



# High Rate Secondary Clarification For Wet Weather Applications



Prepared for  
Texas Water 2007

April 12, 2007

Prepared by:  
Nathen Myers and Randel West, P.E.



I. Kruger Inc.  
401 Harrison Oaks Blvd., Suite 100  
Cary, NC 27513



Chiang, Patel & Yerby, Inc.  
1820 Regal Row, Suite 200  
Dallas, TX 75235

# Table of Contents

---

Executive Summary .....	4
1.0 Technology Overview.....	5
High Rate Clarification (HRC) .....	5
High Rate Secondary Clarifier (HRSC).....	6
2.0 Murfreesboro, TN .....	9
Overview.....	9
Summary .....	10
3.0 Auburn, AL.....	12
Overview.....	12
Summary .....	13
4.0 Weig Cartonboard Mill, Mayen, Germany .....	15
Overview.....	15
Summary .....	16
5.0 Conclusion .....	18

## List of Figures and Tables

Figure 1.0: ACTIFLO Process Flow Diagram.....	5
Figure 1.1: ACTIFLO <sup>®</sup> High Rate Secondary Clarification Schematic .....	6
Figure 1.2: Example of a High Rate Secondary Clarification Plant Layout.....	7
Table 1.0: HRSC Design Summary .....	8
Figure 2.0: HRSC Pilot Plant Layout .....	9
Table 2.0: Murfreesboro HRSC Case Study Results .....	10
Table 2.1: Murfreesboro HRSC UVT Data .....	11
Table 2.2: Murfreesboro HRSC Case Study Results without Lamella Tubes .....	11
Table 3.0: Secondary Influent Characteristics .....	12
Figure 3.0: HRSC Pilot Plant Layout .....	13
Table 3.1: Results Summary for Varying Overflow Rates .....	14
Figure 4.0: Plant layout utilized during the case study.....	15
Figure 4.1: Case Study Data Summary.....	16

Table 4.0: Full Scale Economic Analysis .....	16
Figure 4.2: Full Scale Plant Layout including the HRSC .....	17
Table 5.0: HRSC Design Summary .....	18

### **List of Abbreviations**

BOD:	Biochemical Oxygen Demand
Capex:	Capital Expenditure
COD:	Chemical Oxygen Demand
CSO:	Combined Sewer Overflow
HRC:	High Rate Clarification/Clarifier
HRSC:	High Rate Secondary Clarification/Clarifier
MGD:	Million Gallons per Day
MLSS:	Mixed Liquor Suspended Solids
NTU:	Nephelometric Turbidity Units
Opex:	Operating Expenditure
RAS:	Return Activated Sludge
SSO:	Sanitary Sewer Overflow
SVI:	Sludge Volume Index
TKN:	Total Kjeldahl Nitrogen
TSS:	Total Suspended Solids
UVT:	Ultraviolet Transmissivity
VFD:	Variable Frequency Drive
WAS:	Waste Activated Sludge
WWTP:	Wastewater Treatment Plant

## **Executive Summary**

---

Many wastewater plants across the country experience operational difficulty during peak wet weather flows caused by storm events. Prolonged peak wet flows can cause problems at plants by hydraulically washing out the biological solids from secondary clarifiers. This causes poor effluent quality during the event and for a period after the storm passes due to a lack of biological solids left in the system. Typical aeration basins can handle large hydraulic events, the hydraulic bottleneck occurs at the secondary clarifier. Additional secondary clarifiers can be constructed to alleviate hydraulic overloading, but these units require large footprints are expensive to build and complicate operation during normal dry weather flows.

The ACTIFLO<sup>®</sup> process is a High Rate Clarification (HRC) process using microsand to ballast flocs and provide rapid settling. Recent pilot study results demonstrate that the HRC process can be successfully applied as a High Rate Secondary Clarification (HRSC) system following activated sludge systems. Sludge production from the HRSC system has a solids concentration comparable to that of traditional secondary clarifiers and is returned back to the biological plant as return activated sludge (RAS). Because the clarified effluent has been biologically treated in the aeration basins, it complies with secondary limits for TSS and BOD. The process also provides a rapid startup time, high peaking capacity, and very small footprint. Since the process reaches steady state conditions in minutes and has a footprint 10 to 15 times smaller than conventional clarifiers it is ideally suited for high rate secondary clarification of mixed liquor produced during peak wet weather flows. Supplementing traditional secondary clarification with high rate sedimentation will enable a treatment facility to sustain peak flows for longer periods of time while minimizing the potential for washout.

During dry weather flows the HRSC trains can be maintained offline. When plant flows reach the hydraulic capacity of the existing secondary clarifiers the HRSC trains are brought on line to treat the additional plant flow from the biological treatment process. Influent MLSS concentrations from the biological process are expected to be as high as 4,000 mg/l, but decrease as the period of a storm is increased.

Pilot studies conducted at a conventional municipal wastewater treatment facility and an industrial wastewater treatment facility employing biological treatment demonstrated the efficiency of the process. During the municipal wastewater study, the process received mixed liquor suspended solids at concentrations between 2,600 and 3,000 mg/l. Settled effluent from the process averaged less than 10 mg/l TSS and less than 5 mg/l BOD. During the industrial pilot study, the process received MLSS between 5,000 and 6,000 mg/l and the clarified effluent averaged less than 30 mg/l TSS. This paper details the operating conditions and results of these studies.

# 1.0 Technology Overview

## High Rate Clarification (HRC)

The HRC design is an ACTIFLO<sup>®</sup> process supplied by I. Kruger Inc. Cary, NC. The process is a proven, high performance, compact clarification system that utilizes micro-sand enhanced flocculation and settling. The microsand also enhances system stability, enabling the HRC process to produce a consistent high quality effluent despite changing raw water conditions such as flow rate or solids content. A coagulant is added to the raw water for destabilization of the colloids. The coagulated water then goes through a two-stage flocculation where micro-sand and polymer are added. The destabilized suspended solids bind to the micro-sand particles through polymer bridges creating extremely dense floc particles, which have excellent settling characteristics. This permits clarifier designs that have much shorter hydraulic retention times and much higher surface loading rates compared to conventional clarifiers. With the additional aid of lamellar settling tubes, the micro-sand ballasted floc particles then settle very rapidly. The sludge/micro-sand mixture collected at the bottom of the tube settler is continuously pumped by open-end centrifugal pumps to hydrocyclones, which separate the micro-sand from the residuals by the centrifugal force of the vortex action. The residuals are then discharged and the micro-sand is reinjected into the system. A general HRC process diagram is depicted in figure 1.0.

