction Cost	**26,910,000**	**26,221,000**	**33,580,000**
Engineering, Legal, and Administration [7]	5,382,000	5,244,000	6,716,000
Opinion of Total Project Cost	**32,292,000**	**31,465,000**	**40,296,000**

Table 8
Summary of Opinion of Probable Project Costs [1]

Item	Alternative 1A Actiflo HRC, $	Alternative 1B DensaDeg HRC, $	Alternative 2 WWETCO CMF, $

1. All costs presented in May 2009 dollars (ENR BCI = 4773).
2. An Actiflo facility will require an additional fine screening facility not required by the other alternatives. The additional screening costs for Actiflo are presented herein. The base screening costs for the remaining wet weather alternatives are presented in TM-CSO-12/TM-WW-3 – Screening and Grit Removal Facilities.
3. Site related costs are placeholders and must be revised following final siting of the facilities. Site related costs are provided for the site area required for the HRT facilities.
4. Electrical and instrumentation and controls (I&C) projected at 25% of the total of all equipment and structure costs. The electrical and I&C cost does not include any new or back-up power feeds; these facilities will be evaluated in TM-WW-9 – Site Considerations, Utility Improvements, and Ancillary Facilities. Sitework projected at 10% of the total of equipment, structures, electrical, and I&C costs. Contractor general requirements projected at 12% of the total of equipment, structures, electrical, I&C, and sitework costs.
5. Project contingency is projected at 25% of the total of all equipment, structures, electrical, I&C, sitework, contractor general requirements, flood protection/fill, and site remediation costs.
6. Land acquisition cost is based on a projection provided by the City from a recent purchase of land directly south of the WPF.
7. Engineering, legal, and administration (ELA) costs are projected at 20% of the total of all equipment, structures, electrical, I&C, sitework, contractor general requirements, flood protection/fill, site remediation costs, contingency, and land acquisition.

8.1.2 Opinion of Probable Operations and Maintenance Costs

Opinion of probable O&M costs were determined for the proposed high rate treatment facility alternatives. O&M costs associated with HRT are dependent upon the volume of flow that the facilities treat. Therefore, O&M cost projections for each alternative are based on providing wet weather suspended solids treatment for volumes associated with average annual conditions.

The approximate wet weather volumes and corresponding O&M costs for the proposed treatment and disinfection processes were determined by reviewing historical WPF inflow data, rainfall data, and LTCP CSO typical year modeling results. Eight years of rainfall data, from 2000 to 2008, were reviewed in St. Joseph, Missouri to determine the annual and recreational season average number of wet weather events. A wet weather event is defined as a rainfall event followed by a specified period of dry weather. Since the eight year St. Joseph rainfall data was provided in daily depths, it was assumed that periods of rainfall (either one day or multiple days) followed by a dry day with no rain defined a wet weather event. Wet weather treatment and disinfection facilities are assumed to operate continuously during a wet weather event (i.e., the facilities operate for the entire duration of the event, independent from the passage of one calendar day).

Table 9 provides both the annual and recreation season average number of rainy days and wet weather events from the eight years of rainfall data analyzed. Disinfection facilities are assumed to only operate during the recreation season while the wet weather high rate treatment facilities (i.e., Actiflo, DensaDeg, Filtration, etc.) are assumed to operate year round.

Table 9
Wet Weather Event Statistics from St. Joseph, Missouri

Time Period	Days with Rainfall	Wet Weather Events
Annual Average	74	50
Missouri Recreation Season (April 1 – October 31)	52	34

Three years (2006 through 2008) of historical WPF flows were also analyzed. A statistical analysis was performed on the historical flows to determine the number of days that the facility treated wet weather flows. There was a strong correlation between the observed historical WPF wet water day frequency and the rainfall rainy day frequency. In other words, the historical WPF data and the rainfall data both support that there are approximately, on average, 70 plus rainy days per year.

Table 10 presents the projected annual and recreation season wet weather treatment volumes using the statistics developed from the historical WPF flow data, rainfall data, and LTCP CSO typical year modeling.

Table 10
Annual Average Wet Weather Treatment Volume Delivered to WPF and HRT

Time Period	Total Wet Weather Treated Volume, MG	Wet Weather Treatment Volume Through 27 mgd WPF Headworks, MG	Wet Weather Treatment Volume Through Proposed 61 mgd High Rate Treatment, MG
Annual Average	1,860	550	1,310
Missouri Recreation Season (April 1 – October 31)	1,540	460	1,080

Notes
1. The volumes presented above do not account for dry weather flow volumes. Dry weather disinfection volumes and corresponding dry weather O&M costs are additional to those presented and derived from this table.
2. A "wet weather day" does not imply that the WPF and HRT operated continuously at *peak* capacity for an entire day. Most rain events are shorter than a day in duration and therefore would not cause the WPF or the HRT to have a daily average equal to their maximum capacity of 27 and 61 mgd, respectively. The volumes presented above are based on data acquired from modeling and historical WPF flows.

From review of Table 10, it is projected that 1,860 million gallons (MG) of flow would be treated during the approximately 74 rainy days per year. Of this total volume, 1,310 MG of flow is projected to be treated by the proposed HRT facilities. The actual number and duration of rain events and wet weather HRT volume occurring during any given year will vary widely from the average. These projected values represent the anticipated long term average volumes that will be used to derive O&M costs for the HRT alternative.

Table 11 presents the unit costs employed for HRT O&M cost development. Unit costs shown in Table 11 for power and labor were provided by the City. The remaining chemical unit costs are based on current costs obtained by Black & Veatch. Annual O&M costs for each alternative calculated were determined by multiplying the unit costs in Table 11 by the quantities needed to treat the anticipated wet weather HRT volume. The anticipated O&M costs are presented in Table 12. Appendix B provides additional detail on the development of the O&M costs.

Table 11
O&M Unit Costs [1]

General	
Power [2]	$0.10/kW-hr
Labor (including benefits and overhead) [2]	$32.78/hr
Chemicals	
Alum	$1.07/gal
Polymer	$10.00/gal
Microsand (for Actiflo)	$0.11/lb

1. All costs provided in May 2009 dollars. Except for those indicated as City provided, all unit costs based on Black & Veatch project experience.
2. Units costs based on data provided by the City.

Table 12
Average Annual O&M Costs[1] by Alternative

	Alternative 1A Actiflo HRC, $	Alternative 1B DensaDeg HRC, $	Alternative 2 WWETCO CMF, $
Wet Weather	307,000	297,000	23,000

8.1.3 Opinion of Probable Net Present Worth Costs

The project capital and O&M costs were used to develop life cycle costs for each alternative on a present worth basis. The present worth provides the equivalent amount of money that must be invested at a given interest rate at the start of the project in order to provide all funds necessary to construct, operate, and maintain the facilities and equipment throughout the design life of the project. The net present worth of an alternative is the sum of the present worth of the project capital and O&M costs less any remaining value of facilities at the end of the project's design life. By capturing both project capital and O&M expenses associated with the project, the net present worth method allows the City to understand the full life cycle cost associated with each alternative.

Table 13 presents a summary of the projected net present worth costs developed for each alternative. A 20-year design life was utilized in the present worth calculations; 2009 was assumed as "Year 0" for consistency of present worth calculations throughout the Facilities Plan. A five percent interest rate was applied for present worth calculations. Service life for determination of replacement frequency and salvage value was projected as follows: structures – 50 years and equipment, electrical, instrumentation and controls – 20 years.

Table 13
20-Year Net Present Worth Costs by Alternative [1]

	Alternative 1A Actiflo HRC, $	Alternative 1B DensaDeg HRC, $	Alternative 2 WWETCO CMF, $
Net Project Capital Present Worth [2]	26,145,000	25,311,000	32,130,000
O&M Present Worth [3]	6,454,000	6,246,000	479,000
Total Net Present Worth	**32,599,000**	**31,557,000**	**32,609,000**

1. Costs are in May 2009 dollars. Present worth calculated with 20-year life cycle costs at 5% interest.
2. Net project capital present worth represents the present worth of project costs less the remaining value of facilities at the end of the 20-year life cycle. Service life for determination of replacement frequency and salvage value was projected as follows: structures – 50 years; equipment, electrical, instrumentation and controls – 20 years.
3. O&M costs were assumed to escalate at 5% per year.

As presented in Table 13, the 20-year net present worth costs between the alternatives are within 5 percent of each other. For conceptual level pricing, these alternatives would be considered equal on a net present worth basis. Although the CMF facility (Alternative 2) has significantly higher project capital costs than the HRC alternatives (Alternatives 1A and 1B), the CMF operating costs are significantly less than the HRC O&M costs that result from high chemical use. Appendix C provides additional detail on the calculation of the net present worth for each alternative.

8.1.4 Sensitivity of Cost to Wet Weather Flow Volumes

The O&M costs follow a linear relationship with respect to the treated volume. For example, if the wet weather treatment volumes of a specific year happen to be twice the annual average, then the O&M costs for that year would also be approximately double. Given that the annual O&M cost is projected to be approximately $300,000 for Alternatives 1A and 1B for average conditions, the City would need a funding mechanism in place to cover an additional $300,000 should the treated wet weather flow volume for a given year be double the projected average. The CMF O&M cost projection is roughly one order of magnitude less expensive than the HRC alternatives. Since the net present worth values of both alternatives are essentially equal, having smaller O&M cost fluctuations may make Alternative 2 more attractive.

8.1.5 Additional Cost Considerations

As design commences, there may be potential to optimize the design and refine the cost opinions in several areas, such as the following:

- Treatment Basin Superstructures. The current conceptual design assumes that the treatment basins will be entirely enclosed within a superstructure (block and brick walls, roof, HVAC, etc.). For Alternatives 1A and 1B, startup operations will require routine visual observations of the flocculation process in the treatment basins. For Alternative 1A, operations will require routine sampling at the hydrocyclones. Both of these activities may warrant a superstructure for operator protection during a storm event. Alternative 2 does not require operating staff at the treatment basins since the treatment process can be remotely monitored and controlled with instrumentation for liquid level, blower status, and valve status. Therefore, freeze protection is the primary function provided by the superstructure in Alternative 2. Alternate freeze protection measures should be considered as design progresses, such as maintaining some flow of secondary effluent through the filter cells.
- Blower Alternatives. The current conceptual design assumes that new dedicated blowers and a new blower building will be provided for backwashing the filter cells in Alternative 2. Refinement of this alternative could consider integrating the blower capacity of the WPF with that of the CMF facility. The WPF currently has excess blower capacity; however, future nitrification requirements will likely use at least some of

that capacity. Nevertheless, there appears to be some potential to optimize Alternative 2 by integrating its blower needs with the blower capacity of the WPF.

- Pilot Testing. Treatability testing in this assessment was only conducted for one wet weather event. Pilot-scale testing over multiple events may allow for further optimization of certain process design criteria. For example, Alternative 2 was sized based on a hydraulic loading rate of 10 gpm/ft^2, whereas pilot testing of this technology at other facilities has shown good results with loading rates as high as 12 to 15 gpm/ft^2, which could lower the system footprint and capital costs. Pilot testing of Alternative 1A or 1B would help to confirm the relatively low chemical dosages suggested by the jar tests conducted in this assessment.
- Stage of Technology Development. HRC in general is a more developed technology for sanitary sewer overflow (SSO)/CSO control than the CMF technologies, particularly the WWETCO version of CMF. On one hand utilizing a more developed technology could be regarded as an advantage for Alternatives 1A and 1B. However, designs are typically refined over time and there may be more potential for discovering cost savings as the WWETCO technology is further developed making Alternative 2 more economically favorable in the future.
- O&M Cost Variability. It should be noted that the O&M costs for Alternatives 1A and 1B are driven largely by the required chemicals with future costs that are unknown but have recently experienced significant volatility. The O&M costs for Alternative 2 are driven largely by the required blower electricity with future costs that are also unknown but with trends that have been fairly stable and much more predictable.

8.2 Non-Economic Considerations

Many factors besides conventional construction and O&M costs can affect a facility planning decision. Although such factors may be difficult to quantify, some of them may potentially have cost implications. The following sections describe several non-economic factors for the various alternatives and provide a summary of non-economic advantages and disadvantages.

8.2.1 Non-Economic Criteria

8.2.1.1 Health and Safety. The health and safety of the surrounding community and plant personnel is one factor to consider when selecting an HRT alternative. High rate clarification requires the use of coagulants and polymers. The coagulants are typically corrosive liquids, posing risks to the community during transportation and risks to plant personnel during storage and handling. Spill prevention measures and safe-handling procedures would be required. The polymers are not corrosive, but may be irritating to the skin and eyes and pose a slipping hazard if spilled.