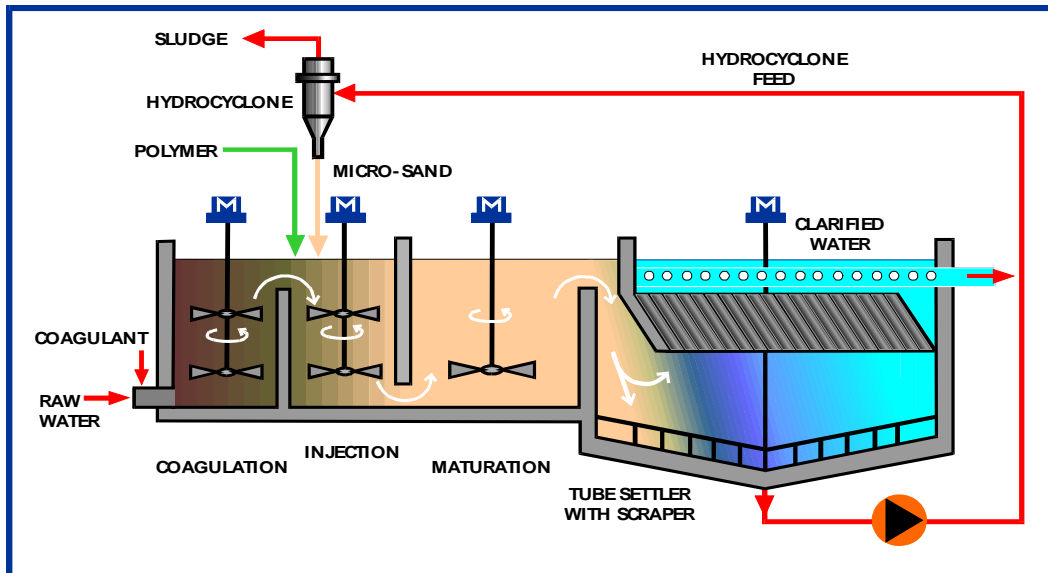


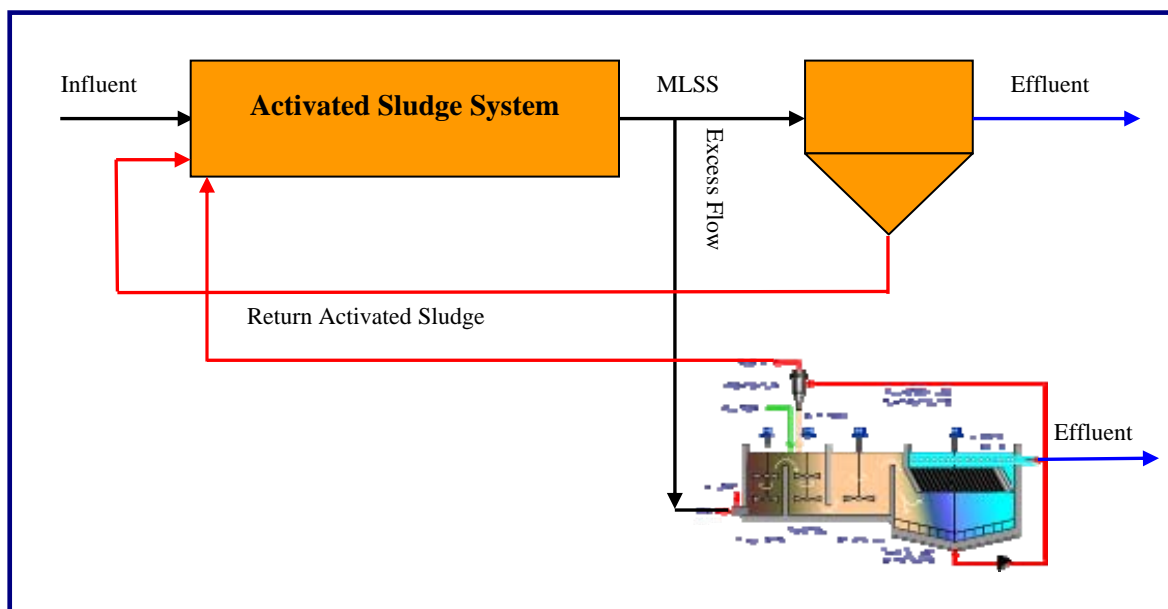
Figure 1.0: ACTIFLO Process Flow Diagram

The ACTIFLO<sup>®</sup> process has been successfully applied to treat wet weather flows in parallel with existing wastewater treatment plants. These plants experienced limited peaking capacity of the biological process and have limited available space for traditional treatment options. The HRC process has also been used as a satellite treatment facility located in the collection system in situations where active overflows cannot be effectively delivered to a central treatment facility. These designs protect the wastewater treatment plants from washout of secondary

treatment processes, effluent degradation, and slow treatment recovery. There are presently 14 ACTIFLO<sup>®</sup> wet weather treatment facilities in the United States.

## High Rate Secondary Clarifier (HRSC)

Enhancements to the HRC system have demonstrated that the ACTIFLO<sup>®</sup> process can be successfully applied as a high rate secondary clarification system. Sludge production from the HRSC system has a solids content comparable to that of traditional secondary clarifiers and is readily returned back to the biological plant as return activated sludge (RAS). This design complies with secondary limits for TSS and BOD. The design also provides a rapid startup time, high peaking capacity, and very small footprint. Since the process reaches steady state conditions in minutes and has a footprint 10-15 times smaller than conventional clarifiers it is ideally suited for high rate secondary clarification of mixed liquor produced during peak wet weather flows. Figure 1.1 illustrates a typical flow diagram.