Other potential safety hazards to plant personnel from these alternatives include falls into open basins, injuries from machinery and equipment, and confined space entries. Such hazards do not appear to be particularly greater for these alternatives compared to process units already operating at the WPF. Design, operating, and maintenance measures typical to the industry should mitigate such hazards.

8.2.1.2 Impacts on the Environment. Each of the technologies evaluated has been shown in the wastewater treatment industry to improve the quality of wet weather excess flows, producing an effluent that is amenable to the disinfection processes being considered by the City (refer to TM-CSO-11/TM-WW-5). The treatability testing conducted as a part of this assessment indicates that the HRC and CMF processes should produce similar effluent quality; however, the testing also indicated that the influent had a very low pH buffering capacity. With its use of coagulating chemicals, HRC processes pose more of a risk for low effluent pH excursions.

8.2.1.3 Operability and Maintenance. Wet-weather events are inherently unpredictable. Besides their normal tasks, plant operators may be faced with many unplanned tasks during a wet weather event (power losses, flooding, etc.). Therefore, having a treatment process that requires minimal operator interaction can be particularly advantageous for wet weather treatment. During startup, HRC processes require that the operator visually observe the flocculation process to make any required adjustments to the coagulant or polymer feed rates or other process adjustments such as flocculation mixer speed. During normal operation, the Actiflo HRC process also requires that the operator take samples at the hydrocyclones to monitor the sand inventory and periodically add sand to the system during the treatment event. The DensaDeg HRC process may require the operator to monitor sludge thicknesses during the treatment event to optimize the process. Filtration processes are typically monitored and controlled by level instrumentation, requiring very little operator interaction.

None of the HRT alternatives are anticipated to be particularly maintenance intensive compared to WPF process units already operating at the WPF. In other words, maintenance personal will have more equipment to service, but the actual wet weather servicing will be routine and similar to what is performed now. Preventative maintenance can be conducted between wet-weather events. The sand slurry pumps and hydrocyclones in the Actiflo process are the only pieces of equipment in these alternatives that are not currently installed at the WPF.

8.2.1.4 Process Flexibility. This factor refers to the ability to make adjustments to the process to handle different influent characteristics. Operations at other facilities have demonstrated that both the HRC and CMF processes are capable of handling significant variations in influent flows and concentrations and still produce consistent effluent quality. Chemical types, doses, and flocculation mixing intensity can generally be adjusted somewhat in the HRC processes to optimize the high rate clarification process. However, the influent during the test event in April exhibited low buffering capacity, indicating that large coagulant doses may not be feasible for this particular application, although alternate coagulants with basicity (such as a polyaluminum chloride) or alkalinity supplementation could be considered. CMF processes accommodate changes in influent solids loading by automatically adjusting filter backwash frequency based on the level of influent above the filter media. Although testing did not indicate any need for it, chemical coagulation and flocculation can be conducted upstream of CMF to further enhance solids capture.

Another aspect that is unique to wet weather HRT applications is the feasibility that the wet weather facilities could perform other functions when they are not being used for wet weather treatment. For example, the HRC processes could be designed to provide additional primary treatment redundancy or be designed to provide tertiary phosphorus removal during normal dry weather conditions. However, HRC use during dry weather would require chemical dosing which could have significant cost implications. The CMF process could be designed to provide tertiary filtration during dry weather. Although this is not anticipated to be required to consistently meet effluent permit limits, tertiary filtration upstream of the disinfection process would provide a "safety net" to the existing WPF secondary clarifiers, would likely decrease disinfection operating costs (lower disinfectant dosage and cleaning requirements), and would provide a cost-effective method for routinely exercising the filtration equipment and providing freeze-protection of the filter beds.

8.2.1.5 Constructability. The alternatives do not appear to be significantly different in terms of ease of construction or construction methods. At this stage of the project, site selection has not been finalized and underground investigations (soil borings, etc.) have not been conducted. The HRC alternatives have a smaller footprint than the CMF alternatives, but have deeper basin depths than the CMF alternatives.

8.2.1.6 Permitting Issues. The alternatives do not appear to be significantly different in terms of the ability to obtain construction or operating permits. Black & Veatch is not aware of any HRC or CMF processes operating in Missouri for CSO control; however, there are approximately 20 HRC installations currently operating in the United States for either SSO or CSO control and approximately six CMF installations currently operating in the United States for either CSO or stormwater treatment. MDNR has permitted conventional clarification for wet weather excess flow treatment at many wastewater treatment plants across the state and both HRC and CMF should provide superior effluent quality than the unassisted gravity settling typically used in wet weather clarifiers. The City of Lawrence, Kansas operates an Actiflo facility permitted by the Kansas Department of Health and Environment (KDHE) for SSO control. MDNR has approved CMF as an acceptable technology for tertiary filtration (e.g. Rogersville, Missouri). As discussed elsewhere in this TM, there are still significant regulatory issues that remain unresolved within the wastewater treatment industry with respect to wet weather treatment; however, both HRC and CMF technologies are state of the art methods for achieving the treatment goals outlined in USEPA's CSO Control Policy.

8.2.1.7 Expandability. The alternatives are comparable in terms of their ability to accommodate future flow increases. Expanding for future flows should be considered in design. At this stage of the project, site selection has not been finalized, which could present additional constraints. The proposed layout for the Actiflo HRC system could be expanded by adding treatment modules adjacent to and northwest of the layout shown in Figure 36 and Figure 38. The proposed layout for the DensaDeg HRC system and the CMF system could most easily be expanded by adding treatment modules to the influent end of the current layout expanding the facility in a northeasterly direction (refer to Figure 41 for aerial view). The chemical/blower building in these alternatives will need to be arranged such that it can be expanded without interfering with the expansion of the HRC/HRF basins.

8.2.1.8 Public Acceptance. The alternatives do not appear to be significantly different in terms of general public acceptance. However, this factor would likely play a much larger role if the facilities are constructed in an area that is more accessible to the general public.

8.2.2 Non-Economic Evaluation

Table 14 presents a summary of comparative advantages and disadvantages for the different HRT technologies being considered.