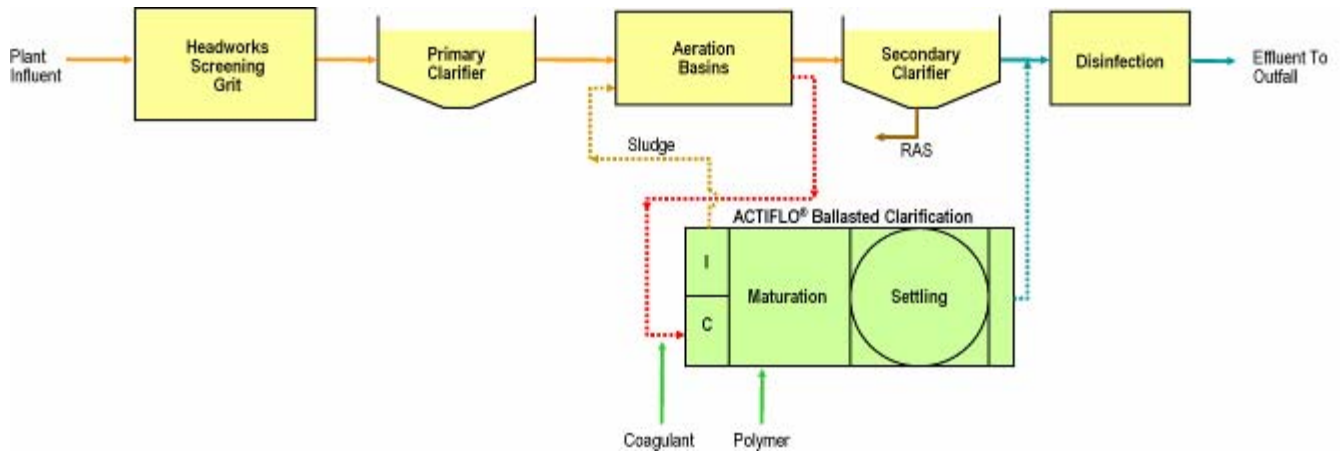


**Figure 1.1: ACTIFLO<sup>®</sup> High Rate Secondary Clarification Schematic**

During dry weather flows the HRSC trains can be maintained offline. When plant flows begin to reach the hydraulic capacity of the existing secondary clarifiers the HRSC trains are brought on line to treat the additional plant flow from the biological treatment process. The expected influent MLSS concentrations from the biological process are expected to be approximately 4,000 mg/l.

A dosage of coagulant is added to the influent stream prior to entering the HRSC process. The coagulated water then enters a coagulation tank for first stage mixing. Coagulant destabilizes the suspended solids and colloidal matter in the influent stream. Efficient mixing is provided in the coagulation tank to thoroughly disperse the coagulant over a hydraulic retention time of approximately 5 minutes. The destabilized particles collide and begin early stage floc formation.

The coagulated water then flows over a weir into an injection mixing tank where flocculent aid polymer and microsand are added to initiate floc formation. Here, the combination of flash mixing and a hydraulic retention time of approximately 5 minutes allow for thorough incorporation of microsand ballast and polymer into the coagulated water. The combination of microsand and polymer serve as a “seed” for floc formation and development in the next process step.



**Figure 1.2: Example of a High Rate Secondary Clarification Plant Layout**

HRSC treatment continues as water passes through the underflow passage from the injection tank into the maturation tank. Although chemical floc formation actually begins with the addition of polymer and microsand in the injection tank, the majority of ballasted floc formation occurs during the maturation process step. Gentle mixing and increased hydraulic retention time of approximately 15 minutes provide ideal conditions for the formation of polymer bridges between the microsand and the destabilized suspended solids. The large effective surface area of the microsand provides enhanced opportunity for polymer bridging and enmeshment of microsand and floc already in suspension.

The fully formed ballasted floc particles leave the maturation tank and enter the settling tank. Here the ballasted flocs rapidly settle and are removed from the flow stream. Laminar upflow through the settling zone provides rapid and effective removal of the microsand/sludge floc. Due to the settling properties of the ballasted floc, plate settlers are not required in the settling tank. Clarified water exits the ACTIFLO® process via a series of collection troughs with weirs for subsequent downstream treatment or discharge.

The ballasted floc sand-sludge mixture is collected at the bottom of the settling tank, moved to the center collection pit via a scraper mechanism and withdrawn using a rubber-lined centrifugal slurry pump. The sand-sludge mixture is then pumped to the hydrocyclone for separation. Energy from pumping is effectively converted to centrifugal forces within the body of the hydrocyclone causing the sludge to be separated from the higher density microsand. Once separated, the microsand is concentrated and discharged from the bottom of the hydrocyclone and re-injected into the HRSC process for re-use. The lighter density sludge is discharged out the top of the hydrocyclone and sent back to the biological process as return activated sludge

(RAS) or sent to waste (WAS). Solids concentration in the hydrocyclone sludge varies between 2 to 4 times the HRSC influent MLSS concentration.

**Table 1.0: HRSC Design Summary**

<b>Variable</b>	<b>Value</b>
Raw Water MLSS	Up to 4000 mg/l
Coagulation/Flocculation Time	15-20 min.
Nominal Overflow Rate	10-25 gpm/ft <sup>2</sup>
Recirculation Rate	20 to 30 %
Sludge Concentration	8,000-16,000 mg/l
Effluent TSS	<10 mg/l
Effluent BOD	<10 mg/l*
Total P	>90% removal
Coagulant Dosage	<10 mg/l
Polymer Dosage	5-20 mg/l
Sand Consumption	16-48 lbs/MG treated

\*BOD removal efficiencies are estimates and dependent upon specific biological plant design and operating conditions

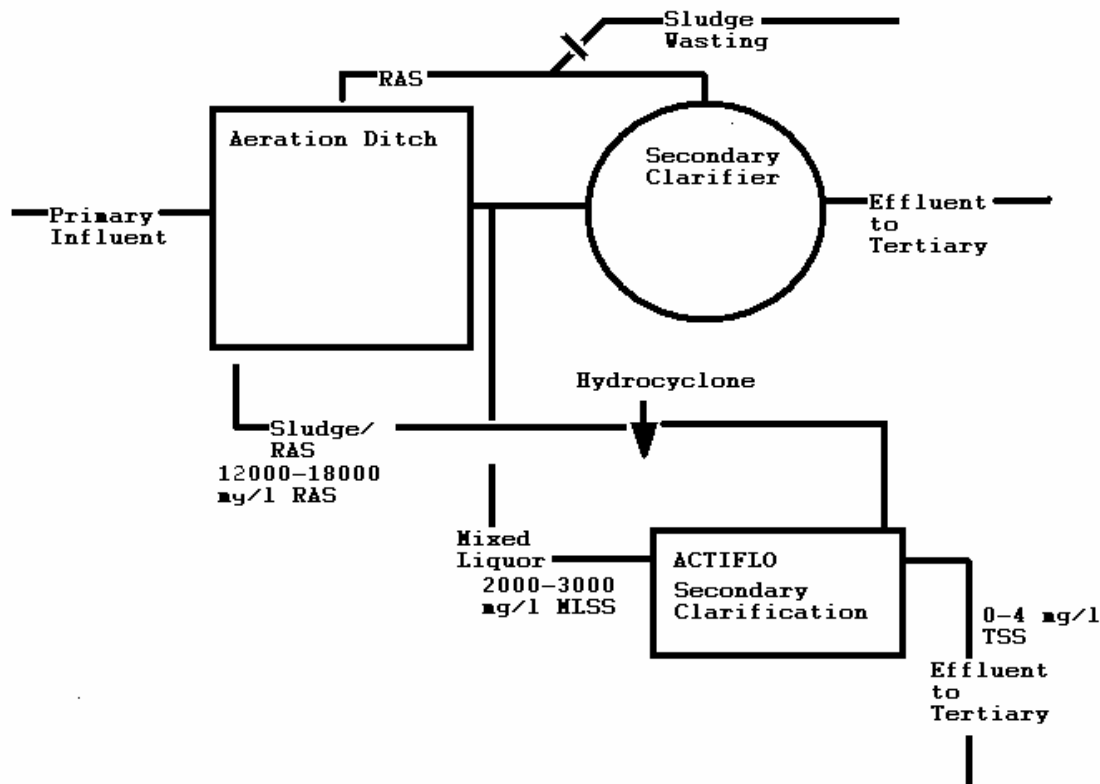
NOTE: NH<sub>3</sub>-N removal efficiencies should be evaluated on a case-by-case basis.

## 2.0 Murfreesboro, TN

---

### Overview

I. Kruger, Inc. performed a HRSC case study to evaluate the MLSS treatment efficiency from aeration basins located at the Sinking Creek Wastewater Treatment Plant in Murfreesboro, Tennessee. The Sinking Creek WWTP has limited capacity to treat the excess flows experienced during wet weather CSO events. The plant would like to expand their existing secondary clarification capacity for use during wet weather events and also evaluate the possibility of utilizing the HRSC process as a side stream operation during non wet weather events. Figure 2.0 illustrates the case study layout performed at the Sinking Creek WWTP.



**Figure 2.0: HRSC Pilot Plant Layout**

The testing period for this case study lasted for two (2) months starting in January 2005. Over the course of the study, turbidity, pH, and alkalinity were monitored in the field, while TSS, BOD, Phosphorous, and Iron were collected for lab analysis. The testing conditions for this study adhered to the following:

### Operating Parameters

- Loading Rate: 9 and 15 gpm/ft<sup>2</sup>
- HRT: 30 and 45 minutes
- Recirculation Rates: 17 and 25 gpm
- Raw Turbidities: 1,100 – 2,100 NTU
- Raw TSS: 2,500 – 3,290 mg/l
- Raw Total P: 22 – 84 mg/l
- Raw BOD: 154 mg/l
- RAS 12,000 – 18,000 mg/l

### Chemical Dosages:

- Ferric Sulfate: 5 – 13 mg/l
- Ferric Chloride: 8 – 15 mg/l
- ACH: 3 – 10 mg/l
- No Coagulant
- Cationic Emulsion: 4 – 14 mg/l

## Summary

The HRSC process proved that it could meet and exceed all the goals set forth for this pilot study. The three coagulants that were evaluated in conjunction with the cationic emulsion polymer proved to meet and exceed the set objectives. In addition, the HRSC was able to demonstrate successful treatment with polymer alone between doses of 12.0 and 14.0 mg/l.

Once the HRSC system was optimized, effluent turbidities less than 2 NTU were consistently maintained. Turbidity removals during the study averaged 99.9 % and TSS removals averaged 99.9 %. Phosphorous removals averaged 96.7 % while BOD removals averaged 98.3 % with an average effluent BOD of 2.73 mg/l. TSS associated with the sludge was also monitored during this study since the sludge from the HRSC system would be sent back to the oxidation ditch as RAS. Sludge TSS needed to range between 12,000 mg/l to 18,000 mg/l. The solids in the sludge were maintained within the range specified at the different overflow rates by varying the sand recirculation rates. Table 2.0 provides a performance summary realized during the case study.

**Table 2.0: Murfreesboro HRSC Case Study Results**

Coag. Type	Dose mg/l	Poly Dose*	NTU		TSS*		Phosphorous*		BOD*	
			Raw	Effluent	Raw	Effluent	Raw	Effluent	Raw	Effluent
Fe <sub>2</sub> SO <sub>4</sub>	13	14	1,615	1.4	2,731	8.8	55.4	0.83	154	1.1
ACH	5	14	1,784	1.2	2,840	5.8	65.0	2.33	154	4.3
No Coag.	--	14	1,714	1.4	2,883	9.0	53.3	2.49	150	1.6
Plant Secondary	--	--	1,442	1.4	2,619	7.4	60.3	2.57	154	2.0

\*Units are in mg/l

Note: The averaged data collected from the plant's secondary clarifier reflects an overflow rate of 1 gpm/ft<sup>2</sup> compared to the data obtained from the HRSC with overflow rates of 9 to 15 times greater with similar or better results.

In evaluating different coagulants, there was no significant difference in treatment efficiency regarding any of the parameters being monitored. Additionally, operating with no coagulant and increasing the polymer yielded similar removal rates. While dosing Ferric Sulfate at 13 mg/l, effluent iron samples were taken to ensure levels were low so not to interfere with the downstream UV system. Influent iron measured 18 mg/l, effluent iron measured 0.12 mg/l and iron in the sand being returned in the system measured 13 mg/l. HRSC effluent samples were also sent to Trojan Technologies for UVT analysis and the percent transmittance averaged 78 % (see table 2.1 for analysis results).