Table 14
Non-Economic Advantages/Disadvantages of HRT Technologies

Treatment Method	Advantages	Disadvantages
HRC	• More reference installations	• Chemical hazards • Risk of low effluent pH excursions • Operating staff required at treatment basins during startup makes remote operation unfeasible
CMF	• No chemicals required • Simpler to operate, remote operation is feasible • Acceptable for tertiary filtration	• Few reference installations for SSO/CSO control

9.0 Conclusions and Recommendations

Based on the current schedule of the revised LTCP, the need to construct HRT facilities is up to 15 years away. Therefore, it is not imperative that a specific technology be selected at this time and the City could realize advantages by deferring such a decision. Based on what is currently known, both Alternatives 1A and 1B (HRC) and Alternative 2 (CMF) appear to be viable options for the new HRT facilities and have essentially equivalent 20-year net present values (Alternative 1A - $32.6 million, Alternative 1B – $31.6 million, Alternative 2 – $32.6 million). Alternative 2 appears to have slightly higher capital costs, but lower O&M costs and offers more non-economic benefits. It also appears that Alternative 2 may have more opportunities to lower its capital costs than Alternatives 1A and 1B as these emerging CMF technologies become further refined and optimized. It would be to the City's benefit to monitor technology advancements and when the time comes to select a technology, proceed based on the knowledge acquired at that time.

The following steps are recommended as the City approaches the time to proceed with these improvements:

- Defer selecting the specific HRT technology until the actual time period wet weather treatment facilities must be implemented.
- Conduct additional pilot testing of the CMF technology over multiple wet-weather events to confirm process design criteria. During the pilot study,

influent samples of wet weather event flows should also be sent to HRC manufacturers to conduct additional jar tests to further evaluate coagulants and polymers and help confirm the process design criteria for the HRC technologies.

- Monitor changes in technologies between now and when the improvements need to be constructed. Revisit the economic and non-economic factors for these technologies to confirm which technology best meets the City's needs.
- Consider a pre-selection process to select a specific technology prior to design. The different HRT alternatives require different equipment and different facility designs; therefore, the equipment should be pre-selected prior to detailed design of the facilities. The information presented herein can be updated at that time to select the most appropriate wet weather technology.

10.0 References

The following references were used in the preparation of this memorandum:

- TM-CSO-3a – Phase IA CSO Control Recommended Improvements Model (Black & Veatch, June 18, 2009).

Appendix A

Opinion of Probable Capital Cost Breakdown

St. Joseph, Missouri
TM-CSO-10 - Wet Weather Treatment Facilities
Alternative 1A - Actiflo HRC

Item Description	Units	Unit Cost	Quantity	Total Cost
Ballasted Flocculation Building				
110' by 55' Building Superstructure (Single Story)	sq ft	170.00	6,050	1,028,500
Earthwork				
Structural Excavation	cu yd	20.00	4,163	83,267
Compacted Fill	cu yd	25.00	623	15,583
Granular Fill	cu yd	35.00	126	4,416
Piling	each	3,900.00	121	471,900
Sheeting and Dewatering	LS			150,000
Concrete				
Slab on Grade/Footings	cu yd	530.00	395	209,350
Walls	cu yd	850.00	860	731,000
Suspended Slab and Beams	cu yd	950.00	246	233,700
Embedded Accessories	LS			30,020
Metal				
Grating	sq ft	45.00	2,500	112,500
Stairs and Landing	LS			25,000
Painting	LS			70,000
Process Piping	LS			80,000
HVAC	sq ft	30.00	6,050	181,500
Plumbing	sq ft	10.00	6,050	60,500
Fire Protection	sq ft	4.00	6,050	24,200
Lightning Protection	LS			10,000
Ballasted Flocculation Building				***3,521,000***
Chemical Building				
55' by 60' Building Superstructure (Single Story)	sq ft	190.00	3,300	627,000
Earthwork				
Structural Excavation	cu yd	20.00	909	18,181
Compacted Fill	cu yd	25.00	172	4,297
Granular Fill	cu yd	35.00	70	2,447
Piling	each	4,875.00	76	370,500
Sheeting and Dewatering	LS			
Concrete				
Slab on Grade/Footings	cu yd	530.00	300	159,000
Walls	cu yd	850.00	75	63,750
Suspended Slab and Beams	cu yd	950.00	10	9,500
Embedded Accessories	LS			7,700
Metal				
Handrail	ln ft	60.00	65	3,900
Painting	LS			50,000
Process piping	LS			100,000
HVAC	sq ft	30.00	3,300	99,000
Plumbing	sq ft	25.00	3,300	82,500
Fire Protection	sq ft	4.00	3,300	13,200
Lightning Protection	LS			5,000
Chemical Feed and Storage Building Subtotal				***1,616,000***
Fine Screen Building				
25' by 30' Building Superstructure (Single Story)	sq ft	235.62	750	176,715
Earthwork				
Structural Excavation	cu yd	20.00	622	12,439
Compacted Fill	cu yd	25.00	220	5,500
Granular Fill	cu yd	35.00	19	660
Piling	each	4,875.00	28	136,500
Sheeting and Dewatering	LS			
Concrete				
Slab on Grade/Footings	cu yd	530.00	38	19,978
Walls	cu yd	850.00	80	67,882
Suspended Slab and Beams	cu yd	950.00	28	26,389
Embedded Accessories	LS			2,907
Metal				
Handrail	ln ft	60.00	-	-
Painting	LS			50,000
Process piping	LS			-
HVAC	sq ft	30.00	750	22,500
Plumbing	sq ft	25.00	750	18,750
Fire Protection	sq ft	4.00	750	3,000
Lightning Protection	LS			5,000
Fine Screen Building				***548,000***
Ballasted Flocculation Equipment				
Actiflo Equipment per Kruger	LS			4,480,000
Ballasted Flocculation Equipment				***4,480,000***
Chemical Feed Equipment				
Polymer System	LS			91,000
Alum Feed System	LS			112,000
Chemical Feed Equipment Subtotal				***203,000***
Screening				
Fine Screens for ActiFlo	*each*	314,000.00	3	942,000
Washer Compactor	*each*	137,000.00	3	411,000
Screening Subtotal				***1,353,000***
Yard Piping/Structures				
60-inch UV Influent	LF	900.00	100	90,000
Junction Box	LS			50,000
60-inch Influent Line from Grit Facility	LF	900.00	1,300	1,170,000
Yard Piping/Structures Subtotal				***1,310,000***
Subtotal				***13,031,000***
Electrical, Instrumentation, & Controls	LS	25%		3,258,000
Subtotal				***16,289,000***
Sitework	LS	10%		1,629,000
Subtotal				***17,918,000***
General Requirements	LS	12%		2,150,000
Flood Protection (placeholder)	cu yd	25.00	8,075	201,875
Site Remediation (placeholder)	cu yd	150.00	8,075	1,211,000
Subtotal				***21,481,000***
Contingency	LS	25%		5,370,000
Land Acquisition (placeholder)	sq ft	1.33	43,605	58,000
Opinion of Probable Construction Cost				***26,909,000***
Engineering, Legal, & Administration	LS	20%		5,382,000
Opinion of Probable Project Cost				**32,291,000**