**Table 2.1: Murfreesboro HRSC UVT Data**

SAMPLE NO.	SAMPLE DESCRIPTION	%T	%T FILTERED	TSS (PPM)
S05-117	Actiflo Effluent, 10mg/L $Fe_2(SO_4)_3$ , 10mg/L KILL Cationic Polymer	78	79	1
S05-118	Actiflo Effluent, 0mg/L $Fe_2(SO_4)_3$ , 10mg/L KILL Cationic Polymer	77	78	5
S05-119	Actiflo Effluent, 0mg/L $Fe_2(SO_4)_3$ , 13mg/L KILL Cationic Polymer	78	78	<1
S05-120	Secondary Effluent (PSE 1A) #4 Clarifier	78	78	1
S05-121	MWSD, SCWWTP – Filtered F1	78	78	2

Additional testing to evaluate settling efficiencies was performed at overflow rates between 9 and 15 gpm/ft<sup>2</sup> without lamella tubes in the settling tank. ACH, Ferric Sulfate, and no coagulant were evaluated with a cationic emulsion polymer (see table 2.2 for performance details).

**Table 2.2: Murfreesboro HRSC Case Study Results without Lamella Tubes**

Coag. Type	Dose mg/l	Poly Dose*	NTU		TSS*		Phosphorous*	
			Raw	Effluent	Raw	Effluent	Raw	Effluent
ACH	10	14	1,830	1.25	2,740	0	48	2.6
$Fe_2SO_4$	8	14	2,004	1.75	2,740	0	54	1.9
No Coag.	--	14	1,967	1.88	2,825	0	59.5	2.9

\*Units are in mg/l

## 3.0 Auburn, AL

---

### Overview

A case study to demonstrate the reliability, operation efficiency and associated cost benefits was performed by I. Kruger Inc at the H.C. Morgan Wastewater Treatment Plant located in Auburn, Alabama. The testing period began in late September 2005 and lasted for more than two (2) months. Data collected from past case studies proved that a HRSC can successfully operate at an overflow rates of 12 gpm/ft<sup>2</sup>. This data served as a reference for establishing a base line of operating parameters particularly in investigating peak overflow rates and optimum treatment.

After establishing initial treatment, overflow rates were increased and the performance of the process was evaluated using turbidity, Total Suspended Solids (TSS) and Biochemical Oxygen Demand (BOD). These parameters were monitored to establish chemical dosages and sand recirculation rate.

To simulate excess flow resulting from a CSO event, the secondary influent MLSS was diluted with the secondary effluent before entering the HRSC. Dilutions rates of 20, 30 & 50 % were analyzed during the study (see table 3.0). Turbidity was used as an indicator for dilution rates. Once operating parameters were optimized for each dilution, extended runs were conducted to evaluate impacts of the settled sludge return on the stability of the conventional process. The results demonstrated that extended periods of operation did not affect the overall water quality of the secondary effluent.

**Table 3.0: Secondary Influent Characteristics**

Parameter	Concentration			
	No Dilution*	50% Dilution	30% Dilution	20% Dilution
Turbidity (NTU)	2,500 – 3,000	1,600 – 1,800	920 – 1,020	500 – 550
BOD (mg/l)	200 – 300	184 – 396	123 – 396	66.5 – 196
TSS (mg/l)	2,500 – 4,500	1,300 – 2,500	1,600 – 1,800	1,000 – 1,100

\*Represents the water characteristics of the primary clarifiers

Once all parameters for secondary clarification were completed the pilot unit was relocated to the head works to access primary influent. Figure 3.0 reflects the case study layout for both the secondary and primary operations.

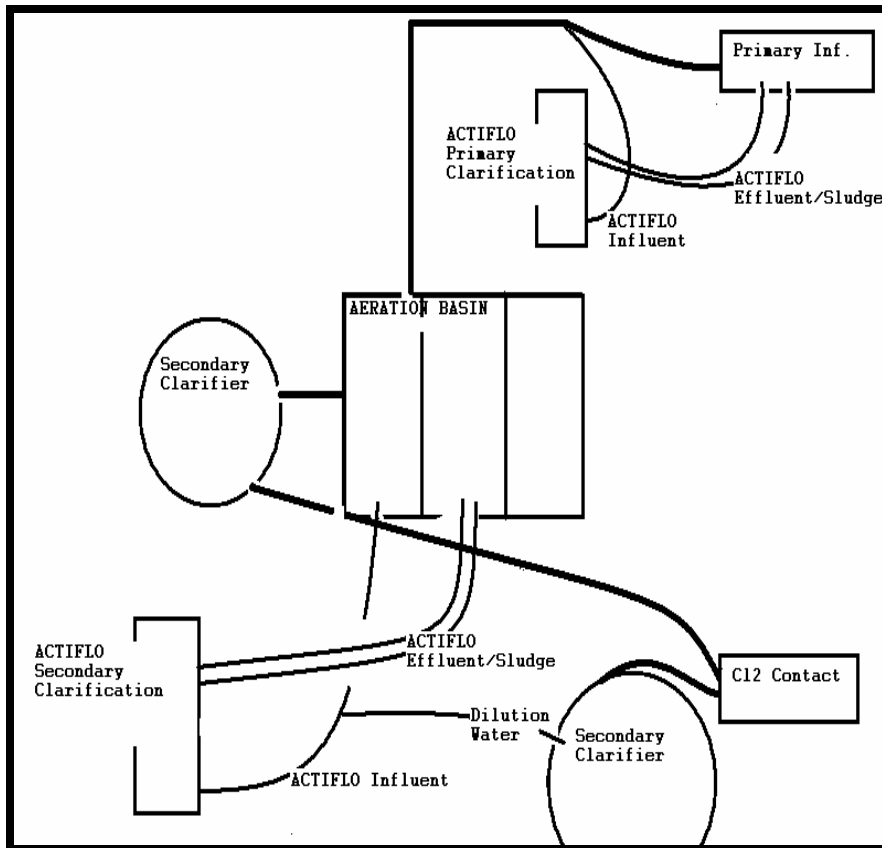


Figure 3.0: HRSC Pilot Plant Layout

## Summary

Baseline operations of 12 gpm/ft<sup>2</sup> reflected optimum treatment using ferric chloride (FeCl<sub>3</sub>) between 5 and 10 mg/l and a cationic polymer at 12 mg/l. As overflow rates were increased throughout the study, coagulant dosages remained constant at 5 to 10 mg/l. Polymer dosages and sand recirculation however increased in accordance with the increased solids loading rate. At 24 gpm/ft<sup>2</sup> a coagulant dose of 5 mg/l of FeCl<sub>3</sub> and a dose of 24 mg/l of cationic polymer was applied, along with a recirculation rate of 31-33 % for steady treatment. Turbidity removals in excess of 99 % and a TSS removal in excess of 99 % were achieved at these parameters. During optimization up to 99 % removal of BOD was achieved.