Structure or Other Non-Equipment Costs
Equipment Costs

St. Joseph, Missouri
TM-CSO-10 - Wet Weather Treatment Facilities
Alternative 1B - DensaDeg HRC

Item Description	Units	Unit Cost		Quantity	Total Cost
Sludge Recirculation Facility					
105' by 70' Building Superstructure (Single Story)	sq ft	160.00		7,350	1,176,000
Earthwork					
Structural Excavation	cu yd	20.00		4,985	99,706
Compacted Fill	cu yd	25.00		660	16,500
Granular Fill	cu yd	35.00		151	5,287
Piling	each	3,900.00		74	288,600
Sheeting and Dewatering	LS				150,000
Concrete					
Slab on Grade/Footings	cu yd	530.00		410	217,300
Walls	cu yd	850.00		1,420	1,207,000
Suspended Slab and Beams	cu yd	950.00		130	123,500
Embedded Accessories	LS				39,200
Metal					
Grating	sq ft	45.00		5,040	226,800
Stairs and Landing	LS				25,000
Painting	LS				70,000
Process Piping	LS				100,000
HVAC	sq ft	30.00		7,350	220,500
Plumbing	sq ft	10.00		7,350	73,500
Fire Protection	sq ft	4.00		7,350	29,400
Lightning Protection	LS				10,000
Slude Recirculation Facility Subtotal					**4,078,293**
Chemical Feed and Storage Building					
55' by 60' Building Superstructure (Single Story)	sq ft	190.00		3,300	627,000
Earthwork					
Structural Excavation	cu yd	20.00		909	18,181
Compacted Fill	cu yd	25.00		172	4,297
Granular Fill	cu yd	35.00		70	2,447
Piling	each	4,875.00		76	370,500
Sheeting and Dewatering	LS				
Concrete					
Slab on Grade/Footings	cu yd	530.00		300	159,000
Walls	cu yd	850.00		75	63,750
Suspended Slab and Beams	cu yd	950.00		10	9,500
Embedded Accessories	LS				7,700
Metal					
Handrail	in ft	60.00		65	3,900
Painting	LS				50,000
Process piping	LS				100,000
HVAC	sq ft	30.00		3,300	99,000
Plumbing	sq ft	25.00		3,300	82,500
Fire Protection	sq ft	4.00		3,300	13,200
Lightning Protection	LS				5,000
Chemical Feed and Storage Building Subtotal					***1,615,975***
Slude Recirculation Equipment Costs					
Equipment per DensaDeg	LS				5,180,000
Sludge Recirculation Equipment Subtotal					***5,180,000***
Chemical Equipment					
Polymer System	LS				91,000
Alum Feed System	LS				112,000
Chemical Equipment Subtotal					***203,000***
Screening					
Screen Costs Included in TM-WW-3	*LS*				**-**
Screening Subtotal					**-**
Yard Piping/Structures					
60-inch UV Influent	LF	900.00		100	90,000
Junction Box	LS				50,000
60-inch Influent Line from Grit Facility	LF	900.00		1,300	1,170,000
Yard Piping/Structures Subtotal					***1,310,000***
Subtotal					***12,387,269***
Electrical, Instrumentation, & Controls	LS	25%			3,097,000
Subtotal					***15,484,269***
Sitework	LS	10%			1,548,000
Subtotal					***17,032,000***
General Requirements	LS	12%			2,044,000
Flood Protection (placeholder)	cu yd	25.00		10,516	262,894
Site Remediation (placeholder)	cu yd	150.00		10,516	1,577,000
Subtotal					***20,916,000***
Contingency	LS	25%			5,229,000
Land Aqcuistion (placeholder)	sq ft	1.33		56,785	76,000
Opinion of Probable Construction Cost					***26,221,000***
Engineering, Legal, & Administration	LS	20%			5,244,000
Opinion of Probable Project Cost					**31,465,000**

Structure or Other Non-Equipment Costs
Equipment Costs

St. Joseph, Missouri
TM-CSO-10 - Wet Weather Treatment Facilities
Alternative 2 - WWETCO CMF

Item Description	Units	Unit Cost	Quantity	Total Cost
Compressible Media Filter Structure				
115' by 115' Filter Building	sq ft	150.00	13,225	1,983,750
Earthwork				
Structural Excavation	cu yd	20.00	8,727	174,536
Compacted Fill	cu yd	25.00	862	21,542
Granular Fill	cu yd	35.00	264	9,256
Piling	each	4,225.00	192	811,200
Sheeting and Dewatering	LS			150,000
Concrete				
Slabs, Wall, and Suspended Beams and Slabs	cu yd	750.00	2,550	1,912,500
Embedded Accessories	LS			51,000
Metal				
Grating	sq ft	45.00	1,540	69,300
Stairs and Landing	LS			25,000
Painting	LS			70,000
HVAC	sq ft	30.00	13,200	396,000
Plumbing	sq ft	10.00	13,200	132,000
Fire Protection	sq ft	4.00	13,200	52,800
Lightning Protection	LS			5,000
Compressible Media Filter Structure Subtotal				***5,864,000***
Blower/Electrical Building				
65' by 75' Blower Building	sq ft	170.00	4,875	828,750
Painting	LS			45,000
Earthwork				
Structural Excavation	cu yd	20.00	1,312	26,246
Compacted Fill	cu yd	25.00	208	5,200
Granular Fill	cu yd	35.00	101	3,533
Piling	each	4,875.00	76	370,500
Sheeting and Dewatering	LS			-
Concrete				
Slab on Grade/Footings	cu yd	530.00	125	66,250
Walls	cu yd	850.00	-	-
Suspended Slab and Beams	cu yd	950.00	-	-
Embedded Accessories	LS			2,500
Bower Piping	LS			500,000
Painting	LS			50,000
HVAC	sq ft	30.00	4,900	147,000
Plumbing	sq ft	10.00	4,900	49,000
Fire Protection	sq ft	4.00	4,900	19,600
Lightning Protection	LS			10,000
Blower/Electrical/Control Building Subtotal				***2,124,000***
Blower Equipment				
7,200 SCFM, 5 PSI, MultiStage, 300 HP Soft Start Blowers	each	257,600.00	4	1,030,400
Bridge Crane, 15 ton	LS			62,000
Blower Equipment Subtotal				***1,092,000***
Compressible Media Filter Equipment				
All Equipment, Appurtenances, and Controls (except for blowers)	LS			5,495,000
Compressible Media Filter Equipment Subtotal				***5,495,000***
Screening				
Screen Costs Included in TM-WW-3	*LS*			-
Screening Subtotal				**-**
Yard Piping/Structures				
60-inch UV influent	LF	900.00	100	90,000
Junction Box	LS			50,000
60-inch Influent Line from Grit Facility	LF	900.00	1,300	1,170,000
Yard Piping/Structures Subtotal				***1,310,000***
Subtotal				***15,885,000***
Electrical, Instrumentation, & Controls	LS	25%		3,971,000
Subtotal				***19,856,000***
Subtotal				***19,856,000***
Sitework	LS	10%		1,986,000
Subtotal				***21,842,000***
General Requirements	LS	12%		2,621,000
Flood Protection (placeholder)	cu yd	25.00	13,285	332,130
Site Remediation (placeholder)	cu yd	150.00	13,285	1,993,000
Subtotal				***26,788,000***
Contingency	LS	25%		6,697,000
Land Aqcuistion (placeholder)	sq ft	1.33	71,740	95,000
Opinion of Probable Construction Cost				***33,580,000***
Engineering, Legal, & Administration	LS	20%		6,716,000
Opinion of Probable Project Cost				**40,296,000**

Structure or Other Non-Equipment Costs
Equipment Costs

Appendix B

Opinion of Probable O&M Cost Breakdown

St. Joseph, Missouri
TM-CSO-10 - Wet Weather Treatment Facilities
Alternative 1A - Actiflo HRC
Operations and Maintenance Costs

	Quantity (per MG)	Unit	Cost/Unit, $	Cost per MG Treated, $	Volume (Annual Avg), MG	Annual Avg Cost, $
Polymer	14.3	gallons	$10.00	$143.00	1,310	$187,330
Alum	49	gallons	$1.07	$52.43	1,310	$68,683
Microsand (66 tons for start-up included in Kruger bid)	5	lb	$0.11	$0.55	1,310	$721
Power Cost	217	kW/MG	$0.10	$21.67	1,310	$28,392
Labor Cost (one person, 10 hrs)				$300 per event day	74 days / yr	$22,200
					Total Annual Cost	**$307,000**

St. Joseph, Missouri
TM-CSO-10 - Wet Weather Treatment Facilities
Alternative 1B - DensaDeg HRC
Operations and Maintenance Costs

	Quantity (per MG)	Unit	Cost/Unit, $	Cost per MG Treated, $	Volume (Annual Avg), MG	Annual Avg Cost, $
Polymer	14.3	gallons	$10.00	$143.00	1,310	$187,330
Alum	49	gallons	$1.07	$52.43	1,310	$68,683
Power Cost	146.68	kW/MG	$0.10	$14.67	1,310	$19,214
Labor Cost (one person, 10 hrs)				$300 per event day	74 days / yr	$22,200
				Total Annual Cost		**$297,000**

St. Joseph, Missouri
TM-CSO-10 - Wet Weather Treatment Facilities
Alternative 2 - WWETCO CMF
Operations and Maintenance Costs

Wet Weather

	Quantity	Unit	Cost/Unit, $	Cost per MG Treated, $	Volume (Annual Avg), MG	Annual Avg Cost, $
Power Cost	138.05	kW/MG	$0.10	$13.80	1,310	$18,084
Labor Costs (one person, 2 hrs)				$300 per event day	74 days / yr	$4,736
				Total Annual Wet Weather Cost		**$23,000**

Appendix C

Opinion of Probable Net Present Worth Breakdown

St. Joseph, Missouri

TM-CSO-10 - Wet Weather Treatment Facilities

Alternative 1A - Actiflo HRC

Net Present Worth

Capital Project Elements	1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461
Actiflo														
Structure	2009	50	$3,521,000	$3,521,000	$3,521,000	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$4,480,000	$4,480,000	$4,480,000	-	-	-	-	-	-	-	-	-
Chemical Feed Building														
Structure	2009	50	$1,616,000	$1,616,000	$1,616,000	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$203,000	$203,000	$203,000	-	-	-	-	-	-	-	-	-
Electrical, Instrumentation, and Controls	2009	20	$3,258,000	$3,258,000	$3,258,000	-	-	-	-	-	-	-	-	-
Yard Piping To UV	2009	50	$1,310,000	$1,310,000	$1,310,000	-	-	-	-	-	-	-	-	-
Fine Screening Building														
Strucutre	2009	50	$548,000	$548,000	$548,000	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$1,353,000	$1,353,000	$1,353,000	-	-	-	-	-	-	-	-	-
Land Acquisition	2009	10,000	$58,000	$58,000	$58,000	-	-	-	-	-	-	-	-	-
	2009			$0										
Sitework	2009		$1,629,000	$1,629,000	$1,629,000									
General Requirements	2009		$2,150,000	$2,150,000	$2,150,000									
Flood Protection/Fill (placeholder)	2009		$201,875	$201,875	$201,875									
Site Remediation (placeholder)	2009		$1,211,000	$1,211,000	$1,211,000									
Contingency	2009		$5,370,000	$5,370,000	$5,370,000									
Construction Subtotal			$26,908,875	$26,908,875	$26,908,875									
Engineering, Legal, and Administration 20%	2009		$5,381,775	$5,381,775	$5,381,775									
Interest During Construction (yrs)		0												
Opinion of Probable Project Cost			$32,290,000	$32,290,000	$32,290,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
Factored Totals					$32,290,000	$0	$0	$0	$0	$0	$0	$0	$0	$0