During optimization it was established that polymer was one of the key constituent in treatment. It is important to note that overflow rates directly correlate with polymer doses and recirculation rates. At 15 gpm/ft<sup>2</sup> a polymer dose of 15 mg/l was needed to obtain steady treatment. During the dilution phase of the secondary clarification turbidities remained at or below 2 NTU. All tested parameters met excellent removals, polymer doses did decrease as diluted secondary influent decreased. At a 50 % dilution only 12 mg/l of polymer was needed to maintain treatment at 24 gpm/ft<sup>2</sup>. A 30 % dilution was evaluated and polymer dosages remained constant at 12 mg/l, but decreased to 8 mg/l at 20 gpm/ft<sup>2</sup>.

Recirculation rates and sand concentrations were also evaluated as process parameters. Recirculation rates varied in accordance with the overflow rates and MLSS concentrations. Initial testing of 4,000 mg/l MLSS, a recirculation rate of 27 % was used to establish treatment at 15 gpm/ft<sup>2</sup>. Recirculation rates were increased to 29 % at 17 gpm/ft<sup>2</sup> and 38 % at 24 gpm/ft<sup>2</sup> to accommodate the increased solids. During the dilution phase the recirculation rate remained at 38 % for a mixed liquor concentration of 2,500 mg/l and decreased to 33 % at lower mixed liquor concentrations of 1,750 and 1,000 mg/l.

Turbidity removals were used as a quick reference for treatment during optimization and were also used for treatment stability during extended runs. Approximately 2 NTU was used as a reference point to gain initial treatment. At overflow rates of 15, 17, and 24 gpm/ft<sup>2</sup>, less than 2 NTU turbidity from raw water turbidities between 2,500 and 3,500 NTU was achieved throughout each extended run. This represents greater than 99.9 % removal.

TSS removals were relatively consistent throughout all extended run phases of secondary testing. Although dilutions varied, removals greater than 99 % were observed during every extended run including the dilutions phases.

BOD removal of 99 % was recorded for overflow rates of 15 and 17 gpm/ft<sup>2</sup>. No data was collected at 24 gpm/ft<sup>2</sup> due to time constraints on lab personnel. Dilutions of 30 % and 50 % produced greater than 99 % removal but decreased during the 20 % dilution extended run. BOD was also collected throughout an eight-hour period as a composite sample to test for consistencies and stability. Table 3.1 summarizes the average data obtained at optimum conditions.

**Table 3.1: Results Summary for Varying Overflow Rates**

Overflow Rate gpm/ft <sup>2</sup>	TSS*		BOD*		Ammonia*		TKN*		Phosphorous*	
	Raw	Effluent	Raw	Effluent	Raw	Effluent	Raw	Effluent	Raw	Effluent
15	4,100	6	354	1	0.32	0.03	150	1.3	140	0.1
17	3,880	2	216	1	0.19	0.03	180	0.66	140	0.17
24	3,015	6	--	--	7.6	0.03	35	1.7	40	0.3

\*Units are in mg/l

NOTE: All data represents optimum conditions using a FeCl<sub>3</sub> dose between 5 and 10 mg/l and a cationic polymer dose less than 15 mg/l

During the primary clarification phase of testing, ferric chloride (FeCl<sub>3</sub>) and aluminum sulfate (Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>). Both coagulants had similar results in regards to turbidity, TSS, and BOD removals. Both coagulants performed under optimum conditions at 85 mg/l. In addition to the coagulants, an anionic polymer was evaluated. It was established that 2.5 mg/l of polymer was needed to gain treatment at the established overflow rates with both coagulants. Both NTU and TSS removals were greater than 95 % and BOD exceeded 75 % removal.

## 4.0 Weig Cartonboard Mill, Mayen, Germany

### Overview

Two (2) case studies were performed at the Weig cardboard mill located in Mayen, Germany. The first occurred in September 2002 for one (1) month and the second took place in October 2005 for approximately one (1) month to demonstrate secondary clarification. The plant processes 600,000 tons per year of recycled paper and uses a combination of surface and ground water as its fresh water source. Due to a production increase, the mill must increase the wastewater treatment capacity while reducing TSS. The existing secondary clarifier is operating at maximum capacity and constraints in the available space cannot support expanding the existing treatment process. Due to the footprint limitations, the case study was limited to only technologies that could feasibly fit in the proposed full scale location. Figure 4.0 illustrates the case study layout within the existing plant. Two technologies were chosen based on this limiting factor, which included the HRSC and submerged membranes. Both technologies were evaluated on treatment ability and cost associated with capital, operations, and installation. The treatment goal required a reduction of TSS between 4,000 to 6,000 mg/l to less than 30 mg/l. Operating parameters associated with the HRSC included the following:

#### Operating Parameters:

- No Lamella: Removed to avoid sludge build-up & floc carry over
- Overflow Rate: 13.5 gpm/ft<sup>2</sup>
- HRT: 10 to 15 minutes
- Raw TSS: 5,000 – 6,500 mg/l
- Sludge Discharge: 28 – 32 % of influent flow
- Sludge Concentration: 1.5 – 2.0 % solids

#### Chemical Dosages:

- No coagulant added: Client adds ~ 20 mg/l of Fe(II) in aeration tank for P removal
- Coag. Aid Polymer: 4 – 5 mg/l active PolyDADMAC
- Polymer: Cationic Polymer at 4 mg/l