Capital Project Elements	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Actiflo															
Structure	-	-	-	-	-	-	-	-	-	-	-		$8,175,095		
Equipment	-	-	-	-	-	-	-	-	-	-	$17,336,186		$17,336,186		
Chemical Feed Building															
Structure	-	-	-	-	-	-	-	-	-	-	-		$3,752,046		
Equipment	-	-	-	-	-	-	-	-	-	-	$785,546		$785,546		
Electrical, Instrumentation, and Controls	-	-	-	-	-	-	-	-	-	-	$12,607,432		$12,607,432		
Yard Piping To UV	-	-	-	-	-	-	-	-	-	-	-		$3,041,572		
Fine Screening Building															
Strucutre	-	-	-	-	-	-	-	-	-	-	-		$1,272,352		
Equipment	-	-	-	-	-	-	-	-	-	-	$5,235,683		$5,235,683		
Land Acquisition	-	-	-	-	-	-	-	-	-	-	-	-	$57,884		
Sitework															
General Requirements															
Flood Protection/Fill (placeholder)															
Site Remediation (placeholder)															
Contingency															
Construction Subtotal											$35,960,000				
Engineering, Legal, and Administration 20%															
Interest During Construction (yrs)															
Opinion of Probable Project Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$35,960,000		$52,263,797		
Factored Totals	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,553,000	$45,843,000	19,697,675	$26,145,325	$2,100,000

O&M Elements	2009 Annual Cost ($)	2009 Year Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461
Power Costs	$28,392	$28,400	$28,400	$29,820	$31,311	$32,877	$34,520	$36,246	$38,059	$39,962	$41,960	$44,058
Labor Costs	$22,200	$22,200	$22,200	$23,310	$24,476	$25,699	$26,984	$28,333	$29,750	$31,238	$32,800	$34,439
Alum Costs	$68,683	$68,700	$68,700	$72,135	$75,742	$79,529	$83,505	$87,681	$92,065	$96,668	$101,501	$106,576
Polymer Costs	$187,330	$187,300	$187,300	$196,665	$206,498	$216,823	$227,664	$239,048	$251,000	$263,550	$276,727	$290,564
Microsand	$721	$700	$700	$735	$772	$810	$851	$893	$938	$985	$1,034	$1,086
Opinion of Probable O&M Cost	$307,326		307,300	322,665	338,798	355,738	373,525	392,201	411,811	432,402	454,022	476,723
Factored Totals			$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300

O&M Elements	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Power Costs	$46,261	$48,574	$51,002	$53,552	$56,230	$59,042	$61,994	$65,093	$68,348	$71,765	$75,354		
Labor Costs	$36,161	$37,970	$39,868	$41,861	$43,954	$46,152	$48,460	$50,883	$53,427	$56,098	$58,903		
Alum Costs	$111,905	$117,500	$123,375	$129,544	$136,021	$142,822	$149,963	$157,462	$165,335	$173,601	$182,282		
Polymer Costs	$305,092	$320,347	$336,364	$353,182	$370,841	$389,383	$408,852	$429,295	$450,760	$473,298	$496,963		
Microsand	$1,140	$1,197	$1,257	$1,320	$1,386	$1,455	$1,528	$1,604	$1,685	$1,769	$1,857		
Opinion of Probable O&M Cost	500,559	525,587	551,867	579,460	608,433	638,855	670,797	704,337	739,554	776,532	815,358		
Factored Totals	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$307,300	$6,454,000	$517,886

NET PRESENT WORTH = $32,599,325

$26,145,325
$6,454,000
$32,599,325

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773

St. Joseph, Missouri

TM-CSO-10 - Wet Weather Treatment Facilities

Alternative 1B - DensaDeg HRC

Net Present Worth

Capital Project Elements	1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Cost ($)	2009 Year 0 1.00000
DensaDeg	2009	50		$0	
Structure	2009	50	$4,078,293	$4,078,293	$4,078,293
Equipment	2009	20	$5,180,000	$5,180,000	$5,180,000
Chemical Feed Building	2009	50		$0	
Structure	2009	50	$1,615,975	$1,615,975	$1,615,975
Equipment	2009	20	$203,000	$203,000	$203,000
Electrical, Instrumentation, and Controls	2009	20	$3,097,000	$3,097,000	$3,097,000
Yard Piping To UV	2009	50	$1,310,000	$1,310,000	$1,310,000
	2009	100		$0	
	2009	100		$0	
Land Acquisition	2009	10,000	$76,000	$76,000	$76,000
	2009			$0	
Sitework	2009		$1,548,000	$1,548,000	$1,548,000
General Requirements	2009		$2,044,000	$2,044,000	$2,044,000
Flood Protection/Fill (placeholder)	2009		$262,894	$262,894	$262,894
Site Remediation (placeholder)	2009		$1,577,000	$1,577,000	$1,577,000
Contingency	2009		$5,229,000	$5,229,000	$5,229,000
Construction Subtotal			$26,221,162	$26,221,162	$26,221,162
Engineering, Legal, and Administration 20%	2009		$5,244,232	$5,244,232	$5,244,232
Interest During Construction (yrs)		0			
Opinion of Probable Project Cost			$31,470,000	$31,470,000	$31,470,000
Factored Totals					$31,470,000

Capital Project Elements	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
DensaDeg										
Structure	-	-	-	-	-	-	-	-	-	-
Equipment	-	-	-	-	-	-	-	-	-	-
Chemical Feed Building										
Structure	-	-	-	-	-	-	-	-	-	-
Equipment	-	-	-	-	-	-	-	-	-	-
Electrical, Instrumentation, and Controls	-	-	-	-	-	-	-	-	-	-
Yard Piping To UV	-	-	-	-	-	-	-	-	-	-
Land Acquisition	-	-	-	-	-	-	-	-	-	-
Sitework										
General Requirements										
Flood Protection/Fill (placeholder)										
Site Remediation (placeholder)										
Contingency										
Construction Subtotal										
Engineering, Legal, and Administration 20%										
Interest During Construction (yrs)										
Opinion of Probable Project Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Factored Totals	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Capital Project Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
DensaDeg														
Structure	-	-	-	-	-	-	-	-	-	-		$9,469,025		
Equipment	-	-	-	-	-	-	-	-	-	$20,044,966		$20,044,966		
Chemical Feed Building														
Structure	-	-	-	-	-	-	-	-	-	-		$3,751,989		
Equipment	-	-	-	-	-	-	-	-	-	$785,546		$785,546		
Electrical, Instrumentation, and Controls	-	-	-	-	-	-	-	-	-	$11,984,413		$11,984,413		
Yard Piping To UV	-	-	-	-	-	-	-	-	-	-		$3,041,572		
Land Acquisition	-	-	-	-	-	-	-	-	-	-	-	$75,848		
Sitework														
General Requirements														
Flood Protection/Fill (placeholder)														
Site Remediation (placeholder)														
Contingency														
Construction Subtotal										$32,810,000				
Engineering, Legal, and Administration 20%														
Interest During Construction (yrs)														
Opinion of Probable Project Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$32,810,000		$49,153,358		
Factored Totals	$0	$0	$0	$0	$0	$0	$0	$0	$0	$12,366,000	$43,836,000	18,525,384	$25,310,616	$2,000,000