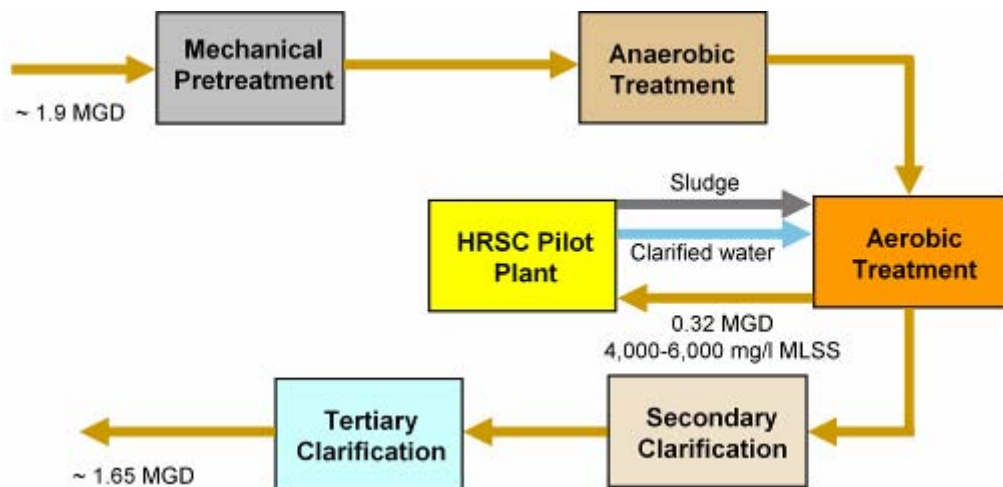
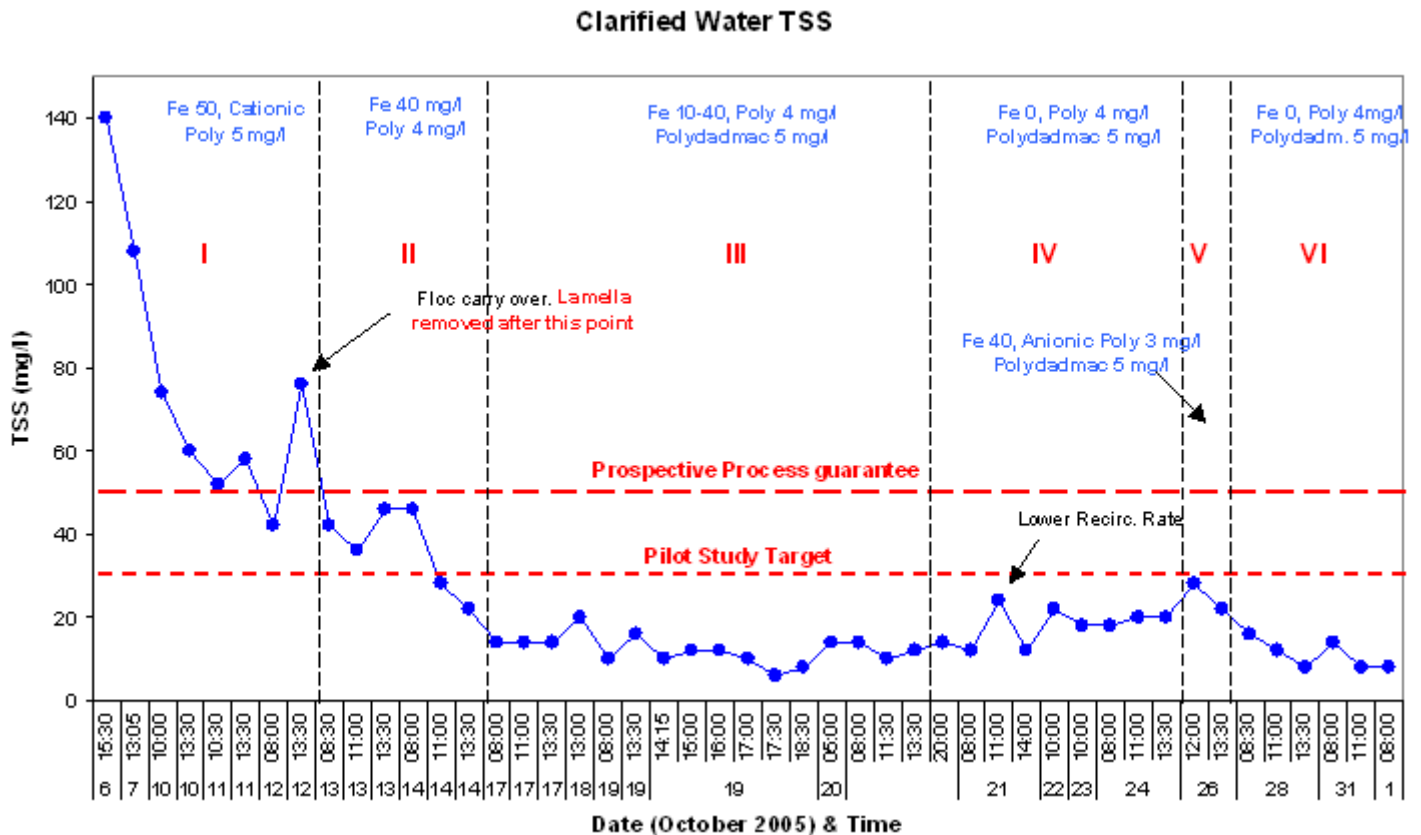


Figure 4.0: Plant layout utilized during the case study

## Summary

During the study, the HRSC was able to prove successful treatment based on the set objectives. Figure 4.1 illustrates the data obtained during the testing period. The data is separated into six (6) phases. Phases I, II, III, IV, and V are considered optimization phases while phase VI illustrate the effectiveness of the HRSC to treat under the desired parameters.



**Figure 4.1: Case Study Data Summary**

Based on these favorable results and a complete economic evaluation, Weig decided to employ the ACTIFLO® process for the full scale HRSC design. The economic analysis reflected the information provided in table 4.0.