O&M Elements	2009 Annual Cost ($)	2009 Year Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
Power Costs	$19,214	$19,200	$19,200	$20,160	$21,168	$22,226	$23,338	$24,505	$25,730	$27,016	$28,367	$29,786	$31,275
Labor Costs	$22,200	$22,200	$22,200	$23,310	$24,476	$25,699	$26,984	$28,333	$29,750	$31,238	$32,800	$34,439	$36,161
Alum Costs	$68,683	$68,700	$68,700	$72,135	$75,742	$79,529	$83,505	$87,681	$92,065	$96,668	$101,501	$106,576	$111,905
Polymer Costs	$187,330	$187,300	$187,300	$196,665	$206,498	$216,823	$227,664	$239,048	$251,000	$263,550	$276,727	$290,564	$305,092
Opinion of Probable O&M Cost	$297,428		297,400	312,270	327,884	344,278	361,492	379,566	398,544	418,472	439,395	461,365	484,433
Factored Totals			$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400

O&M Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Power Costs	$32,839	$34,480	$36,204	$38,015	$39,915	$41,911	$44,007	$46,207	$48,517	$50,943		
Labor Costs	$37,970	$39,868	$41,861	$43,954	$46,152	$48,460	$50,883	$53,427	$56,098	$58,903		
Alum Costs	$117,500	$123,375	$129,544	$136,021	$142,822	$149,963	$157,462	$165,335	$173,601	$182,282		
Polymer Costs	$320,347	$336,364	$353,182	$370,841	$389,383	$408,852	$429,295	$450,760	$473,298	$496,963		
Opinion of Probable O&M Cost	508,655	534,088	560,792	588,832	618,273	649,187	681,646	715,729	751,515	789,091		
Factored Totals	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$297,400	$6,246,000	$501,195

NET PRESENT WORTH = $31,556,616

$25,310,616
$6,246,000
$31,556,616

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773

St. Joseph, Missouri

TM-CSO-10 - Wet Weather Treatment Facilities

Alternative 2 - WWETCO CMF

Net Present Worth

Capital Project Elements	1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
Filter Structure	2009	50		$0											
Structure	2009	50	$5,864,000	$5,864,000	$5,864,000	-	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$5,495,000	$5,495,000	$5,495,000	-	-	-	-	-	-	-	-	-	-
Blower Building	2009	50		$0											
Structure	2009	50	$2,124,000	$2,124,000	$2,124,000	-	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$1,092,000	$1,092,000	$1,092,000	-	-	-	-	-	-	-	-	-	-
Electrical, Instrumentation, and Controls	2009	20	$3,971,000	$3,971,000	$3,971,000	-	-	-	-	-	-	-	-	-	-
Yard Piping To UV	2009	50	$1,310,000	$1,310,000	$1,310,000	-	-	-	-	-	-	-	-	-	-
	2009	100		$0											
	2009	100		$0											
Land Acquisition	2009	10,000	$95,000	$95,000	$95,000	-	-	-	-	-	-	-	-	-	-
	2009			$0											
Sitework	2009		$1,986,000	$1,986,000	$1,986,000										
General Requirements	2009		$2,621,000	$2,621,000	$2,621,000										
Flood Protection/Fill (placeholder)	2009		$332,130	$332,130	$332,130										
Site Remediation (placeholder)	2009		$1,993,000	$1,993,000	$1,993,000										
Contingency	2009		$6,697,000	$6,697,000	$6,697,000										
Construction Subtotal			$33,580,130	$33,580,130	$33,580,130										
Engineering, Legal, and Administration 20%	2009		$6,716,026	$6,716,026	$6,716,026										
Interest During Construction (yrs)		0													
Opinion of Probable Project Cost			$40,300,000	$40,300,000	$40,300,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Factored Totals					$40,300,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Capital Project Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Filter Structure														
Structure	-	-	-	-	-	-	-	-	-	-		$13,615,098		
Equipment	-	-	-	-	-	-	-	-	-	$21,263,916		$21,263,916		
Blower Building														
Structure	-	-	-	-	-	-	-	-	-	-		$4,931,526		
Equipment	-	-	-	-	-	-	-	-	-	$4,225,695		$4,225,695		
Electrical, Instrumentation, and Controls	-	-	-	-	-	-	-	-	-	$15,366,517		$15,366,517		
Yard Piping To UV	-	-	-	-	-	-	-	-	-	-		$3,041,572		
Land Acquisition	-	-	-	-	-	-	-	-	-	-	-	$94,810		
Sitework														
General Requirements														
Flood Protection/Fill (placeholder)														
Site Remediation (placeholder)														
Contingency														
Construction Subtotal										$40,860,000				
Engineering, Legal, and Administration 20%														
Interest During Construction (yrs)														
Opinion of Probable Project Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$40,860,000		$62,539,134		
Factored Totals	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,400,000	$55,700,000	23,570,342	$32,129,658	$2,600,000

O&M Elements	2009 Annual Cost ($)	2009 Year Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
Power Costs	$18,084	$18,100	$18,100	$19,005	$19,955	$20,953	$22,001	$23,101	$24,256	$25,469	$26,742	$28,079	$29,483
Labor Costs	$4,736	$4,700	$4,700	$4,935	$5,182	$5,441	$5,713	$5,999	$6,298	$6,613	$6,944	$7,291	$7,656
		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Opinion of Probable O&M Cost	$22,820		22,800	23,940	25,137	26,394	27,714	29,099	30,554	32,082	33,686	35,370	37,139
Factored Totals			$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800

O&M Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Power Costs	$30,957	$32,505	$34,130	$35,837	$37,629	$39,510	$41,486	$43,560	$45,738	$48,025		
Labor Costs	$8,039	$8,441	$8,863	$9,306	$9,771	$10,260	$10,772	$11,311	$11,877	$12,470		
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Opinion of Probable O&M Cost	38,996	40,946	42,993	45,142	47,400	49,770	52,258	54,871	57,614	60,495		
Factored Totals	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$22,800	$479,000	$38,436

NET PRESENT WORTH = $32,608,658

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773