**Table 4.0: Full Scale Economic Analysis**

Variable	HRSC	Membranes
Capital Equipment	840,000	2,160,000
Installation <sup>(1)</sup>	840,000	480,000
Total Capex	1,680,000	2,640,000
Total Opex	192,000 <sup>(2)</sup>	276,000 <sup>(3)</sup>

NOTE: all cost were calculated using an exchange rate average for March 2006 of 1 Euro = 1.2 American dollars

(1): Includes electrical and civil

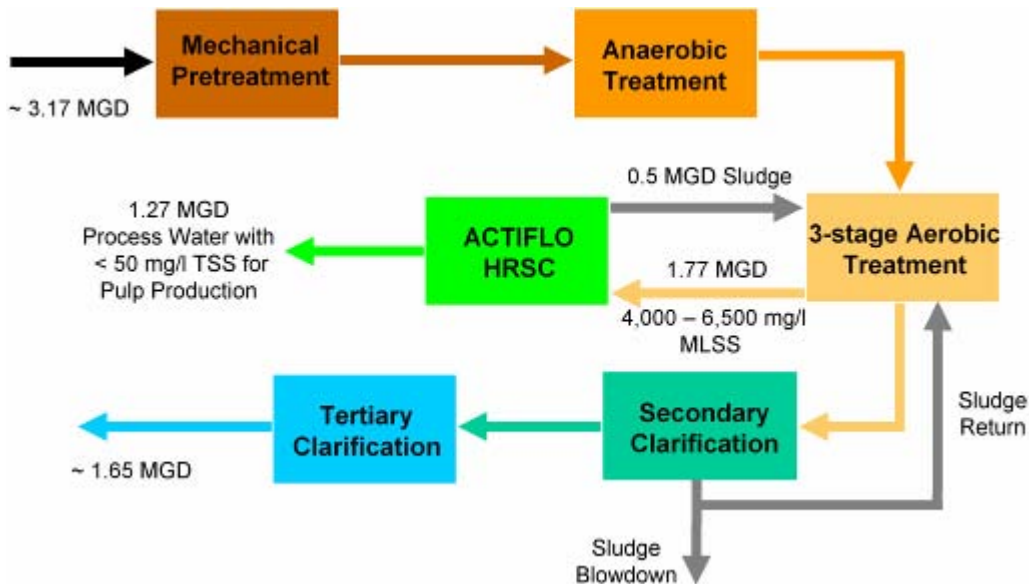
(2): Includes chemicals, energy, manpower, and spare parts

(3): Includes energy, manpower, and membrane replacement

The Capex (Capital Expenditure) associated with the HRSC included additional scope items representing a complete equipment package. The final HRSC design as illustrated in figure 4.2 was based on proven pilot data as described in the following list:

#### Operating Parameters:

- Sand concentration: 30 – 40 g/l to account for high TSS
- Mixers: Included VFDs for proper speed control
- No lamella: Removed to avoid sludge build-up and floc carry-over
- Design overflow rate: 13.5 gpm/ft<sup>2</sup>
- Sludge discharge: 28 – 32 % of influent flow
- Sludge Concentration: 1.5 – 2.0 % solids



**Figure 4.2: Full Scale Plant Layout including the HRSC**

Since startup in July 2006, the HRSC has successfully operated and maintain treatment according to the process guarantee. Full scale HRSC results at the Weig mill reflect the following:

#### Full Scale Results

- Influent TSS: 4,000 – 6,500 mg/l (Activated Sludge)
- Effluent TSS: 10 – 35 mg/l
- Effluent Turbidity: 5 – 33 NTU

#### Chemical Dosages:

- No coagulant: Client adds ~ 20 mg/l of Fe(II) in aeration tanks for P removal)
- Coagulant Aid: 4 – 5 mg/l active PolyDADMAC
- Cationic Polymer: 4 – 7 mg/l depending on SVI (Sludge Volume Index)

## 5.0 Conclusion

Data collected from the case studies mentioned in this paper were used to evaluate the ACTIFLO® process for high rate secondary clarification (HRSC). The purpose of these studies was to establish a base line of operating parameters particularly investigating peak overflow rates. Throughout each of the studies, overflow rates were increased and evaluated using turbidity, TSS and BOD. These parameters served as the basis to establish chemical dosages and sand recirculation rate. It was documented that overflow rates directly correlated with polymer doses and recirculation rates.

During initial testing of the HRSC, a MLSS concentration was evaluated at varying overflow rates. As overflow rates increased, coagulant dosages remained constant. A ferric-based coagulant proved to be more efficient and stable in regards to treatment. To simulate a wet weather event, the secondary influent was diluted with the secondary effluent before entering the HRSC. Each of the dilutions tested required similar ferric dosages. As dilutions were evaluated it was observed that a polymer dosage was affected directly by MLSS concentration. As the MLSS concentration was reduced the polymer demand was also reduced. Recirculation rates increased in parallel with the increased loading rates and this can be expected due to the augmented applied solids. As applied solids increased within the HRSC the solids removal demand must be met. If the demand was not met solids had a propensity to increase in the system over time causing a need for an increased recirculation rate. Overflow rates and mixed liquor concentrations both had a direct effect on the recirculation rate. As overflow rates increased the recirculation rates increased. Table 5.0 illustrates the optimum conditions obtained from each of the case studies.

**Table 5.0: HRSC Design Summary**

Variable	Value
Raw Water MLSS	Up to 4000 mg/l
Coagulation/Flocculation Time	15-20 min.
Nominal Overflow Rate	10-25 gpm/ft <sup>2</sup>
Recirculation Rate	20 to 30 %
Sludge Concentration	8,000-16,000 mg/l
Effluent TSS	<10 mg/l
Effluent BOD	<10 mg/l*
Total P	>90% removal
Coagulant Dosage	<10 mg/l
Polymer Dosage	5-20 mg/l
Sand Consumption	16-48 lbs/MG treated

\*BOD removal efficiencies are estimates and dependent upon specific biological plant design and operating conditions

NOTE: NH<sub>3</sub>-N removal efficiencies should be evaluated on a case-by-case basis.

Loading rates for conventional secondary clarifiers range on average from 1 to 2 gpm/ft<sup>2</sup>. Utilizing a HRSC can increase these overflow rates by expanding the capacity of the conventional RAS system. In addition to this application, the HRSC can also be operated during non-wet weather events to treat primary influent, filter backwash, or treat phosphorous by operating in tertiary mode. Additional design details will need to be considered in order to operate under these conditions; however this gives a plant greater functionality when considering what technology is best suited for wet weather applications.